COMPARATIVE EVALUATION OF CHEMICAL FUNGICIDES AGAINST SHEATH BLIGHT DISEASE OF RICE IN *AMAN* SEASON

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CERTIFICATE

*This is to certify that the thesis entitled, "***COMPARATIVE EVALUATION OF CHEMICAL FUNGICIDES AGAINST SHEATH BLIGHT DISEASE OF RICE IN** ***AMAN*** **SEASON***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka-1207, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***PLANT PATHOLOGY****, embodies the result of a piece of bona fide research work carried out by* ***NURJAHAN NUPUR, Registration No.14-05930*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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.

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BELOVED

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The Author

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LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL WORD
%	Percentage
PDA	Potato Dextrose Agar
G	Gram
^{o}C	Degree Celsius
Psi	Per square inch
Cm	Centimeter
et al.	and others (at ell)
CRD	Complete Randomized Design
RCBD	Randomized Complete Block Design
DAI	Days After Incubation
DAS	Days After Sowing
sp.	Species
etc.	Et cetera
viz.	Videlicet (namely)
BRRI	Bangladesh Rice Research Institute
EC	Emulsifiable Concentrate
WP	Wettable Powder
WC	Wettable Concentrate
EW	Emulsion in Water
PPM	Parts Per Million

COMPARATIVE EVALUATION OF CHEMICAL FUNGICIDES AGAINST SHEATH BLIGHT DISEASE OF RICE IN *AMAN* SEASON

ABSTRACT

Two experiments were conducted to evaluate the efficacy of chemical fungicides for the management of sheath blight disease of rice at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during July 2019 to November 2019, following randomized complete block design (RCBD) and complete randomized design (CRD) with 3 replications for *in vivo* and *in vitro* experiments, respectively. Sheath blight disease susceptible variety BR 11 was used in these experiments. Fifteen treatments viz. T_1 (Tilt 250 EC), T_2 (Contaf 5 EC), T_3 (Folicur 250 EC), T_4 (Score 250 EC), T_5 (Combi 230 EC), T_6 (Filia 525 SE), T_7 (Amister Top 325 SC), T_8 (Acibin 28 SC), T_9 (Awal 72 WP), T_{10} (Nativo 75 WP), T_{11} (Autostin 50 WP), T_{12} (Dithane M-45), T_{13} (Sunvit 50 WP), T_{14} ($Control_1$) and T_{15} ($Control_2$) were evaluated against *Rhizoctonia solani* causing sheath blight disease of rice (BR 11) in *aman* season. In field experiment thirteen fungicides and two controls were used, in which T_{14} was with inoculation and T_{15} was without inoculation. After the 4^{th} spray the lowest disease incidence per hill (30%), disease incidence per tiller (10.80%), disease severity (10.80%) and percent relative lesion height (%RLH), (2.44%) was found in T_2 treated plot. The highest disease incidence per hill (93.33%), disease incidence per tiller (44.71%), disease severity (48.36%) and %RLH (9.11%) was found in T_{14} after the final spray. In case of yield contributing characters, the highest yield (6.94 ton/ha) and straw yield (7.12 ton/ha) was found in T_2 treated plot while lowest yield (3.49 ton/ha), straw yield (4.32 ton/ha) observed in T_{14}. Moreover, T_3 and T_4 were also significantly effective against this disease. *In vitro* condition at 1000 ppm concentration all fungicides 100% inhibited the mycelial growth of *R. solani.* At 250 ppm concentration six fungicides T_1, T_2, T_3, T_4, T_{10} and T_{11} completely inhibited the mycelial growth of *R. solani.* Among all, fungicides, T_{12} gave the worst result to inhibit the mycelial growth of *R. solani*.

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family of Gramineae (Poaceae). Rice is among the three most important grain crops in the world and it has a major contribution to fulfill the food needs across the globe. Rice constitutes the staple food of 60 percent of the world population; rice is also the most important cereal crops in Bangladesh. It occupies about 75% of the total cropped area covering 26.1 million acres of land in Bangladesh (Anonymous, 2009). The role of rice crop is inevitable in the current and future global food security. Although rice is predominant in Asia, this crop has also been cultivated in Europe since the 15th century, mainly in Mediterranean countries including Italy, Spain, Portugal, Greece and France (FAO, 2016). Rice is grown in at least 114 countries of the world. China is the largest producer in the world. China produced some 146.7 million metric tons of milled rice, a higher volume than any other country. India came in second place with 118.9 million metric tons of milled rice (Statista, 2021). About 77.12% of cropped area of Bangladesh is used for rice production. Bangladesh is ranked as fourth based on the annual milled rice production of 36.39 million metric tons during 2018-19 in the world (BBS, 2020). It is cultivating almost one fifth of the total land area covered under cereals. Rice sector contributes one-half of the agricultural GDP and one-sixth of the national income in Bangladesh. The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Rice yield therefore, needs to be increased from the present 2.74 to 3.74 t ha^{-1} (BRKB, 2019).

Productivity of rice fluctuates significantly from region to region, season to season due to various biotic and abiotic stresses. There are so many constraints responsible for low yield of rice in Bangladesh. Among all the pathogenic organisms, fungal pathogens are the major limiting stresses for rice productivity. More than 60 diseases attack the rice crop every year among which sheath blight, bacterial leaf blight, stem rot and blast are considered important diseases at various parts of rice growing areas of the world (Latif *et al*., 2011). It is a great threat to successful rice cultivation during rainy season especially in northern part of the country (Rahman *et al*., 2016).

In Bangladesh, sheath blight disease is a major problem particularly in *kharif* season for rice production (Dey *et al*., 1996; Ali, 2002). High rainfall and humidity prevailing and the susceptibility of the predominant varieties in cultivation are factors contributing high disease incidence. The disease is recorded in all rice growing areas throughout the year in all three seasons and 6.5 to 48.4% of the rice plants are infested by sheath blight disease with an average incidence of 20.8%. Yield loss by this disease was estimated 40-17800 kg ha^{-1} (Ali, 2002).

The intensity of the disease is severe in *aus* and transplanted *aman* seasons. Northern and central part of the country experiences frequent epidemic outbreak of the disease. In Rangpur, at *T. aman* 2018 season, average sheath blight (incidence: 24.5% and severity 3.4), In Cumilla, average disease incidence was 5-80%, where in Keshobpur, Jashore, it was found higher (90%). In *boro* 2018-19 seasons, on an average sheath blight disease was widespread in Rangpur. Sheath blight (incidence: 32.5%; severity: 5.4%) was predominant compared to brown spot, bacterial blight and blast disease (BRRI, 2019).

The disease is caused by *Rhizoctonia solani* AG1-1A Kuhn (Teleomorph: *Thanatephorus cucumeris*) is one of the most ubiquitous and destructive soil borne pathogen. Miyake (1910) first reported the disease on rice from Japan and it has become a major constraint to rice production only during the last two decades (Hashiba and Kobayashi, 1997). The disease first reported in Bangladesh in 1973 (Miah *et al*., 1995). It is also known as "*Kholpora rog*" by local farmers of Bangladesh. Rice sheath blight, caused by *R. solani* Kuhn is a soil borne, semi-saprophytic fungus (Almasia *et al*., 2008). Due to the semi-saprophytic nature and un characterized pathogenicity mechanism, *R. solani* has a wide host range and infects at least 200 plant species including most of the important crops in the world such as rice, maize, wheat, potato, soybean, carrot, tomato, cotton etc (Lehtonen *et al*., 2008).

The yield reduction due to sheath blight disease in Bangladesh has estimated to be from 14 to 31% under experimental and farmer field condition (Shahjahan *et al*., 1986) and 50% was reported when susceptible cultivars were planted (IRRI, 2017 and Ou, 1985). The disease can cause yield losses up to 50% in advanced stage and adversely affects quality of straw, limiting its value as fodder (Prakasam *et al.*, 2013 and Ali *et al*., 2004). In Bangladesh yield losses occurred 6-36% in *aus* and 19% in transplanted *aman* rice (Dey *et al*., 1996). In hot and high humid condition, yield loss can even reach as high as 50% (Meng *et al*., 2001). Short stature, high tillering and high nitrogen loving varieties are comparatively more susceptible as the micro climates inside the rice canopy is more favorable than those of the traditional ones of tall plant type with low tillering ability (Miah *et al.*, 1985). Both seedlings and mature plants are equally affected but loss is much more when the disease appears in seedlings. The older plants are attacked in flooded conditions and swampy rice fields (Shimamoto, 1995). The infection and spread of disease before the flag leaf stage revealed 20% grain loss. Further, a strong relationship between the severity of symptom and yield reduction was reported among cultivars (Marchetti and Bollchi, 1991).

All the commercially cultivated rice inbreeds and hybrids are susceptible to sheath blight. The complex genetic nature of resistance to sheath blight and genetic variability of the pathogen increases the difficulty in developing resistant host genotypes, as well as in effectively deploying available tolerant cultivars (Meena *et al*., 2013). Unfortunately, at present there is no known rice variety, which is either immune or possess high degree of resistance to sheath blight disease. In the absence of suitable resistant donors, fungicides are the main answer to check these diseases.

Sheath blight can be effectively controlled with the application of systemic fungicides (Groth, 2007). However, bio-fungicides and resistant varieties are the other options of control management but, are not as par with chemical control. Most of the fungicides like Benomyl, Carbendazim, Edifenphos and Iprobenphos etc. have been found effective for the control of the disease under field conditions (Roy, 1993). Several new fungicides are available in the market and farmers are going for 3-4 sprays for the control of sheath blight under field conditions. Fungicidal sprays have been used successfully to control the sheath blight which is most effective for inhibiting infection lesion enlargement. Timely application of effective fungicides is essential for the management of the disease. Systematic evaluation of commercially available fungicides from time to time is needed for evolving recommendations on chemical fungicides, so that the farmers can choose the fungicides based on the efficacy as well as cost. Evaluate the commercially available best fungicide with potential is required to control sheath blight of rice and later on transfer this information to farmer level in order to get maximum yield of the crop.

Objectives of the Research work:

Considering above facts and points this research work is designed to achieve the following objectives:

1. To measure the incidence and severity of sheath blight disease in *aman* season under natural epiphytic conditions; and
2. To evaluate the efficacy of commercially available fungicides against sheath blight disease of rice under *in vitro* and *in vivo* conditions.

CHAPTER 2

REVIEW OF LITERATURE

Sheath blight (*R. solani*) is a worldwide important disease of rice. Many works and researches have been done in respect of chemical control for the management of sheath blight disease of rice under varying soil and climatic conditions. The findings also have little relevance to the SAU farm conditions for rice cultivation. For better and precise presentation only the related literatures are presented there.

2.1. History and distribution of sheath blight disease of rice

The occurrence of sheath blight in rice caused by *R. solani* Kuhn was first described by Miyake (1910) in Japan and subsequently its occurrence on rice has been reported from almost all rice growing countries of world in Asia, Africa and Americas (Kozaka, 1975; Ou, 1985; Shahjahan *et al.*, 1987).

Rice sheath blight disease caused by the fungus *Thanetephorus cucuneris* (Frank) Donk (*Rhizoctonia solani* Kuhn) was first reported in Bangladesh by Talukdar in 1968. Later on, Miah (1973) confirmed its occurrence and reported that the incidence of the disease was increasing in Bangladesh. With the intensification of rice cultivation, it has now become a major disease of rice in the country.

Wei (1934) found the disease in China and it has been seen in many countries in Asia. It was considered to be a disease of the Orient, but it has also been reported from Brazil, Surinam, Venezuela, Madagascar and the USA.

Sugiyama (1988) Reported that the areas by sheath blight in Japans increased from 35% of the cultivated areas in the 1960’s to 46% in 1970’s and 48% in 1980’s.

Suryadi *et al.* (1991) reported that the areas affected by sheath blight in Japans increased from 35% of cultivated areas in the 1960’s to 46% in 1970’s and to 48% in 1980’s.

2.2. Symptoms of sheath blight disease

Ou (1985) stated that sheath blight causes spots on the leaf sheath. The spots are at first ellipsoid or ovoid, somewhere irregular, greenish-grey, and varying from 1 to 3 cm long. Sclerotia were formed on or near these spots, but are easily detached. The size and color of spots and the formation of sclerotia depend upon environmental conditions mycelium of the fungus may grow over the surface of the leaf sheaths and can spread to a considerable distance.

Singh *et al*. (1988) found that the pathogen normally attacked the leaf sheath and leaf blade but the symptoms were also found on emerging panicles which chaffy, grayish brown and matted together by fungal mycelium. Numerous white and brown sclerotia were found on diseased panicles.

Rangaswami and Mahadevan (1999) observed that the pathogen causes spots or lesion mostly on the leaf sheath, extending to the leaf blades under favorable conditions. At first, the spots are greenish gray, ellipsoid or ovoid, and about 1 cm long. They enlarge and may reach 2 or 3 cm in length and become grayish white with brown margins and somewhat irregular in outline. In the advance stage brown sclerotia are formed which are easily detached from these spots. Under humid conditions, the fungal mycelium spreads to other leaf sheaths and blades. Eventually, the whole sheath rots and affected leaf can easily be pulled up from the plant. In severe case all usually attacked at the tillering stage, when the leaf sheaths become discolored at or above water level.

Rush and Lee (1992) observed that the symptoms of sheath blight do not appear until plants are in the late tillering or early inter node elongation growth stages. Initial symptoms consist of circular, oblong or ellipsoid, green-grey, water-soaked spots about 1 cm long that occur on the leaf sheath near the waterline. The lesions enlarge to approximately 2-3 cm in length and 1 cm in width, and the centers of the lesions become pale green or white and are surrounded by an irregular purple brown border. Under favorable conditions i.e., low sunlight, humidity near 95% and high temperature (28-32 °C), infection spreads rapidly by means of runner hyphae to upper plant parts including leaf blades, and to adjacent plants. Lesion on the upper portion of plants may coalesce to encompass entire leaf sheaths and stems. Sclerotia are produced superficially on or near infected tissue after symptoms first appear and are loosely attached and easily dislodge from the plant when they are mature. Heavily infected plants produce poorly filled grains, particularly in the lower portion of panicle. Additional losses in yield result from increased lodging or reduced ratoon production as a result of death of culm.

Yu (1975) reported that outer leaf sheaths are first affected, gradually extending towards the inner sheath. Sheath blight lesion spread more rapidly on the leaf sheath blade than the sheath, and spread is hastened by loosening. Lesion length increases faster at heading than at booting and maximum at tillering stage. At booting the developments is more rapid on lower leaf sheaths than the upper, but reverse at heading of the rice plants.

2.3. Favorable conditions for the growth of *R. solani* and sheath blight disease of rice

Sheath blight is basically a disease of wet conditions. It is especially destructive under conditions of high humidity and high temperature. Temperature near the leaf sheath will be related to air temperature but humidity within the crop stand will vary according to tillering nature of the variety, density of stand and amount of fertilizers added. Therefore, very close stand and heavy doses of nitrogen, especially when the crop has passed tillering stage, pre-dispose the plants to sheath blight. Optimum temperature for growth and sclerotia formation by the fungus is about 30 °C, the minimum being 10 °C and maximum 40-42 °C. A sudden rise and fall in temperature accelerates sclerotia formation. Infection occurs in the temperature range of 25-35 °C but optimum conditions are temperature of 30 °C and 32 °C and relative humidity 96% to 97%.

The pure cultures of *R. solani* isolates from high temperature regions grow well on PDA at 35°C but tented to grow poorly at 12°C, whereas those from low temperature regions at 35°C and well at 12°C reported by Hashiba and Magi (1974). There was no difference in growth between the isolates at 15 °C. With a daily average temperature of 26-28 °C (daily maximum 30-32°C) the rate of upward development of the disease caused by higher temperature isolates was greater than that of these caused by the low temperature isolates. There was no significant difference in the growth of *R. solani* on rice leaf sheath held in the dark or light but lesions development more rapidly in the light reported by Yuno *et al.* (1978). Mycelial growth increased with temperature 20-28 °C. From 25-26 hrs, after disease development, lesions of leaf sheaths were clearly defined and the lesions diameter then remained constant.

Leano (1993) stated that the infection efficiency in sheath blight significantly increased with prolonged wet and dry daily cycles, particularly with three (3) days of intermittent wet and dry (12/12 hrs.) periods. Soil moisture was important factor determining the survival and persistence of the fungal pathogen in soil reported by Kannaiyan and Prasad (1979). The increase in moisture levels gradually decreased the seedling infection. Low moisture favored the survival of *R. solani*, whereas, higher moisture inhibited the survival and the multiplication of the propagules of *R. solani*. Higher moisture content also stimulated the bacterial activity which in turn might result in lysis of *R. solani* mycelium.

Leano (1993) observed that sheath blight intensity and yield loss were higher in plots where flooding was intermittent compared to continuously flooded ones.

Lakpale *et al.* (1994) noticed that viability of sclerotia remained unchanged when sclerotia were submerged for periods up to 96 hrs. followed by drying treatments of 24-168 hrs. However, viability decreased with an increase in submergence until it was completely lost after 168 hrs. Submergence also lowered the inoculum potential by reducing the production of sclerotia from those which had been under the water.

2.4. Plant growth stages and sheath blight severity

Boyette and Lee (1979) conducted that plant growth stages have significant effects on *R. solani* Kuhn and development of rice sheath blight in the field. In field trials maximum yield losses occurred when plant becomes infected at the 1/2 in inter node elongated growth stage.

Miah *et al.* (1985) found that the disease severity and yield losses were significantly higher when inoculated at booting stage than when inoculated at maximum tillering, panicle initiation and flowering stages.

Suparyono and Nuryanto (1991) observed that the severity of sheath blight and its effect on rice yield depended on the rice variety and the host growth stage at which plants were inoculated. Disease development was greatest when plants at maximum tillering and primordial stages were inoculated with *R. solani*. Disease severity of the early mature varieties was less when plants were inoculated at the later stage, although disease severity was affected long duration rice varieties. Yields of both early and long duration varieties were significantly reduced by the disease when the plants were inoculated at the maximum tillering and primordial plant growth stages. Yield reduction decreased when plants of the early maturing varieties were inoculated at the later stage, although the reduction of the yield loss was smaller on the long duration varieties.

Sharma and Teng (1996) studied the development of sheath blight on two rice cultivars IR-42 and IR-72 inoculated at different growth stages with *R. solani*. They reported that disease development was highest at later growth stages. Disease progress was faster at flowering and booting stages than at tillering and panicle initiation stages in both cultivars. The percent productive tillers, grain weight per plants, filled grain number per panicle, 1000-grain weight, filled grain percent and total biomass per plant were usually higher at early stages of inoculation and lower at booting and flowering stages of inoculation. The disease development was also higher at later growth stages and consequently the yield parameters also declined. Yield losses at different stages of inoculation ranged from 23.01 to 32.15% and 13.53 to 34.83% in IR-42 and IR-72, respectively. The yield losses were higher in flowering stage than those of other three (3) stages in both the cultivars.

2.5. Management of sheath blight through chemical fungicides

Arunayanart *et al.* (1986) tested 13 fungicides for the management of sheath blight disease of rice where Pencycuron 25% WP, Validamycin 3% liquid, Carbendazim 60% WP, and Propicanozonal 25% EC were found most effective.

Dev and Mary (1986) tested seven fungicides to control sheath blight disease of rice. All the fungicides checked sheath blight intensity. Validamycin and carbendazim performed similarly and significantly better performance than other fungicides.

Jones *et al*. (1987) noticed that Propiconazole (Tilt) applied twice or Propiconazole (Tilt) followed by Benomyl significantly reduce disease severity and increase yield. An economic return from Propiconazoel (Tilt) could be anticipated when >5% diseased tillers were observed at the panicle differentiation growth stage.

Torabi and Binesh (1987) observed that *in-vitro* condition Benomyl, Iprodine + Carbendazim and Mepronil at 50 ppm, Carboxin + Thiram and Carbendazim at 300 ppm, Edifenphos at 200 ppm and Zineb at 400 ppm inhibited mycelial growth of *Rhizoctonia solani* . In field trials, Iprodine + Carbendazim, Tilt and Validamycin effectively decreased disease incidence and increased yield where Mepronil, Zineb, Carboxin + Thiram and Edifenphos were less effective.

Suryadai and Kadir (1989) inoculated Pelita 1-2 rice plants with *R. solani* 55 day after transplanting (DAT). Eight fungicides were sprayed at 60, 67 and 74 DAT and disease incidence measured 25 days after flowering. Triazole was the most effective followed by Chlorothalonil, Mencozeb and Maneb + Zineb treatments. No phytotoxicity occurred in any treatment.

Izadyar and Baradaran (1989) tested five fungicides to control sheath blight disease of rice. They reported, IBP, Mepronil, Validamycine and Iprodine effectively controlled sheath blight disease. Yield was higher while spraying with IBP, Validamycine and Iprodine.

Thangasamy and Rangaswamamry (1989) tested carbendazim and mancozeb to control sheath blight caused by *Thanatephorous cucumeris* applied at different crop growth and disease development stage. Fungicides were applied when disease severity was 1, 3 and 5 at panicle initiation (PI) or at heading stage. Carbendazim and Mancozeb sprayed at PI and 15 day after PI controlled disease development.

Suryadi *et al.* (1991) evaluated the effectiveness of several fungicides against rice blast and sheath blight. Spraying of fungicides was done at full tillering stage before and after panicle initiation stage respectively using Knapsack sprayer. The degree of efficacy was evaluated by using the percentage reduction of disease severity and the yield in each treatment. Mancozeb (1.6 kg ha^{-1}) was found good in controlling rice sheath blight. Treated plot yielded better than did the control plot.

Groth *et al.* (1993) found a number of fungicides for control of rice disease. Tilt (Propiconazole) gave good sheath blight control but did not control blast. Rovral (Ipridion) was effective against sheath blight and gave good yield stability.

Peng *et al.* (1993) reported that a single spray in the booting stage of rice (early to mid July) with a mixture of Applaud (Buprofezin) and Bayleton (Triadimefon), both of which are highly effective and persistent and safe to humans, domestic animals and natural enemies and provided efficient reduction in yield loss.

Miah *et al.* (1994) evaluated fourteen systemic and non systemic fungicides for the control of sheath blight of rice caused by *R. solani* Kuhn as foliar spray on inoculated plants in the field. Among them Benlate or Fundazole (50% Benomyl), topsin-M (70% Thiophanate Methayl + 20% Thiram were consistent in their effectiveness at 2.25 kg ha^{-1} sprayed either once at boot or twice at panicle initiation and boot stages. They were also effective under farmer field condition. The results suggested that the disease can be managed by a single foliar spray with any of the above mentioned fungicides at boot stage or after the symptom appearance.

Acharya *et al.* (1997) conducted an experiment with four fungicides, Ziram, Tolclofos-methayl, Carbendazim and Edifenphos for their *in-vitro* efficacy against the rice sheath blight pathogen (*R. solani*). When studied by the poison food technique, Toclofos-Methyl and Edifenphos showed complete inhibition of fungal growth at concentrations of 0.2, 0.1 and 0.05 %. When tested by dipping the mycelial and sclerotial inocula in the different concentrations of the test fungicides, there was a significant reduction in growth with all the fungicides. Maximum inhibition occurred with Tolclofos-Methyl followed by Carbendazim.

In an experiment, Tiwari (1997) tested the efficacy of Carbendazim (as Bavistin), Benomyl, Hexaconazole (as Contaf), Mancozeb (as Dithane M-45), Edifenphos (as Hinosan) and Thiophanate-Methyl (as Topsin-M) for control of *Rhizoctonia solani* on rice in the field, in Madhya Pradesh, India. Maximum disease control was obtained using Hexaconazole, followed by Edifenphos and the least control was obtained using Mencozeb. It is suggested that Edifenphos sprays would be economical for the control of *R. solani* on rice as Edifenphos also controls other rice diseases.

Parveen (1998) observed that the chemical's (Tilt) effect against sheath blight lesion development was found to be statistically significant but no significant difference on lesion length was obtained between single and double spray of Tilt 250 EC. She concluded that sheath blight disease of rice could be controlled by only one spray of Tilt 250 EC.

Mia (1999) noticed Tilt 250 EC at the rate of 1 L ha^{-1} for spraying at panicle initiation to boot stage for successful control of sheath blight disease of rice from Bangladesh Rice Research Institute. He also suggested Homai or Topsin M at the rate of 2 kg ha^{-1} spraying at panicle initiation or booting stage.

Kandhari and Gupta (1999) reported that Benomyl, Carbendazim, Ediphenfos and IBP had been extensively used for the control of sheath blight of rice in India. Two new organophosphorous compounds, G/F T-3 and G/F T-9 were highly potent against *R. solani*.

Akter *et al.* (2001) conducted an experiment by using six fungicides, namely, Bavistin 50WP (carbendazim), Contaf 5EC (hexoconazole). Forastin 50 WP (carbendazim), Anvil 5SC (hexoconazole), Tilt 250EC (propiconazole), and Thiovit 80WP (micronized sulfur), and a fertilizer, muriate of potash, in Gazipur, Bangladesh, in 1999 and 2000 against sheath blight of rice (cv. Swarna) caused by *R. solani.* They found that Contaf appeared to be the best in reducing the percent relative lesion height, percent disease index (PDI), and tiller infection.

Rodriguez *et al.* (2001) noticed that an experiment with rice cultivars (Fonaiap 1 and Cimaron) infected with sheath blight (*R. solani*) and were treated with Febuconazole (100 and 125 g ha^{-1}), Citrex (563 and 750 ml ha^{-1}), Propiconazole + Difenoconazole (50 + 50, 63 + 63 and 75 + 75 g ha^{-1}) and Flutolanil (300 ml ha^{-1}) in 1997-99. They reported that 125 g Tebuconazole ha^{-1} reduced sheath blight 72.33% to 82.81% and produced the highest yield (5050 kg ha^{-1}). Only two applications of 750ml ha^{-1}, Citrex controlled the disease but gave less control than that of Flutolanil. The best result was obtained with Propiconazole + Difenoconazole (both at 75 g ha^{-1}) as well as Flutolanil, obtaining 59.02 and 58.51% reductions of disease incidence and severity respectively.

Hossain and Mia (2001) stated that the effectiveness of four fungicides against sheath blight disease of rice where two foliar sprays with Tilt 250 EC @ 0.1% caused significant reduction in sheath blight severity and improved grain yield.

Hossain and Mia (2001) carried out an experiment in Rajshahi, Bangladesh, during *T. aman* season (June to December) of 1998 to evaluate the effectiveness of four fungicides, i.e. Aimcozim 50 WP (Carbendazim), Bavistin 50 WP (Carbendazim), Shincar 50WP (Carbendazim), and Tilt 250 EC (Propiconazole) and two additional rates of muriate of potash (MP), i.e. 20 and 40 kg ha^{-1}, against sheath blight disease (*R. solani*) of rice. The application of two additional 40 kg MP ha^{-1} in two equal splits as top dressing and two foliar sprays with Tilt 250 EC at 0.1% caused significant reduction in sheath blight severity and improved grain yield.

Sitansu *et al*. (2001) evaluated the efficacy of Iprodione (Rovral 50) and carbendazim (Bavistin 50 WP) both at 0.5, 1.0, 2.0 or 4.0 ppm as single and combinations closes against rice sheath blight caused by *R. solani* and found the single doses of Carbendazim best in field condition but in vitro single dose of Iprodione showed best.

Johnson *et al.* (2002) conducted an experiment with Hexconazole against *R. solani* causing rice sheath blight disease of rice. They reported that Hexaconazole did not remarkable change in Peroxidize activity of *R. solani* inoculated rice plant.

Kazempour *et al.* (2003) carried out an experiment with some fungicides (Benomyl, Carbendazim, Carboxin-Thiram, Edifenphos and Zineb) to control sheath blight disease of rice infected by *Rhizoctonia solani in-vitro* and under greenhouse conditions. Benomyl, Carbendazim, Carboxin-Thiram, Edifenphos and Zineb reduced disease by 32.5, 21.5, 12.8, 9.5 and 0% respectively.

Ali and Archer (2003) conducted an experiment with fungicides of diverse group and mode of actions was evaluated *in-vitro* and *in-vivo* for their efficacy against sheath blight disease (*R. solani*) of rice. Ten fungicides viz. Azoxytrobin 250 SC (Strobilurin), Carbendazim 500 Flo 2 (Benzimidazole), Cyproconazole 240 EC (Triazole), Fenpropimorph 750 EC (Morpholine), Fludioxonil 2.5 SC (Phenylpyrroles), Hexaconazole 250 SC (Triazole), Iprodine50 WP (Dicarboximide), Pencycuron 250 Flo (Phenylurea), Propiconazole 250 EC (Triazole) and Tolclofos-Methyl 500 Flo (Aromatic Hydrocarbon) were tested. Except Azoxytrobin, all fungicides were highly effective *in-vitro*. The highest inhibition of mycelia growth was obtained with Pencycuron. In *in-vivo* test, Azoxytrobin, Pencycuron and Hexaconazole were highly effective against sheath blight disease. Tolclofos-Methyl and Carbendazim were effective only in high doses. Phytotoxcity was recorded in Triazole and Morpholine fungicides, which expressed as yellowing (chlorosis), inhibition of plant elongation and incomplete panicle emergence contributed to high sterility and yield loss.

Chahal *et al.* (2003) reported that Propiconazole (0.1%), Ediofenphos (0.1%), Iprodione (0.3%), Carboxin (0.2%) and Carbendazim (0.1%) effectively controlled sheath blight of rice.

Biswas (2004) evaluated the relative efficacy of mix fungicides showing 250 EC (125 g Epoxyconazole + 125 g Carbendazim), Auintal 50 WP (25%) Iprodione + 25% Carbendazim) and Armune 30 EC (15 g Rpmycondzole + 15 g Difenoconazole) against sheath blight disease of rice (caused by *R. solani*) of rice.

Mian *et al.* (2004) conducted two field experiments in Bangladesh during *T. aus* and *T. aman* season in 2002 to tind out the efficacy of eight fungicides viz. Forastin 50 WP (carbendazim), Genuine 50 WP (carbendazim), Cindazim 50WP (carbendazim), Akonazole 250 EC (propiconazole), Abgen 50% (carbendazim), Goldazim 50WP (carbendazim), Folicue EW 250 (tebuconazole) and Tilt 250 EC (propiconazole) in controlling the sheath blight disease of rice (*R. solani*). All the fungicides were sprayed twice at 5 and 20 days after inoculation at recommended doses. Akonazole and Folicur appeared to be most effective in reducing percent tiller infection, percent relative lesion height and percent disease index (PDI). In terms of PDI reduction over control, Akonazole and Folicur showed good performance in both sessions ranging from 59.96 to 80.29% and form 53.79 to 80.27%, respectively. The significant increase in grain yield was also recorded by applying Akonazole and Folicur over the untreated control.

Ashrafuzzaman *et al.* (2005) conducted an experiment to ass the single and combined doses of Ash (3 t ha^{-1}), Bleaching powder (10 ppm), Poultry manure (5 t ha^{-1}) and Bavistin (0.05%) for the management of sheath blight caused by *R. solani* Kuhn and their effects on yield components and yield of cv. BRRI dhan 39. They found that highest weight of thousand grains, grain yield per hill, straw yield per hill and lowest percent of unfilled grains were obtained when ash, bleaching powder, poultry manure and Bavistin used in combination.

Lore *et al.* (2005) stated that an experiment to evaluate different fungicides against sheath blight (*R. solani*) of rice under artificial epiphytic conditions (K. Purthala, Punjaab, India, during 2002 and 2003) and indicated that Monceren (pencycuron) 250 SC exhibited superior efficiency over other fungicides such as RIL 010/F1 25SC, RIL 010/F1 50 SC, Rhizolex 50 WP, Rhixocin 3L, Folicur in controlling the disease as well as increasing the yield. Other fungicide such as RIL 010/F1 SC, RIL 010/F1 50 SC, Rhizolex 50 WP, Rhizocin 3L, Fulicur (tebuconazole) 250 EW, Contaf 5 EC and Tilt (propiconazole) 250 EC were also effective at higher concentration and was as per with Bavistin (carbendazim) 50 WP. Shield (clopyralid) 2.62 SC proved least effective.

Lore *et al.* (2007) reported that the efficacy of eight fungicides, Tilt 25 EC (propiconazole), Bavistin 50 WP (carbendazim), Baycor 25 WP (bitertanol), Contaf 5EC (hexaconazole), Dithane Z-78 (zineb), Kitazin 48 EC (iprobenfos), Saaf 75 WP (carbendazim+mancozeb), and Rhizocin

3L (validamycin), was compared against three economically important diseases of rice namely sheath blight (*R. solani*), sheath rot (*Fusarium moniliforme* [*Gibberella moniliformis*]) and brown spot (*Drechslera oryzae* [*Cochliobolus miyabeanus*]), under laboratory and field conditions (Punjab, India) by artificial inoculation technique during the *kharif* seasons of 2002, 2003 and 2004. Tilt 25 EC at 0.1% was the most effective fungicide against the three diseases, where the lowest mean disease severity was 15.7% for sheath blight, 6.7% for sheath rot and 9.0% for brown spot, compared to 51.4%, 24.8% and 48.5% in untreated controls of respective diseases The second best fungicide appeared to be Bavistin 50 WP at 0.1% that was also quite effective against sheath blight (18.1%) and sheath rot (10.5%), followed by Contaf 5EC at 0.1%, but was least effective against brown spot (33.20%). Rhizocin 3 L at 0.25% was also significantly effective against sheath blight. Baycor 25 WP at 0.1% and Dithane Z-78 at 0.25% were the least effective, followed by Kitazin 48EC at 0.2% and Saaf 75 WP at 0.15% against the three diseases. Tilt 25 EC, was also highly effective against grain discoloration, followed by Bavistin 50 WP and Contaf 5 EC. Under laboratory conditions, Tilt 25EC demonstrated a high level of efficacy, followed by Contaf 5EC against the pathogens of the above-mentioned diseases.. Bavistin 50WP was also equally effective against *R. solani* and F. moniliforme, but it did not control the growth of D. oryzae even at 200 ppm. Rhizocin 3L and Saaf 75WP also showed good activity, but Dithane Z-78 exhibited the least activity against the test pathogens.

Janki-Kandhari (2007) reported that seven fungicides and three botanicals were tested at different concentrations against sheath blight (*R. solani*) of rice cv. Pusa Basmati-1 under field conditions in New Delhi, India, during *kharif* 2004 and 2005. All the fungicides and botanicals were found effective. However, among fungicides, Armure 30EC (propiconazole + difenoconazole) at 1.0 ml/l recorded the least disease incidence of 31.3%, compared with 77.9% in the untreated control. Among botanicals Achook (azadirachtin) showed the least incidence of 65.1%, compared with 82.9% in the control. Bavistin used as standard fungicide at 1000 ppm was most effective, with disease incidence of 8.4% only.

Shahid *et al.* (2014) observed that eight fungicides were tested at different concentrations against sheath blight (*R. solani*) of rice, In Punjab, Pakistan. Cordate 75 gm, Precurecombi 62.5 gm, Curon 50 ml , Bandict 62.5 ml, Nativo 15 gm, Valedamycin 25 ml, Tilt 50 ml, Curon (Flooding) 100 ml, and Control was used to compare efficacy with these eight fungides. Nativo was found to be the best fungicide used against sheath blight of rice. Benomyl was reported to be mostly used for this disease but Nativo was another new addition to the group of fungicides used to control sheath blight of rice. In the recent research work Nativo, Bandict and Tilt had shown better result in the field against this disease. These pesticides had improved the agronomic features of the rice crop such as Average number of tillers per hill, Average number of grains, weight of 1000 grains in grams, disease incidence and crop yield.

Aktaruzzaman *et al.* (2015) conducted an experiment three fungicides viz. Bavistin 50 WP, Tilt 250 EC and Folicur 250 EW were sprayed against *R. solani* causing sheath blight on three *aman* rice varieties viz. Hybrid Hera, BRRI Dhan-49 and BR-11. Control plot was sprayed with plain water. The experiments were laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The tallest plant height (116.80 cm) was recorded in Hybrid Hera variety and the shortest plants height (106.00 cm) was obtained from the BR-11 variety. The percent relative lesion height (% RLH) was found significantly in deferent with some extent. Comparatively, the lower % RLH (3.42) was recorded in Folicour 250 EW sprayed plot where the highest % RLH (4.16) was found in control plot. The percent decrease of relative lesion height (17.78%) was recorded in the Folicour 250 EW sprayed plot over control. Highest numbers of infected tiller hill^{-1} (5.28) were recorded in the control plot where the lowest numbers of infected tiller/hill (4.92) was recorded in Folicour 250 EW sprayed plot but incase of varieties the highest numbers of infected tiller hill^{-1} (8.31) was recorded in BR-11 variety and the lowest numbers of infected tiller/hill (3.31) was recorded in Hybrid Hera. The highest yield (t ha^{-1}) (5.81) was recorded in Folicour EW 250 sprayed plot and the lowest yield (t ha^{-1}) (4.24) was recorded in the control plot. The fungicides Folicour 250 EW increased yield (37.02%) than over control. In case of varieties, the highest yield (5.93 t ha^{-1}) was recorded in Variety BR-11 and the lowest yield (5.10 t ha^{-1}) was obtained from Hybrid Hera variety. From the present findings it may be concluded that Folicour 250 EW was a promising fungicide for lowering sheath blight incidence and BR-11 was the best variety among the three *aman* varieties in aspect of yield

Majumdar *et al.* (2017) noticed that nine fungicides were tested against sheath blight of rice (*R. solani*) of rice. The experiment was conducted following RCBD with 10 treatments including control. Each treatment was replicated thrice adopting a plot size of 4m × 2m where plants were spacedat 15cm × 15 cm. The effects of 9 different chemicals including control (T_1=Propiconazole @ 1ml l^{-1}, T_2= Thiophanate methyl @ 1 g l^{-1}, T_3= Mancozeb @ 2.5 g l^{-1}, T_4=Tebuconazole @ 1 ml l^{-1}, T_5= Pencycuron @ 1 ml l^{-1}, T_6=Validamycin @ 1 ml l^{-1}, T_7= Hexaconazole @ 1 ml l $^{-1}$

T_8=Carbendazim @ 1 g l^{-1}, T_9= Tricyclazole @ 1 g l^{-1}, T_{10}= Control (untreated)) were recorded against sheath blight incidence and compared to control for consecutive 3 years. Spraying of Tebuconazole 1ml l^{-1} was found to be most effective in suppressing sheath blight .In spite of reducing PDI chemicals were also effective in increasing yield over control. Validamycin 1ml l^{-1} recorded highest yield (44.78 q ha^{-1}) followed by Carbendazim (41.62 q ha^{-1}) and Tebuconazole (41.06 q ha^{-1}).

Thamarai Selvi *et al.* (2019) conducted an experiment to evaluate efficacy of different fungicides against sheath blight disease (*R. solani*) of rice. Eight fungicides were tested against the rice sheath blight pathogen under lab conditions at various concentrations for analysing the mycelial growth and mycelial dry weight. The results revealed that, among the various fungicides among the eight fungicides, Hexaconazole (Contaf) @ (200 ppm) completely inhibited the mycelial growth and mycelial dry weight of *R. solani*. Propiconazole, metaminostrobin, carbendazim, azoxystrobin, copper oxychloride, difenconazole, tebuconazole @ 400 ppm recorded 0.00 mm, 0.00 mm, 2.70 mm, 5.35 mm, 16.84 mm and 22.15 mm and 26.00 mm radial growth of the test pathogen respectively.

Prasad *et al.* (2020) used 8 fungicides to control sheath blight of rice in their experiment and reported that the tested fungicide i.e. Hexaconazole 5 SC (Contaf) treatment found highly effective in reducing the disease severity of sheath blight 11.11% and 46.50% decrease of the disease over control.

Tiwari *et al.* (2002) used 7 fungicides to control sheath blight of rice and reported that Carbendazim + Epoxiconazole (0.2%), Hexaconazole (0.2%), Epoxiconazole (0.24%) and Propicanzole (0.2%) were significantly more effective in controlling disease severity than other fungicides.

2.6. Yield loss due to the sheath blight disease of rice

Tasi (1975) observed that corresponding yield losses of 43% and 31.9% and 16.3%, occurred for infection at tillering and booting stages in the first and second crops respectively.

Arunyanart *et al*. (1986) reported that rice plants infected by *R. solani* with disease severity 3, 5, 7 and 9 reduced yield 15, 22, 28 and 40%, respectively. Correlation between disease severity and percent yield loss, straw weight loss and empty grains was a linear regression.

Shahjahan *et al*. (1986) stated that in a farmer's field trial yield losses were 31.0% and 28.7% at mean disease indices (DI) of 4.8 and 5.0 in susceptible varieties BR2 and BR3, respectively in Bangladesh. The yields were highly and negatively correlated with DI. The regression of DI on yield showed that a reduction of 0.20 t ha^{-1} for BR2 and 0.26 t $ha\text{-}^{1}$ for BR3 might be attributed to per unit increases in DI. Under inoculated condition BR1 and BR5 two susceptible variety had a mean loss of 17.3% and 13.1% with mean DI differences of 4.1 (5.4- 1.3) and 2.0 (4.8-2.8), respectively. Again in separate experiments BR1 had a loss of 14.0% during *aus* and 15.4% in IR5 during *aman* season at DI 5.0 and 4.5, respectively.

Ahn and Mew (1986) studied the relation between rice sheath blight disease of rice and yield. No significant yield reduction was found when %RLH was less than 20%. If lesion reached the 3rd sheath from the sheath bearing the flag leaf, and if RLH was about 30% a significant yield loss was seen. A 46% yield loss is possible in milled rice if sheath blight lesion reaches 90% of %RLH.

Rajan (1987) reported that percentage yield loss due to sheath blight of rice of 3, 5, and 7 and disease scores in 0-9 scale of SES were 16.8, 22.9, 36.2 and 48.4, respectively.

Naidu (1989) inoculated eight varieties with sheath blight pathogen *R. solani* using a stem tape method and scored for yield. Grain yield losses varied from 49% in Phalguna to 69.1% in Mansui.

Dilla *et al.* (1993) observed that yield per hectare ranged from 3.10 to 7.67 t ha^{-1} during dry season and relatively lower during the wet season, ranging from 3.46 to 5.96 t ha-^{1}. The effect of sheath blight inoculation was very strong in all cases. The variation in yield losses ranged from 0.27 to 1.29 t ha^{-1} in dry season and 0.23 to 1.37 t ha^{-1} in the wet season. Yield loss was strongly affected by amount of inoculums but by population density and nitrogen levels. The value ranged from 3.59 to 27.01% wet season and 3.16 to 28.62% in dry season.

CHAPTER 3

MATERIALS AND METHODS

3.1. Field experiment

3.1.1. Experimental site

The field experiment was carried out in the Central Farm land allotted for the Department of Plant Pathology at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of July 2019 to December 2019.

3.1.2. Land topography and soil

The experimental site was located at 23°77′ N latitude and 90°35′ E longitude with an elevation of 1.0 meter from sea level. The soil of the experimental site belongs to the Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. The morphological description of the field given below:

Location	**:** Sher-e-Bangla Agricultural University Farm, Dhaka,
Agro Ecological Region	**:** Madhupur Tract (AEZ-28)
Land Type	**:** High land
General Type	**:** Deep Red Brown Terrace Soils
Soil Series	**:** Tejgaon
Topography	**:** Fairly level
Depth Inundation	**:** Above flood level
Drainage Condition	**:** Well drained

3.1.3. Variety

BR11, a susceptible variety to sheath blight disease of rice was used for his experiment. This variety was developed by Bangladesh Rice Research Institute (BRRI) and year of release is 1980. Main characteristics of transplanting *aman* variety are plant height 115 cm, clean rice medium bold, planting season is mainly *kharif II*.

3.1.4. Seed collection

Two kg seeds were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur.

3.1.5. Treatments / Fungicides

The four chemical sprays were started from maximum tillering stage of rice plant and continued up to soft dough stage with 15 days intervals. Four sprays were applied in panicle initiation stage, flowering stage, milking stage and soft dough stage. The following fifteen treatments including control (13 fungicides with 2 controls) were used in the experiment (Table 1 and Plate 1).

Table 1: Details of the used fungicides in the experiments

Treat-Ments	Trade Names	Active Ingredients	Rate	Company Names
T_1	Tilt 250 EC	Propiconazole	0.1%	Syngenta Bangladesh Ltd.
T_2	Contaf 5 EC	Hexaconazole	0.1%	Auto Crop Care Ltd.
T_3	Folicur 250 EC	Tebuconazole	0.1%	Bayer Crop Science Ltd.
T_4	Score 250 EC	Difenoconazole	0.1%	Syngenta Bangladesh Ltd.

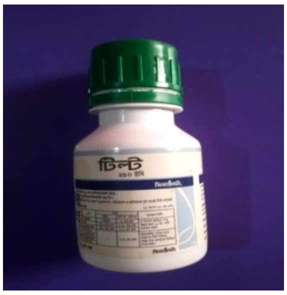
T_5	Combi-2 30 EC	Difenoconazole + Propiconazole	0.1%	National Agricare Ltd.
T_6	Filia 525 EC	Propiconazole +Tricyclazole	0.1%	Syngenta Bangladesh Ltd.
T_7	Amister Top 325 SC	Azoxytrobin + Difenoconazole	0.1%	Syngenta Bangladesh Ltd
T_8	Acibin 28 SC	Azoxytrobin + Cyproconazole	0.1%	ACI Crop Care Ltd.
T_9	Awal 72 WP	Zineb + Hexaconazole	0.2%	Auto Crop Care Ltd.
T_{10}	Nativo 75 WP	Tebuconazole + Trifloxystrobin	0.2%	Bayer Crop Science Ltd.
T_{11}	Autostin 50 WP	Carbendazim	0.2%	Auto Crop Care Ltd.
T_{12}	Dithane M-45	Mencozeb	0.2%	Bayer Crop Science Ltd.
T_{13}	Sunvit 50 WP	Copper Oxychloride	0.2%	McDonald Bangladesh (Pvt.) Ltd.
T_{14}	$Control_1$ (with inoculation)	-	-	-
T_{15}	$Control_2$ (without inoculation)	-	-	-

Here,

EC= Emulsifiable Concentrate

WP= Wettable Powder

WC= Wettable Concentrate



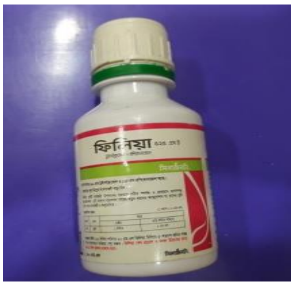
Tilt 250EC

Contaf 5EC

Folicur 250EC

Score 250EC

Combi-2 230EC



Filia 525SE

Amistar Top 325SC

Acibin 28SC

Awal 72WP

Nativo 75WP

Autostin 50WP

Dithane M-45

Sunvit 50WP

Plate 1: Different fungicides used for *in vitro* and *in vivo* experiments

3.1.6. Sprouting of seed

Seeds were soaking with water in a bucket for 24 hours. The seeds were then taken out of water and kept in gunny bags at room temperature for 72 hours for sprouting before sowing in seedbed (Plate 2).

Plate 2: Sprouting of rice seed prepared for sowing in the seedbed

3.1.7. Preparation of seedbed and sowing of seed

Seedbed was prepared by paddling the soil with the help of power tiller and harrow in the field of Central farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. As the land was rich in organic matters, therefore no manuring was done. But 5 kg phosphate and 2.5 kg potash was applied to the seedbed. Sprouted seeds were sown in the wet seedbed 02 July 2019 (Plate 3). Seedlings were properly taken care of. Weeds were removed and irrigation was given in the seedbed as and when necessary.

Plate 3: Sowing of sprouting seed in the seedbed

3.1.8. Preparation of experimental field

The land for the experiment was prepared with the help of power tiller and harrow. The land was first opened on 22 July 2019 and plough. After 9 days, the 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. Thus, the land became ready for transplanting of rice seedlings. The layout of the experiment in the field was done according to the design adopted (Plate 4).

Plate 4: Preparation of experimental field

3.1.9. Application of fertilizer

Fertilizers were applied as per recommendation of BRRI (*Adhunic Dhaner Chash*, 2016). The following doses of fertilizers were applied to the plots are described in Table 2.

Table 2: Used chemical fertilizers in the experiment

Fertilizers	Dose/ha	Dose/plot
Urea	140 kg	28 gm
Triple Super Phosphate (TSP)	90 kg	18 gm
Muriate of Potash (MOP)	40 kg	8gm

All fertilizers except 2/3 Urea were incorporated with soil at the time of final land preparation. Nitrogen in the form of urea was applied in two equal splits at growth stages 30 and 45 days after transplanting.

3.1.10. Transplanting of seedling in the experimental field

Twenty seven old seedlings were uprooted from the seedbed very carefully and then transplanted on 29 July 2019 in the experimental field. In the field experiment, row to row spacing was maintained as 20 cm and that of hill 20 cm and 2-3 seedlings were transplanted in an individual hill (Plate 5).

Plate 5: Tweenty seven days old seedling transferring in the experimental field

3.1.11. Intercultural operations

Intercultural operations like weeding, irrigation etc. were done specifically in the plots. First irrigation was done immediately after seed sowing. After germination, the irrigation was done for several times at 7 to 15 days intervals. Proper drainage system was maintained to release excess water created by rainfall immediately after stagnation.

Plate 6: Weeding was done in the experimental field

3.1.11.a. Weeding: Weeding was done in the field as necessary. Total 4 weeding was done in this field experiment. 1st weeding was done in 10th August 2019, 2nd weeding in 22 August 2019, 3rd weeding in 07 September 2019 and last weeding were done in 15 September 2019 (Plate 6).

3.1.11.b. Irrigation: Irrigation was given in the field as necessary. Several numbers of irrigation was given in the experimental field. 1st irrigation was done just before the transplanting of the field. Proper drainage was also maintained.

3.1.12. Tagging of plants

In field experiments, randomly 5 hills were selected from each plot tagged for data collection. Mean values determined to get rating score of each treatment.

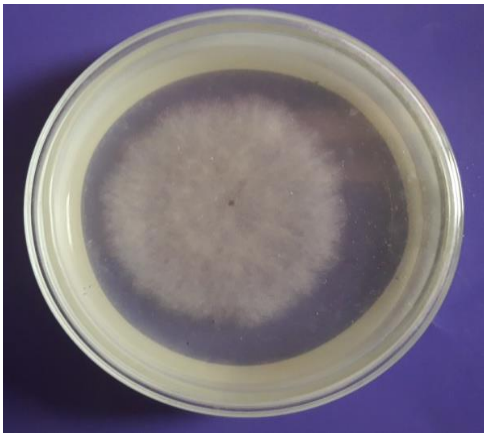
3.1.13. Inoculum and pure culture preparation

Disease infected leaf sheath was collected from the experimental plot by using polyethylene bag was taken to the Plant Pathology laboratory, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The fungus was isolated from infected parts of the rice plants following tissue planting method (Bashar *et al*., 2010). The diseased leaf sheath was cut into small pieces (about 0.5-1 cm) from the infected portion along with some healthy portion. The cut pieces were surface sterilized by dipping it into 10% sodium hypochlorite solution for 2-3 minutes. The pieces were then washed in water three times and were placed on sterilized petri dish with help of sterile forceps. The petri dishes were then incubated at 25±1 ºC for 7-10 days. Later the pathogen was isolated and purified using hyphal tip culture method and grown on PDA media at 25±1 ºC for 1 week. The pure culture of the isolated fungi was preserved in the refrigerator. Fungus was identified based on mycelial growth, colony character, sclerotia formation and sclerotial size. The fungal strain was stored on PDA medium at 4 °C and it was ready for the artificial inoculation in the field (Plate 7).

Sample collection from the experimental field

Growing fungi on blotting paper

Mycelial ball and sclerotia produced on blotting paper



Pure culture of *R. solani*

Plate 7: Inoculum preparation for the experimental field

3.1.14. Artificial inoculation of pathogen in the experimental field

In the field experimental plants at maximum tillering stage, the primary tillers of each hill were tagged and inoculated with *R. solani* by placing a mycelial ball beneath the leaf sheath just into the 1.5 to 2.5 cm above the water surface level as per the position of the sheath. The inoculated sheath was covered immediately with aluminum foil. When typical lesions appeared after 3 days the aluminum foil was removed (Plate 8). *R. solani* infected plants were kept to grow up in natural condition (Prasad *et al.* 2020)

Find out the selected hill

Placing the mycelium in the leaf sheath

Covering the mycelium with foil Paper

Showing the symptom

Plate 8: Artificial inoculation of pathogen in the experimental field

3.1.15. Preparation and application of fungicides

Fungicides were sprayed as solution into the experimental plot as per treatment except the control plot. Each spray solution was prepared by mixing definite amount of fungicides with tap water. The whole surface of the plant was sprayed by the solution of the fungicides. In case of control plot plain tap water was spray on the plants. The fungicides spraying were done in maximum tillering stage of rice plant. Every time the fungicides were freshly prepared prior to application and the spray tank was thoroughly cleaned before filling with the individual spray material. Special attention was given to complete coverage of the growing plants with the fungicides. Adequate precautions were taken to avoid drifting of spray materials from one plot to the neighboring ones.

3.1.16. Spray schedule

The four chemical sprays were started from maximum tillering stage of rice plant and continued upto soft dough stage with 10 days intervals. Four sprays were applied at 57 DAT, 67 DAT, 77 DAT and 87 DAT in maximum tillering stage, panicle initiation stage, flowering stage and soft dough stage, respectively.

3.1.17. Measurement of disease incidence and severity of sheath blight of rice

Measurement of disease was done as disease incidence (hill incidence and tiller incidence) and disease severity. At random 5 hills were assessed for disease incidence (by visual observation) and severity (measuring the lesion length and total sheath length). Disease incidence was calculated by using the following formula (Agrios, 2005):

$$\% \text{ Disease Incidence} = \frac{\text{Number of diseased plant (or parts)}}{\text{Number of total plants (or parts) observed}} \times 100$$

Disease severity was calculated as:

$$\% \text{ Disease severity} = \frac{\text{Total lesion length}}{\text{Total sheath length}} \times 100$$

Five hills from each treatment plot randomly tagged for data collection. Sheath blight disease severity was recorded in one at before spray and four growth stage viz. flowering stage, milking stage, soft dough stage, maturity stage and following the Standard Evaluation System of Rice (IRRI, 2001). The scale was formulated based on % Relative Lesion Height (% RLH) which is given below:

0= No incidence (Highly resistant)

1= Less than 1% sheath area affected (Resistant)

3= 1-5% sheath area affected (Moderately Resistant)

5= 6-25% sheath area affected (Moderately Susceptible)

7= 26-50% sheath area affected (Susceptible)

9= 51-100% sheath area affected (Highly Susceptible)

The %RLH was the average vertical height of uppermost lesion on leaf or sheath expressed as a percentage of the average plant height. The mean value of rating (%RLH) was determined to get rating score of the material under each treatment. The %RLH was calculated as per the formula given below (Ansari, 1995):

$$\text{Relative Lesion Height \%} = \frac{\text{Lesion height}}{\text{Plant height}} \times 100$$

The final disease severity was recorded 15 days after the last spray using SES scale (IRRI, 2001).

Percent disease control over check was calculated by using the following formula:

$$\text{\% Disease control over check} = \frac{\text{(\%) DS in check} - \text{(\%) DS in treatment}}{\text{(\%) DS in check}} \times 100$$

Per cent yield increase over check was calculated by using the following formula:

$$\text{Percent yield over check} = \frac{\text{Yield (t ha}^{-1}\text{) in treatment} - \text{Yield (t ha}^{-1}\text{) in check}}{\text{Yield (t ha}^{-1}\text{) in treatment}} \times 100$$

3.1.18. Data Collection

Data were collected on following parameters

- % Disease incidence
- % Disease severity
- Lesion height (cm)
- Plant height (cm)
- Percent relative lesion height % RLH
- No. of infected hill plot^{-1}
- No. of infected tiller hill^{-1}
- Length of panicle
- Number of filled grains panicle^{-1}
- Number of unfilled grains panicle^{-1}
- Number of tiller hill^{-1}
- Number of effective tiller hill^{-1}
- Number of non effective tiller hill^{-1}
- 1000-grain weight (g)
- Total yield (t ha^{-1})
- Straw weight (t ha^{-1})

3.1.19. Harvesting, threshing and weighting

The crop was harvested on 05 December, 2019 at fully ripening stage from field in plot wise. Moreover five tagged hills of each unit plot were harvested separately. Remaining plants of each plot were also harvested and made bundles. The all bundled were carried to farm office and dried under sunlight for 2 days. The fully dried bundles were threshed carefully and had been taken weight of 1000 seed and yield per plant from five tagged hills. Yield per plot was taken adding the seed weight of five tagged hills to the rest of the plant in a specific plot. The yield per plot was converted to the yield per hectare.

3.1.20. Isolation and identification of causal organism(s)

Isolation and identification of causal organism was done by the following methods

a. By Symptomological study (Visual assessment)

In this study, the development of symptoms was closely observed to confirm disease. The diseased plants were closely and carefully examined by magnifying glass to observe the disease symptoms development, sign of the pathogen, source of infection, mode of dissemination and favorable environment. Idea about causal organism was taken from this information (Kubick and Harman, 1998).

b. Growing on moist blotter paper (Incubation method)

Disease infected leaf sheath was collected from the experimental plot by using polyethylene bag was taken to the Plant Pathology laboratory, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The diseased leaf sheath was cut into small pieces (about 0.5-1 cm) from the infected portion along with some healthy portion. The cut pieces were surface sterilized by dipping it into 10% sodium hypochlorite solution for 2-3 minutes. The pieces were then washed in water three times and were placed on sterilized petridish with help of sterile forceps. Petridishes were then incubated at 25±1 ºC for 7-10 days. When the fungus grew well mycelium and sclerotia were observed under sterio microscope and compound microscope. The identification of the causal organism was done with the help of relevant literature (Kubick and Harman, 1998).

c. Growing on culture media (Tissue planting method)

The diseased leaf sheath was cut into small pieces (about 0.5-1 cm) from the infected portion along with some healthy portion. The cut pieces were surface sterilized by dipping it into 10% sodium hypochlorite solution for 2-3 minutes. The pieces were then washed in water three times and were placed on sterilized petridish with help of sterile forceps. The petridish were then incubated at 25±1 ºC for 7-10 days. Later the pathogen was isolated and purified using hyphal tip culture method and grown on PDA media at 25±1 ºC for 2 weeks and identified according to the key of Kubick and Harman (1998)

3.1.21. Weather data

The data of monthly average temperature, relative humidity, monthly total rainfall (mm) and sunshine hours received an the experimental site during the period of the study were collected from weather yard, Bangladesh Metrological Department, Agargon, Dhaka-1207.

3.2. Laboratory experiment (*In vitro* study)

3.2.1. Poisoned food technique

In vitro evaluation of selected chemical fungicides against *R. solani* was done by following poisoned food technique (Schmitz, 1930) to compare with the Experimental field data. Thirteen fungicides Tilt 250 EC, Contaf 5 EC, Folicur 250 EC, Score 250 EC, Combi 230 EC, Filia 525 SE, Amister Top 325 SC, Acibin 28 SC, Awal 72 WP, Nativo 75 WP, Autostin 50 wp, Dithae M-45, Sunvit 50 WP were used for the study. The effect of selected fungicides on the radial growth of the pathogen was studied by poisoned food technique. Each fungicide with a control was tested against *R. solani.* Required quantity of fungicide solutions were mixed with autoclaved PDA and cooled just before pouring into Petri dishes, so as to obtain the required concentrations. The medium was then dispensed uniformly into 90 mm diameter. Petri dishes are then inoculated with 5 mm mycelial disc of the pathogen from 7 day old culture with their mycelial side down. Pathogen inoculated in unnamed medium served as control. The growth of the fungus was monitored by measuring the radial growth in mm every 24 h, till the fungus covers the plate completely in the control plate. The percent inhibition (PI) of the fungus over control was calculated using the following formula:

$$PI = (C - T)/C \times 100$$

Where, C is colony diameter of the fungus in control plates (mm) and T is colony diameter of the fungus in treated plates (mm)

3.3. Design of the experiments

The field experiment was carried out in a RCBD with 3 replications. Each block comprised 15 unit plot and the total number of unit plots were 45 (15×3). The unit plot size was $2m^2$. The distance maintained between plots was 50 cm and between blocks was 1m (Plate 9). The lab experiment was conducted following CRD with three replications.

3.4. Statistical data analysis

The collected data was analyzed by Statistics 10 computer package program. One way analysis of variance (ANOVA) was used to find out the variation of result from experimental treatments. Treatment means were compared with LSD (Least Significant Difference) value at 0.05% alpha value.

Plate 9: A view of the experimental field

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Symptoms of sheath blight disease

The symptoms of rice sheath blight were investigated and visually observed in the field experimental plot. Early symptoms developed on the leaf sheaths at or just above the water line as circular, oval or ellipsoid, water-soaked spots which are greenish-gray in color (Plate 10A). As the disease progressed, they enlarged and tended to coalesce forming larger lesions with grayish white centers surrounded by tan to dark brown irregular borders or outlines. Infection was spread to leaf blades and caused irregular lesions with dark green, brown, or yellow-orange margins (Plate 10B). The lesions was developed extensively and coalesced on partial or whole leaf blades, which may usually produce the characteristic rattlesnake skin like pattern (Plate 10C). These damaged tissues had interrupted the normal flow of water and nutrients to the plant tissues above (leaves and panicles). As the plant had approached heading, the canopy became dense, created a humid microclimate that was favorable for the rapid development of the disease. The disease was moved up the plant and infected the flag leaves and panicles under severe conditions. The fungus was spread into the culms from early sheath infections and weaken the infected culms, resulted in the lodging and collapse of tillers (Plate 10D). At this stage, the symptoms resembelled to “Kobra snake skin” like appearance on the leaf blade.

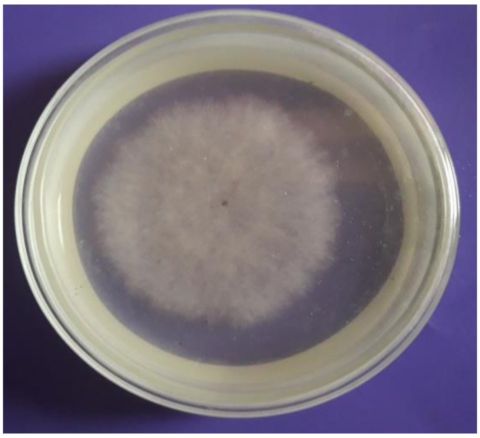
Rangaswami and Mahadevan (1999) as well as Lakshaman and Amaradasa (2016) also reported the same typical even irregularly elongated (3cm × 1cm) and discolored discrete lesions with pale greenish grey to grayish white centre with narrow blackish to dark brown margin lesion on sheath. The similar types of symptoms of sheath blight were also observed earlier by Singh *et al*., 2012; Hollier *et al.*, 2009 and Sivalingam *et al.*, 2006 and on sheath and leaf of rice. Uppala and Zhou (2018) also describe the symptom almost looks like a cobra snake skin from distance.

Plate 10: Characteristics of sheath blight disease symptoms (A) Irregular water soaked greenish gray lesion, (B) Grayish white center surrounded by dark brown irregular border, (C) Lesion coalesced on leaf blade produce cobra skin like pattern, (D) Collapse of culm, panicle and produced mycelial ball, slerotia under severe condition.

4.2. Pure culture of pathogen

The fungal isolates were re-cultured to find the pure culture of *Rhizoctonia solani*. Young colonies of all isolates were identical, they were hyaline on PDA medium (Plate 11), mycelium usually very light brown or whitish; coarsely or finely radiate; occasionally moderately aerial, white patches scattered over the surface (Plate 11). The fungus *R. solani* produced silver colony at initial stage which later turned white in color and appeared smooth. The number of sclerotia was few to abundant with usually about 1.5 mm to 2 mm diameter on agar surface. Dasgupta (1992) reported that young hyphae are hyaline and pigmentation of hyphae appears to be restricted to various shades of brown or silvery, become brown with maturity. Similar findings were also reported by Gnanamanickam (2009) that *R. solani* isolates are known as fast growers that produce hyaline mycelia when young, which eventually turns yellow to brown with age.

2 DAI



5 DAI

7 DAI

12 DAI

Plate 11: Pure culture of *Rhizoctonia solani* at different days after incubation (DAI)

4.3. Causal organism of sheath blight disease of rice

R. solani was isolated in PDA medium from infected plant sample. After well growth *R. solani* on potato dextrose agar (PDA) medium, the organism was recultured by mycelium and sclerotia to obtain pure culture. It was observed that, mycelium growth of causal organism was formed from second days after incubation (DAI) through mycelium and it took three days to from mycelium through sclerotia and finally it took 5-7 days to fill the whole petri dish with mycelium of *R. solani*. Mustard seed like and brownish in color sclerotia was formed in the pure culture of causal organism within the 13-15 days of incubation (Plate 12).

Singh *et al*. (1988) reported that the pathogen normally attacked the leaf sheath and leaf blade but the symptoms were also found on emerging panicles which chaffy, grayish brown and matted together by fungal mycelium. Numerous white and brown sclerotia were found on diseased panicles. Ou (1985) observed that sclerotia are formed on or near these spots, but are easily detached. The size and color of spots and the formation of sclerotia depend upon environmental conditions mycelium of the fungus may grow over the surface of the leaf sheaths and can spread to a considerable distance.

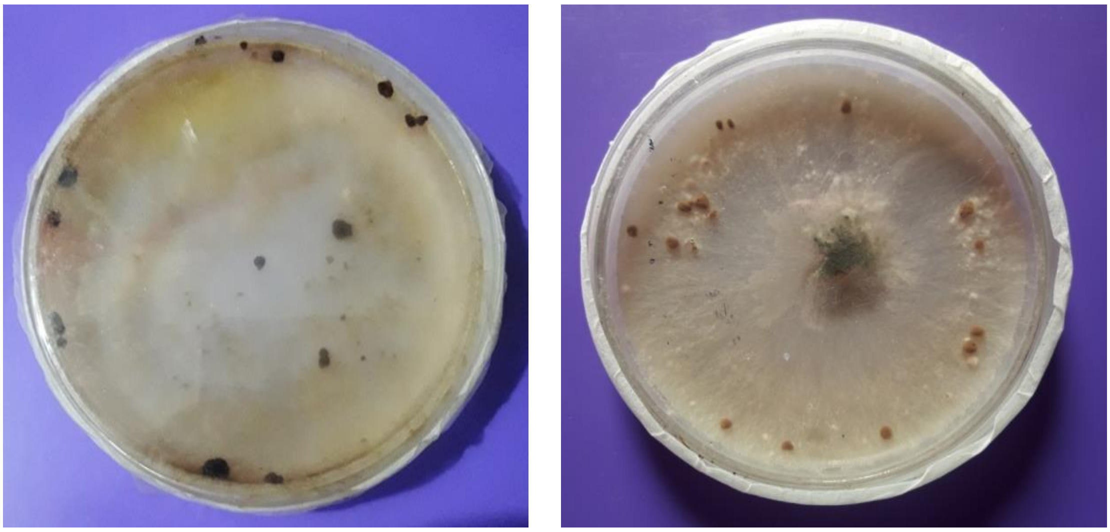


Plate 12: Mustard seed like sclerotia formation on PDA medium

4.4. Identification of pathogen

Pathogen was identified on PDA based on characteristic mycelial branching. Microphotographs were taken to show the typical microscopic characters of hyphae under compound microscope. Branching of the mycelium was found near the distal end of a cell in young and advanced hyphae. The young hyphae *R. solani* had branches forming 45° angles and the more mature branches were perpendicular (90°) and same size (Plate 13). Adult hyphae become stiff because of the thickened cell walls (Plate 13). In older hyphae, branching occurred at any place along the cell. Young hyphal branches are invariably somewhat constricted at the point of union with main hyphae. A septum is formed in the branch near the constriction (Plate 13). Constriction at the point of branching of the mycelium and presence of a septum near or at right angle of the branching junction have immense taxonomical importance. Microscopic studies revealed that all the eight isolates of *R. solani* in the present study characteristically had produced long multinucleate cells that grow approximately at right angles to the main hypha with a slight constriction at the junction of branching. The mycelial characteristics are in conformity as previously described by (Lal and Kandhari 2009; Vidhyasekaran *et al.*, 1997; Parmeter *et al.*, 1970; Bracker and Butler 1963) on rice sheath and plant debris. The variations of hyphal branching were also noticed among the isolates. Butler and Bracker (1970) also described the concept of species of *R. solani* with young hyphae branching at an acute to right angle, with slight constriction at the point of branching, and septum formed near the constriction point.

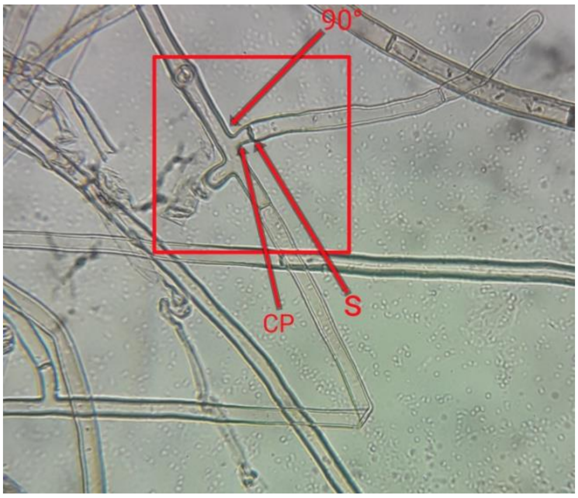


Plate 13: Microscopic view of (40× magnification) of the isolates showing the characteristics mycelia branching at an acute (90°) angle with slight constriction at the point (cp) of branching and septum (s) formed near the branching point

4.5. Effect of fungicides on sheath blight disease of rice

4.5.1. Effect of fungicides on disease incidence hill^{-1}

It was observed that the fungicides showed significant effect on disease incidence per hill recorded at different growth stages and presented in the Table 3.

The effect of various fungicides on disease incidence per hill was found closely statistically similar among the treatments before starting of spray with the chemicals (Table 3). But at advanced stages (after 2nd, 3rd and 4th spray) the effect on disease incidence per hill sharply different among the treatments.

After 1st spray the lowest disease incidence per hill was recorded in treatment T_7 (21.67) followed by T_2 (33.33), T_4 (33.33) and T_8 (33.33). However, maximum disease incidence per hill recorded in T_{14} (57.67) treated plants followed by T_3 (41.67), T_9 (41.67) and T_{15} (51.67) (Table 3).

After 2nd spray, the closely similar trend of results was maintained due to the application of treatments (Table 3). The lowest disease incidence hill^{-1} (23.33 %) was recorded in treatment T_2 which was statistically similar with T_3 (23.33). On the basis of effect on disease incidence per hill, the calculated result showed that the highest disease incidence per hill was found in T_{14} (63.33) which was closely statistically similar with T_{12} (58.33) followed by T_{15} (56.67) and T_{11} (56.67).

After 3rd spray, the treatments showed similar trend of result on disease incidence per hill was maintained against sheath blight disease of rice due to the application of treatments and presented in Table 3. The lowest disease incidence $hill^{-1}$ (23.33 %) was recorded in treatment T_2 which was closely statistically similar with T_3 (28.33). On the basis of effect on disease incidence per hill, the calculated result showed that the highest disease incidence per hill was scored by T_{14} (85.00) which was statistically similar with T_{15} (78.33) followed by T_{12} (71.67).

After 4th or last spray presented in Table 3, the effect of different treatments on disease incidence per hill was also similar as observed in 2nd and 3rd spray. The lowest disease incidence per hill was found in the treatment of T_2 that was 23.33 which was closely similar to the treatment of T_3 (30.00). The highest disease incidence was found in the $control_1$ that was 93.33% which was statistically similar to the $control_2$ (without inoculation) was 91.67%.

In an experiment, Tiwari (1997) tested the efficacy of Carbendazim (as Bavistin), Benomyl, Hexaconazole (as Contaf), Mancozeb (as Dithane M-45), Edifenphos (as Hinosan) and Thiophanate-Methyl (as Topsin-M) for control of *Rhizoctonia solani* on rice in the field, in Madhya Pradesh, India. Maximum disease control was obtained using Hexaconazole, followed by Edifenphos and the least control was obtained using Mencozeb.

Table 3: Effect of different fungicides on disease incidence per hill at different spray schedule

Treatments	Disease incidence per hill				
	Before spray at 55 DAT*	After fungicides spray			
		1st spray at 57 DAT	2nd spray at 67 DAT	3rd spray at 77 DAT	4th spray at 87 DAT
T_1 (Tilt 250 EC)	33.33	36.67 ab	40.00 c-f	35.00 c-e	41.67 d-f
T_2 (Contaf 5 EC)	38.33	33.33 ab	23.33 f	23.33 e	23.33 g
T_3 (Folicur 250 EC)	41.67	41.67 a	23.33 f	28.33 de	30.00 f-g
T_4 (Score 250 EC)	20.00	33.33 ab	28.33 ef	35.00 c-e	41.67 d-f
T_5 (Combi 230 EC)	36.67	35.00 ab	36.67 d-f	45.00 cd	48.33 c-e
T_6 (Filia 525 SE)	31.67	35.00 ab	40.00 c-f	43.33 cd	50.00 cd
T_7 (Amister top 325 SC)	20.00	21.67 b	38.33 d-f	43.33 cd	45.00 d-e
T_8 (Acibin 28 SC)	35.00	33.33 ab	38.33 d-f	35.00 c-e	31.67 e-g
T_9 (Awal 72 WP)	38.33	41.67 a	43.33 b-e	40.00 c-e	46.67 c-f
T_{10} (Nativo 75 WP)	38.33	35.00 ab	36.67 d-f	36.67 c-e	35.00 d-g
T_{11} (Autostin 50 WP)	43.33	43.33 a	56.67 a-c	53.33 bc	48.33 c-e
T_{12} (Dithane M-45)	36.67	40.00 a	58.33 ab	71.67 ab	71.67 b
T_{13} (Sunvit 50 WP)	40.00	45.00 a	48.33 a-d	53.33 bc	63.33 bc
T_{14} ($Control_1$)	30.00	51.67 a	63.33 a	85.00 a	93.33 a
T_{15} ($Control_2$)	31.67	41.67 a	56.67a-c	78.33 a	91.67 a
CV %	31.23*	29.94	24.89	23.80	21.32
LSD (0.05)	24.25*	18.97	17.53	18.75	18.11

*=Non Significant

Here, $Control_1$ = With inoculation; $Control_2$ =Without inoculation

4.5.2. Effect of fungicides on disease incidence/tiller

Fungicides showed significant effect on disease incidence per tiller recorded at different growth stages and presented in the Table 4.

The effect of treatments on disease incidence per tiller was found closely statistically similar among the treatments before starting of spray with the chemicals. But at advanced stages (after 2nd, 3rd and 4th spray) the effect on disease incidence per tiller sharply different among the treatments.

After 1st spray the lowest % of disease incidence tiller^{-1} was recorded in treatment T_3 (11.58). On the basis of effect on disease incidence per tiller, the calculated result showed that the highest reduction of % disease incidence per tiller was scored by T_3 was 11.58 which was closely statistically similar to T_2 (13.26) followed by T_6 (14.47), T_8 (15.05), T_9 (17.56), T_{12} (17.83) and T_{10} (17.91) against sheath blight disease of rice. The highest % of disease incidence tiller^{-1} was recorded in treatment T_{12} (30.46)

After 2nd spray, the closely similar trend of results was maintained due to the application of treatments. The lowest disease incidence tiller^{-1} (8.83) was recorded in the treatment T_3 which closely similar to the T_2 that was 11.487% and the highest disease incidence tiller^{-1} (37.593) was recorded in the treatment T_{12} which was statistically similar to the control$_{1.}$

After 3rd spray,. The lowest disease incidence $tiller^{-1}$ (10.58 %) was recorded in treatment T_{11} (Autostin 50 WP) which closely similar with T_2 (11.94) followed by T_3 (12.12). The highest disease incidence $tiller^{-1}$ (40.29 %) was recorded in the $control_1$ which was statistically similar to the $control_2$

After 4th or last spray, the lowest disease incidence per hill was found in the treatment of T_2 that was 10.80 which was closely similar to the treatment of T_3 that was 12.46 followed by T_{10} (14.18) and T_{11} (14.25) (Table 4). The highest disease incidence per hill was found in the $control_1$ (44.71) which was statistically similar to the $control_2$ (44.70).

Table 4: Effect of different fungicides on disease incidence per tiller at different spray schedule

Treatments	Disease incidence per tiller				
	Before spray at 55 DAT	After fungicides spray			
		1st spray at 57 DAT	2nd spray at 67 DAT	3rd spray at 77 DAT	4th spray at 87 DAT
T_1 (Tilt 250 EC)	16.48 ab	18.82 bc	17.19 c-f	17.84 c-f	16.79 d-f
T_2 (Contaf 5 EC)	13.80 ab	13.26 bc	11.49 ef	11.94 fg	10.80 f
T_3 (Folicur 250 EC)	11.14 ab	11.58 c	8.83 f	12.12 e-g	12.46 ef
T_4 (Score 250 EC)	21.28 ab	24.07 ab	23.18 b-d	26.80 bc	29.04 bc
T_5 (Combi 230 EC)	18.01ab	21.02 a-c	20.253 c-e	23.67 cd	24.47 c-e
T_6 (Filia 525 SE)	10.61 b	14.47 bc	15.87 c-f	20.72 c-f	20.47 c-f
T_7 (Amister top 325 SC)	23.83 a	24.66 ab	24.16 bc	24.80 c	26.71 b-d
T_8 (Acibin 28 SC)	10.39 b	15.05 bc	14.81 c-f	17.78 c-g	19.28 c-f
T_9 (Awal 72 WP)	11.90 ab	17.56 bc	19.53 c-e	21.64 c-e	22.18 c-f
T_{10} (Nativo 75 WP)	13.94 ab	17.91 bc	16.52 c-f	14.92 d-g	14.18 ef
T_{11} (Autostin 50 WP)	11.05 b	14.26 bc	13.36 d-f	10.58.g	14.25 ef
T_{12} (Dithane M-45)	19.64 ab	30.46 a	37.59 a	35.71 ab	37.37 ab
T_{13} (Sunvit 50 WP)	13.60 ab	17.83 bc	19.78 c-e	24.46 cd	24.07 c-e
T_{14} ($Control_1$)	16.55 ab	22.68 a-c	32.33 ab	40.29 a	44.71 a
T_{15} ($Control_2$)	13.01 ab	22.93 a-c	34.47 a	36 78 a	44.70 a
CV %	45.09	35.75	29.2	25.27	30.17
LSD (0.05)	11.34	11.42	10.01	9.58	12.16

Here, $Control_1$ = With inoculation; $Control_2$ = Without inoculation

4.5.3. Effect of fungicides on % disease severity

In case of disease severity (% tissue infected), fungicides showed significant effect at different growth stages (DAT) and presented in Table 5.

The effect of treatments on disease severity was found closely statistically similar among the treatments before starting of spray with the chemicals. However, at advanced stages (after 2nd, 3rd and 4th spray) the effect on disease severity sharply different among the treatments. The lowest % of disease severity was recorded in treatment T_{14} (18.19) and highest % of disease severity was recorded in treatment T_2 (45.74)

After 1st spray the lowest % of disease severity was recorded in treatment T_3 (28.10) and highest % of disease severity was recorded in treatment T_9 (39.83). On the basis of effect on disease severity, the calculated result showed that all the treatments gave the statistically similar results.

After 2nd spray, the lowest disease severity 22.88 was recorded in the treatment T_3 which was closely similar to the T1 (25.68) and the highest disease severity T14 (49.79) was recorded in the $control_{1.}$

After 3rd spray, the lowest disease severity 18.15 was recorded in the treatment T_2 which was closely similar with T_3 (21.06). The highest disease severity T_{14} (67.96) was recorded in the $control_1$ which was closely statistically similar with the T_{14} (62.48) and T_{12} (61.22).

After 4th or last spray, the lowest % of disease severity was found in the treatment of T_2 that was 13.3% which was closely similar to the treatment of T_3 (12.46). The highest disease severity was found in the $control_1$ (48.36) which was statistically similar to the $control_2$ (47.86). Present findings were in agreement with the findings of Prasad *et al.* (2020). 8 fungicides were used to control sheath blight of rice in this experiment and reported that the tested fungicide i.e. Hexaconazole 5 SC (Contaf) treatment found highly effective in reducing the disease severity of sheath blight 11.11% and 46.50% decrease of the disease over control.

Tiwari *et al.* (2002) used 7 fungicides to control sheath blight of rice and reported that Carbendazim + Epoxiconazole (0.2%), Hexaconazole (0.2%), Epoxiconazole (0.24%) and Propicanzole (0.2%) were significantly more effective in controlling disease severity than other fungicides. The above finding were also support Raji *et al.* (2016) that the systematic fungicides Tebuconazole + Trifloxystrobin 75WG (1.4g) Tebuconazole 250 EC (1.5ml) Fluzilazole 40 EC (0.5 ml) and contact fungicide Pencycuron 250 (1.5 ml) were evaluable effective as standard check fungicide Hexaconzole 5 EC (2 ml) in reducing sheath blight severity and improving yield.

Table 5: Effect of different fungicides on percent disease severity at different spray schedule

Treatments	% Disease Severity				
	Before spray at 55 DAT	After fungicides spray			
		1st spray at 57 DAT (*)	2nd spray at 67 DAT	3rd spray at 77 DAT	4th spray at 87 DAT
T_1 (Tilt 250 EC)	27.73 b-d	33.34	25.68 fg	29.94 e-g	17.05 fg
T_2 (Contaf 5 EC)	45.74 a	38.39	33.99 de	18.15 g	13.30 g
T_3 (Folicur 250 EC)	32.24 a-d	28.10	22.88 g	21.06 fg	16.08 fg
T_4 (Score 250 EC)	39.91 ab	32.60	32.05 ef	32.41 d-f	29.78 c-e
T_5 (Combi 230 EC)	33.82 a-c	30.43	36.09 b-e	39.32 c-e	26.99 de
T_6 (Filia 525 SE)	36.87 a-c	32.01	35.57 c-e	50.89 bc	32.58 cd
T_7 (Amister top 325 SC)	32.93 a-d	37.71	37.78 b-e	43.01 cd	29.35 c-e
T_8 (Acibin 28 SC)	42.33 ab	32.27	40.97 b-d	51.69 bc	26.10 de
T_9 (Awal 72 WP)	32.48 a-d	39.83	34.37 de	49.84 bc	31.62 cd
T_{10} (Nativo 75 WP)	34.58 a-c	32.59	35.38 c-e	28.84 e-g	22.25 ef
T_{11} (Autostin 50 WP)	37.89ab	33.05	35.97 c-e	42.81 cd	29.45 c-e
T_{12} (Dithane M-45)	18.39 d	36.23	40.52 b-d	61.22 ab	41.87 ab
T_{13} (Sunvit 50 WP)	39.43 ab	30.67	41.81 bc	39.58 c-e	35.69 bc
T_{14} ($Control_1$)	18.19 d	37.82	49.79 a	67.96 a	48.36 a
T_{15} ($Control_2$)	22.29 cd	37.49	43.14 ab	62.48 ab	47.86 a
CV %	26.85	27.57	11.66	17.80	15.34
LSD (0.05)	14.82	15.76	7.09	12.69	7.67

*=Non Significant

Here, $Control_1$ =With inoculation; $Control_2$ =Without inoculation

4.5.4. Effect of fungicides on percent relative lesion height (%RLH)

It was observed that the fungicides showed significant effect on Disease Severity. The percent relative lesion height was recorded before starting of spray (Table 6) was significantly indifferent with little extent. Comparatively, the lower % RLH was recorded in case of T_1 (3.54) followed by T_3 (3.71), T_8 (3.69), T_9 (3.69), T_2 (4.35), T_5 (4.21).

After starting the spray, marked differences on % RLH were notified at onward growth stage due to the application of treatments. After 1st spray, the lowest disease severity 3.97 was recorded in the treatment T_3 that was statistically similar with the T_9 (4.30) and T_{13} (4.34). The highest % RLH 6.73 was recorded in the treatment T_{12}

After 2nd spray, the lowest % RLH (3.39) was recorded in the treatment T_3 which was closely similar to the T_1 (3.79) and the highest % RLH 6.65 was recorded in the control$_2$ followed by control$_1$ (6.52).

After 3rd spray, the lowest % RLH 18.15 was recorded in the treatment T_2 which was closely similar with T_3 (2.92). The highest % RLH (9.70) was recorded in the control$_1$ which was statistically similar to the control$_2$ (9.66).

After 4th or last spray presented in Table 6, the lowest % RLH was found in the treatment of T_2 that was 2.44 which was closely similar to the treatment of T_3 (3.23). The highest % RLH was found in the $control_1$ (9.11).

Mia (1999) recommended Tilt 250 EC at the rate of 1L/ha for spraying at PI to boot stage for successful control of sheath blight disease of rice.

Akter *et al.* (2001) conducted an experiment by using six fungicides and a fertilizer, muriate of potash, in Gazipur, Bangladesh, in 1999 and 2000 against sheath blight of rice (cv. Swarna) caused by *R. solani.* They found that Contaf appeared to be the best in reducing the percent relative lesion height, percent disease index (PDI), and tiller infection.

Table 6: Effect of different fungicides on percent relative lesion height at different spray schedule

Treatments	Relative lesion height (%)						
	Before spray at 55 DAT	Disease ratting scale before spray	After fungicides spray				Disease ratting scale after 4th spray
			1st spray at 57 DAT	2nd spray at 67 DAT	3rd spray at 77 DAT	4th spray at 87 DAT	
T_1 (Tilt 250 EC)	3.54 d	3	5.93 ab	4.07 d-f	3.86 c-f	3.28 ef	3
T_2 (Contaf 5 EC)	4.35 d	3	6.03 ab	4.353 c-f	2.42 f	2.44 f	3
T_3 (Folicur 250 EC)	3.71 d	3	3.97 b	3.39 f	2.92 ef	3.23 ef	3
T_4 (Score 250 EC)	5.13 d	3	4.66 ab	3.79 ef	4.23 c-f	5.22 d	3
T_5 (Combi 230 EC)	4.21 d	3	4.60 ab	4.15 d-f	5.66 b-d	6.07 cd	5
T_6 (Filia 525 SE)	4.63 d	3	5.08 ab	4.62 c-e	7.203 b	6.33 b-d	5
T_7 (Amister top 325 SC)	5.32 d	3	5.67 ab	4.56 c-f	5.15 b-e	4.83 de	3
T_8 (Acibin 28 SC)	3.69 d	3	4.40 ab	4.93 c-e	6.14 bc	5.12 d	3
T_9 (Awal 72 WP)	3.69 d	3	4.30 b	4.44 c-f	5.92 bc	5.52 cd	3
T_{10} (Nativo 75 WP)	14.04 bc	5	5.17 ab	5.08 cd	3.44 d-f	4.96 de	3
T_{11} (Autostin 50 WP)	16.84 a	5	6.13 ab	4.70 c-e	5.22 b-e	5.62 cd	3
T_{12} (Dithane M-45)	12.47 c	5	6.73 a	4.91 c-e	7.44 ab	7.09 bc	5
T_{13} (Sunvit 50 WP)	13.09 c	5	4.34 b	5.41 bc	5.90 bc	5.85cd	3
T_{14} ($Control_1$)	15.76 ab	5	5.85 ab	6.52 ab	9.70 a	9.11 a	5
T_{15} ($Control_2$)	16.09 ab	5	6.07 ab	6.65 a	9.66 a	8.02 ab	5
CV %	18.65	-	26.79	15.40	25.37	18.92	-
LSD (0.05)	02.63	-	2.36	1.23	2.40	1.75	-

Here, $Control_1$ =With inoculation; $Control_2$ =Without inoculation

4.6 Effect of fungicides on yield and yield contributing characters against sheath blight disease of rice

4.6.1. Effect of fungicides on plant height (cm)

Mean plant height was significantly influenced by the fungicide application which is presented in Table 7. Mean plant heights were recorded in different fungicides ranged from 109.40 cm to 131.07 cm. The tallest plants (131.07 cm) were recorded in T_2 treated plot where the shortest plants (109.40 cm) were obtained from the $control_1$ plot. Regarding the effect of fungicidal sprays on the plant height marked differences had been observed. Comparatively the tallest plants (131.07 cm) were recorded in treatment T_2 treated plot and shortest plants (109.40 cm) were obtained from the treatment $control_1$. In the taller plants with comparatively early leaf senescence, the lower leaf dried up, some of which fall off as the plant grows and new leaves emerged on the upper nodes far above the plant base. So, the lower part of the culm remained clear partly covered with dead and dry leaf sheaths. This condition in taller plant allows more sun rays and better ventilation than the shorter plants. Thus the micro climate as well as the lack of living green leaf sheath at the infection site remain unfavorable for the successful disease development. These are may be main reasons why relatively taller plants produced with the help of T_2 to reduce the growth of pathogen which remain erect show more resistance to this disease.

4.6.2. Effect of fungicides on numbers of tiller hill^{-1}

The effect of different fungicides on number of tiller hill^{-1} of rice were determined and presented in Table 7. The number of tillers per hill was significantly different in respect of different fungicides used. The total numbers of tiller hill^{-1} were 22.56, 23.56, 23.11, 20.23, 22.56, 21, 21.33, 20.72, 19.89, 22.61, 20.64, 20.11, 20.18, 19.78 and 19.33 in Tilt 250 EC, Contaf 5 EC, Folicour 250 EC, Score 250 EC, Combi 230 EC, Filia 525 SE, Amister Top 325 SC, Acibin 28 SC, Awal 72 WP, Nativo 75 WP, Autostin 50 wp, Dithae M-45, Sunvit50 WP and $Control_1$, $Cotrol_2$, respectively. The highest numbers of tiller hill^{-1} (23.556) were recorded in the Contaf 5 EC sprayed plot. The lowest numbers of tiller hill^{-1} (19.33) were recorded in the $Control_1$ plot.

4.6.3. Effect of fungicides on effective tiller hill^{-1}

The yield (g) per 5 hills differed significantly from one fungicide to another (Table 7). The effective tiller per hill ranged from 22.44 to 12.77 where the highest and lowest yield was recorded in T_2 treated plot and lowest recorded in $control_1$ plot respectively.

4.6.4. Effect of fungicides on non-effective tiller hill^{-1}

The yield (g) per 5 hills differed significantly from one fungicide to another (Table 7). The numbers of non effective tiller per hill ranged from 1.00 to 6.55 where the highest and lowest yield was recorded in $control_1$ and the lowest recorded in T_2 treated plot respectively.

4.6.5. Effect of fungicides on panicle length

In case of panicle length, the performance of the treatments maintained the previous trend as observed in the plant height (Table 7). The smallest length of the panicle (20.34 cm) was observed in the $control_1$ plot and the highest length of the panicle (27.44) was observed from T_2 treated plot.

4.6.6. Effect of fungicides on filled grain panicle^{-1}

The yield (g) per 5 hills differed significantly from one fungicide to another (Table 8). The highest number of filled grain per panicle ranged from 175.44 to 89.980, where the highest number of filled grain per panicle was recorded in T_2 treated plot and lowest recorded in $control_1$ plot respectively.

4.6.7. Effect of fungicides on unfilled grain panicle^{-1}

The yield (g) per 5 hills differed significantly from one fungicide to another (Table 8). In case of unfilled grains per panicle, the performance of the treatments maintained the previous trend as observed in filled grains per panicle. The lowest number of unfilled grains (21) was observed from T_2 treatment treated plot and the highest number of unfilled grains (48.67) was observed from $control_1$.

A. Filled grain

B. Unfilled grain

Plate 14: Filled grain and unfilled grain collected from the $control_1$ that was artificially inoculated with pathogen

4.6.8. Effect of fungicides on 1000- grain weight (g)

In terms of 1000 grain weight the different treatments showed significant effect on sheath blight of rice (Table 8). The highest weight of 1000 grains (26.33 gm) was measured in case of T_2 treated plot, second highest weight of 1000 grains (26 gm) was obtained from T_3 treated plot. The lowest weight of 1000 grains (22.29 gm) was measured in case of $control_1$. Arunyanart and Surin (1984) also observed significant difference among the 1000 grain weight, where highest weight was found from disease free plant.

4.6.9. Effect of fungicides on yield (t ha^{-1})

The effect of fungicides differed significantly in respect of yield (t ha^{-1}) (Table 8). The yield (t ha^{-1}) ranged from 3.49 to 6.94. The highest yield (6.94 t $h^{-1)}$ was recorded in the T_2 sprayed plot that was statistically similar to T_3 (6.72 t h^{-1}) sprayed plot. After that T_7 gave the better yield (6.14 t ha^{-1}) result. The lowest yield (3.49 t ha^{-1}) was recorded in the T_{14} that was statistically similar to T_{15}. T_{14} that was artificially inoculated with pathogen gave the lowest result than the T_{15} in case of yield (t/ha) production. Present results were supported by the findings of Prasad *et al.* (2020). They found that the Hexaconazole 5 SC (Contaf) gave highest grain yield (5566 kg ha-^{1}) followed by Captan 70% + Hexaconazole 5% WB (4066 kg ha-^{1}) grain yield, Propiconazole13% + Difenconazole (3266 kg ha-1) grain yield, Carbendazin 50 WP (3233 kg ha^{1}) grain yield, Tebuconazole 50% + Trifloxystrobin 25% WG (3166 kg ha-^{1}) grain yield, Azoxistrobin 23% SC (3166 kg ha-^{1}) grain yield Propiconazole 25% EC (3088 kg ha-^{1}) grain yield, where as the lowest grain yield was recorded under untreated control (2600 kg ha^{1}).

4.6.10. Effect of fungicides on straw yield (t ha^{-1})

The effect of different treatments in case of straw yield was determined and presented in (Table 8). The straw yield (t ha^{-1}) ranged from 4.32 to 7.12. The highest yield (t ha^{-1}) (7.12) were recorded in the T_2 sprayed plot than the other treatments plot. The lowest yield (t ha^{-1}) (4.24) was recorded in the treatment T_{14} (Control with inoculation plot) that was statistically similar to T_{15} (Control without inoculation plot). It was found that all the fungicides gave the better result than the T_{14} and T_{15} for straw production. T_{14} that was artificially inoculated with pathogen gave the lowest result than the T_{15} in case of straw production (t ha^{-1}).

Present finding are in agreement with the findings of Johnson *et al.* (2013) that the Hexaconnazole at different doses viz., 500, 1000, 1500 and 200 ml ha-1 effectively reduced the sheath blight incidence in all the field trail. It also recorded maximum yield of 3000 and 2800 kg ha-1 in second and third trails respectively. Biswas (2004), Lore *et al.* (2005); they found improvement in yield of rice with application of fungicides besides controlling sheath blight. Bag (2009) suggested that application of Tebuconazole showed 50% increment in grain yield of rice over control.

Table 7: Effect of different fungicides on yield contributing characters of rice recorded after harvest

Treatments	Plant height (cm)	Tiller hill^{-1} (no)	Effective tiller hill^{-1} (no)	Non-effective tiller hill^{-1} (no)	Panicle length (cm)
T_1 (Tilt 250 EC)	125.91 ab	22.557 a-c	18.190 a-d	3.667 c-e	24.400 c-f
T_2 (Contaf 5EC)	131.07ab	23.556 a	22.440 a	1.003 g	26.820 ab
T_3 (Folicur 250 EC)	123.56 a-c	23.110 ab	21.413 ab	1.667 fg	27.443 a
T_4 (Score 250 EC)	120.10 a-e	20.223 a-c	18.997 a-d	1.113 fg	24.570 c-e
T_5 (Combi 230 EC)	113.00 c-e	22.556 a-c	19.883 a-c	2.667d-f	24.157c-g
T_6 (Filia 525 SE)	113.22 c-e	21.000 a-c	15.427 d-f	4.130 cd	22.561 e-h
T_7 (Amister top 325 SC)	121.60 a-d	21.333 a-c	18.810 a-d	2.670 d-f	22.403 e-h
T_8 (Acibin 28 SC)	118.73 b-e	20.723 a-c	18.777 a-d	1.943 fg	25.373 a-d
T_9 (Awal 72 WP)	112.96 c-e	19.890 a-c	18.333 b-d	2.443 e-g	23.877 c-g
T_{10} (Nativo 75 WP)	114.76 b-e	22.613 a-c	20.363 a-c	2.277e-g	25.610 a-c
T_{11} (Autostin 50 WP)	121.25 a-e	20.663 a-c	18.633 b-d	1.667fg	24.817 b-d
T_{12} (Dithane M-45)	113.62c-e	20.113 a-c	16.677 c-e	4.777 bc	22.003 gh
T_{13} (Sunvit 50 WP)	118.38 b-e	20.177 a-c	18.113 b-d	2.667 d-f	23.290 d-g
T_{14} (Control$_1$)	109.40 e	19.330 c	12.777 f	6.553 a	20.340 h
T_{15} (Control$_2$)	110.81 de	19.780 bc	13.890 ef	5.890 ab	22.283 f-h
CV %	6.16	10.37	12.47	31.24	5.55
LSD (0.05)	12.16	3.67	3.80	1.57	2.23

Here, Control$_1$ =With inoculation; Control$_2$ =Without inoculation

Table 8: Effect of different fungicides on yield and yield contributing characters of rice recorded after harvest

Treatments	Filled grain panicle^{-1} (no)	Unfilled grain panicle^{-1} (no)	Weight 0f 1000 seed (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1 (Tilt 250 EC)	131.50 b-e	31.33 b	24.67 a-d	5.15 a-e	5.23 a-c
T_2 (Contaf 5 EC)	175.44 a	21.07 d	26.33 a	6.94 a	7.12 a
T_3 (Folicur 250 EC)	161.17 ab	21.77 cd	26.00 ab	6.72 a	6.96 ab
T_4 (Score 250 EC)	124.56 b-f	33.84 b	24.33 b-d	6.48 a-c	6.84 a-c
T_5 (Combi 230 EC)	149.78 a-d	29.72 b-d	25.00 a-c	6.49 ab	6.14 ab
T_6 (Filia 525 SE)	121.17 c-f	32.84 b	24.33 b-d	4.13 de	4.96 a-c
T_7 (Amister top 325 SC)	116.50 d-f	28.61 b-d	24.73 a-c	5.24 a-e	5.68 a-c
T_8 (Acibin 28 SC)	158.39 a-c	27.89 b-d	24.33 b-d	5.79 a-d	6.29 a-c
T_9 (Awal 72 WP)	133.28 b-e	33.11 b	24.20 b-e	4.74 b-e	4.69 a-c
T_{10} (Nativo 75 WP)	151.75 a-d	30.94 bc	24.90 a-c	5.93 a-d	5.68 a-c
T_{11} (Autostin 50 WP)	142.21 a-d	34.22 b	24.33 b-d	5.97 a-d	5.74 a-c
T_{12} (Dithane M-45)	115.73 d-f	29.27 b-d	22.86 d-f	5.13 a-e	4.87 a-c
T_{13} (Sunvit 50 WP)	115.11 d-f	32.39 b	23.73 c-f	4.64 c-e	5.29 a-c
T_{14} (Control$_1$)	89.980 f	34.95 b	22.29 f	3.49 e	4.32 bc
T_{15} (Control$_2$)	97.00 ef	48.67 a	22.47 ef	3.81 e	4.41 bc
CV %	17.73	17.95	4.55	20.24	27.81
LSD (0.05)	39.22	9.42	1.85	1.84	2.57

Here, Control$_1$ =With inoculation; Control$_2$ =Without inoculation

4.7. Effect of used fungicides on percent disease decreased and percent yield increased over $control_1$ and $control_2$

4.7.1. Percent decreased of disease incidence $hill^{-1}$ over $control_1$ and $control_2$

After the last spray, maximum disease reduction (percent of disease incidence per hill) over the $control_1$ was found in the treatment of T_2 treated plot that was 67.86 closely near to the T_3 (66.07). Similar trend of results were found over the $control_2$ and that was shown in the Fig. 1.

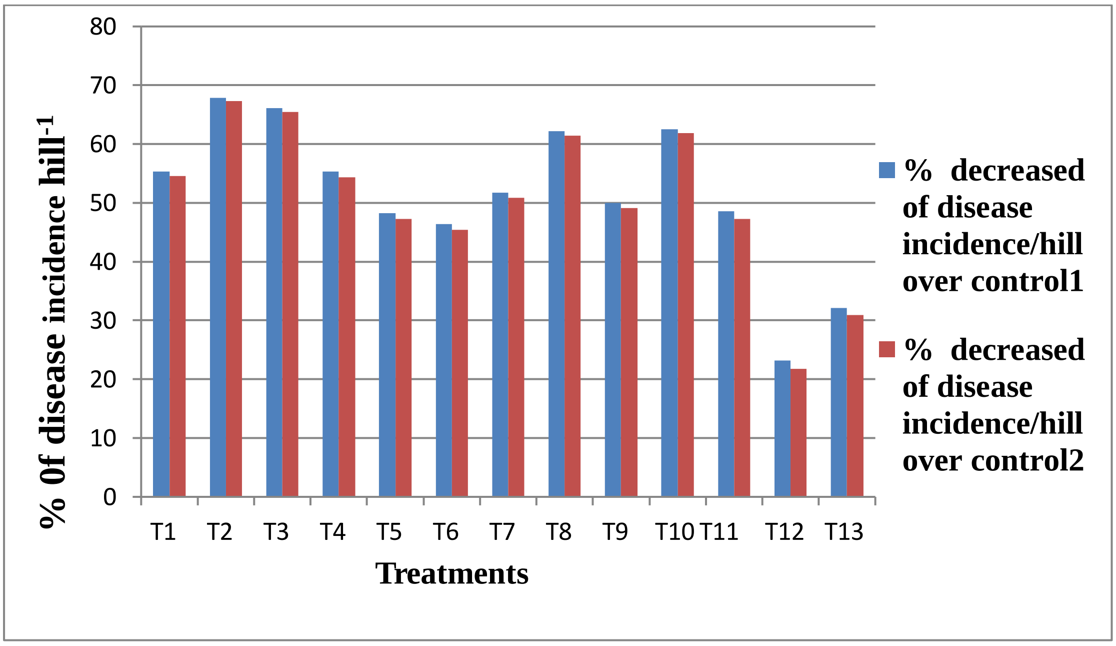


Fig.1: Percent decreased of disease incidence $hill^{-1}$ over $control_1$ and $control_2$ due to fungicidal application

4.7.2. Percent decreased of disease incidence tiller^{-1} over control$_1$ and control$_2$

After the last spray at 87 DAT, maximum disease reduction percent of disease incidence per tiller over the control$_1$ was found in the treatment of T_2 that was 75.84 closely similar to the T_3 was 72.14. The highest percent decreased of disease incidence tiller^{-1} were found over the control$_2$ was T_2 (75.83) same as over the control$_1$ and was shown in the Fig.2. The lowest percent decreased of disease incidence tiller^{-1} were found over the control$_1$ and control$_2$ was T_{12}.

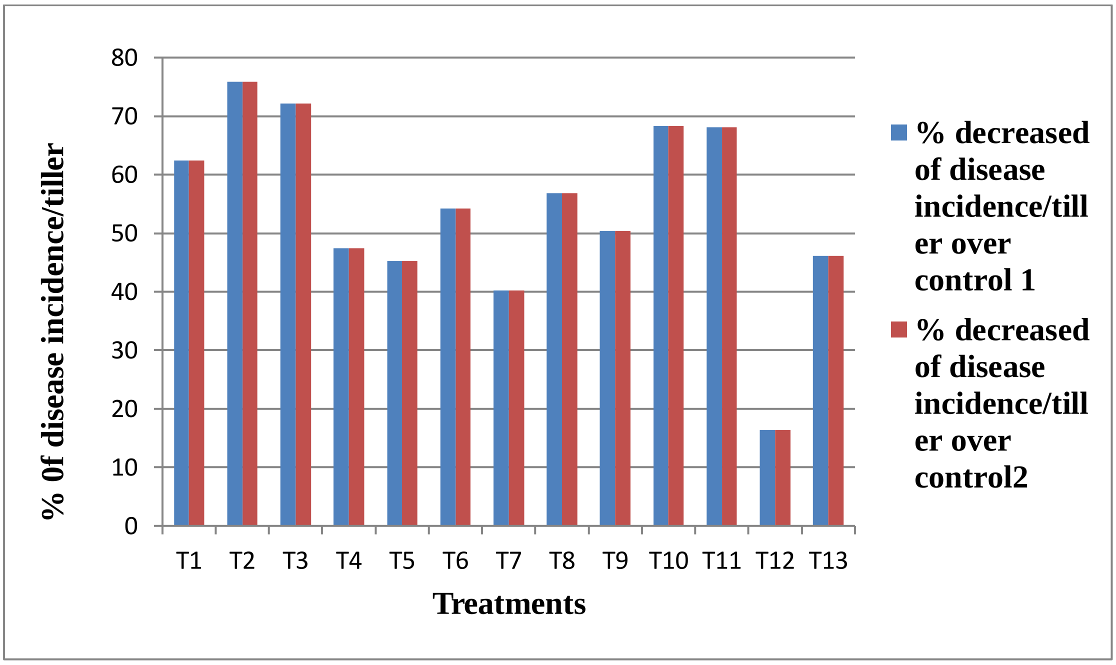


Fig.2: Percent decreased of disease incidence tiller^{-1} over control$_1$ and control$_2$ due to fungicidal application

4.7.3. Percent decreased of disease severity over control$_1$ and control$_2$

After the last spray, maximum disease reduction percent of disease severity over the control$_1$ was found in the treatment of T_2 (72.49) that was closely similar to the T_3 (66.76). Similar results were found over the control$_2$, T_2 (72.21) gave the best result to decrease the disease severity of rice plants and that was shown in Fig. 3.

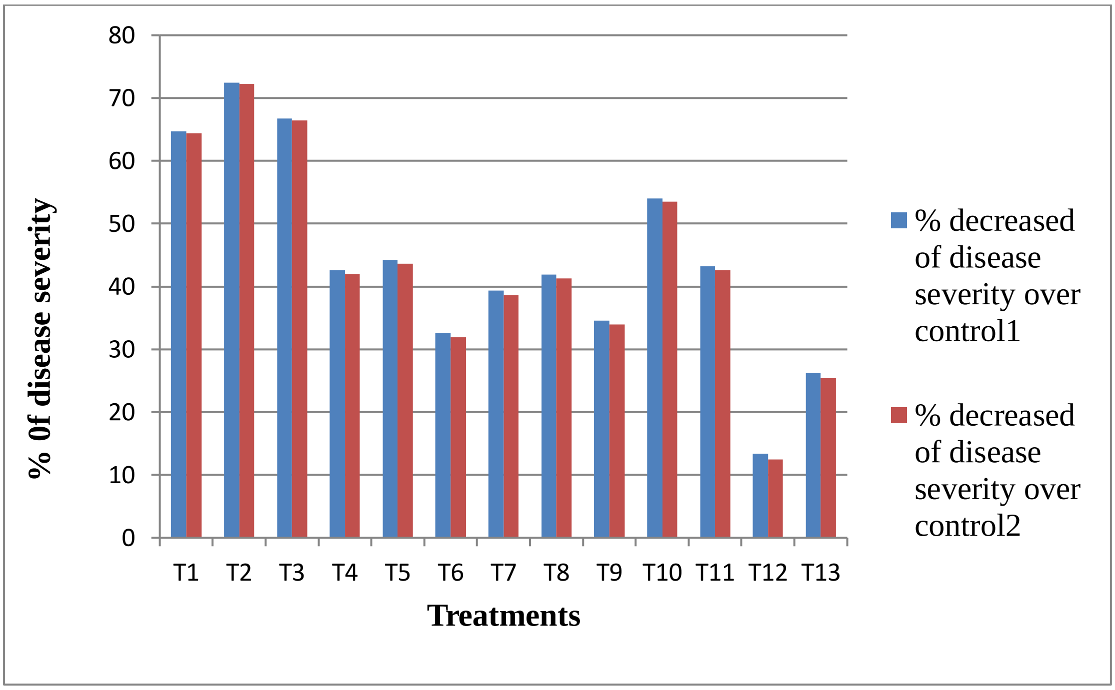


Fig.3: Percent decreased of disease severity over control$_1$ and control$_2$ due to fungicidal application

4.7.4. Percent increased of grain yield over $control_1$ and $control_2$

The highest yield (t ha^{-1}) increased (49.71) over $control_1$were recorded in the fungicide T_2 that was presented in (Fig. 4) T_3 gave the better result (48.07) after the T_2 over the $control_{1.}$ The highest yield (t ha^{-1}) increased (45.10) over $control_2$ were recorded in the fungicide T_2. After that T_3 (43.30) gave the better result over $control_{2.}$ It was found that all the fungicides gave the better result than the $control_1$ and $control_2$ for yield (t ha^{-1}) production.

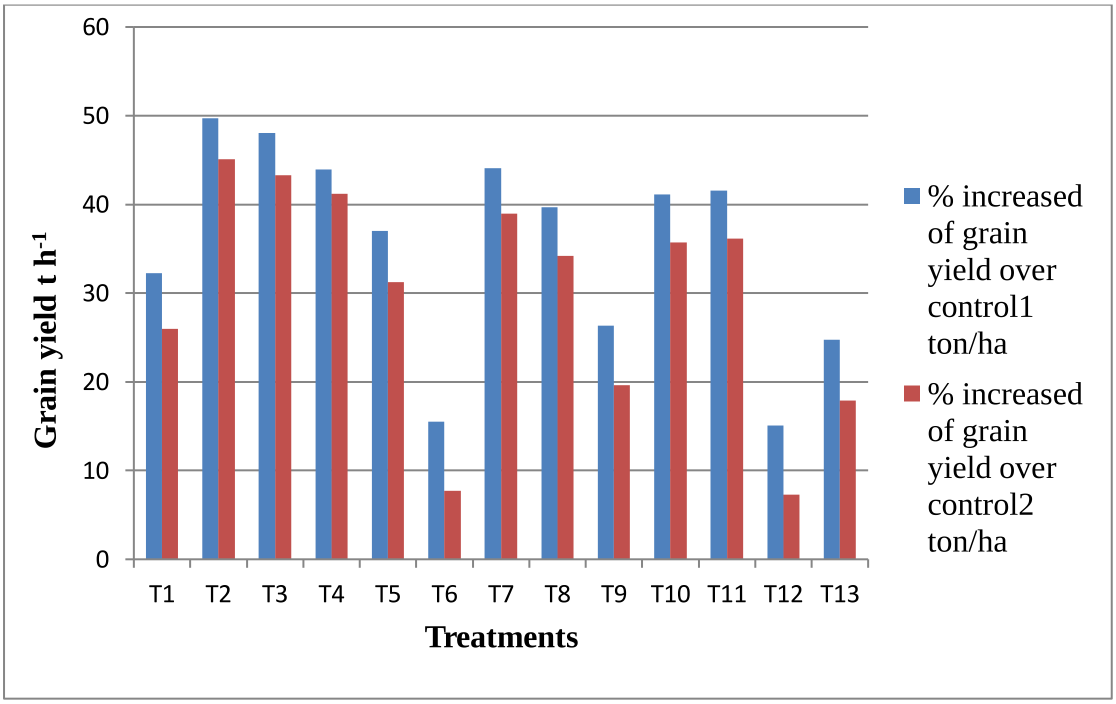


Fig.4: Percent increased of grain yield over $control_1$ and $control_2$ due to fungicidal application

4.7.5. Percent increased of straw yield over $control_1$ and $control_2$

The highest straw yield (t ha^{-1}) increased (39.32) over $control_1$ was recorded in the fungicide T_2 that was presented in (Fig. 5). T_3 gave the better result (37.93%) after the T_2 over the $control_1$ plot. The highest yield (t ha^{-1}) increased (38.06%)over $control_2$ were recorded in the fungicide T_2. After that T_3 (36.63) gave the better result over .$control_2$

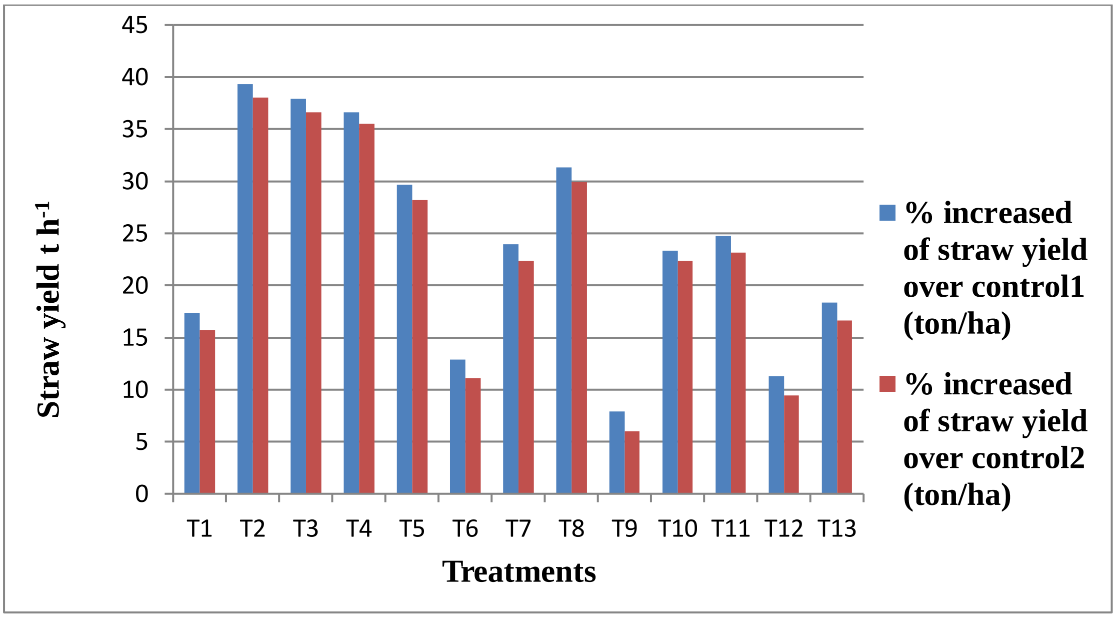


Fig. 5: Percent increased of straw yield over $control_1$ and $control_2$ due to fungicidal application

4.8. *In vitro* evaluation of selected fungicides against mycelia growth of *R. solani* by poisoned food technique

4.8.1. *In vitro* evaluation of mycelial growth of *R. solani* against selected fungicides

In the present study thirteen fungicides were tested against *R. solani* and presented in Table 10. All the tested fungicides control the mycelia growth of the pathogen in varying degrees and they were significantly different from control at different concentrations i.e. at 250 ppm, 500 ppm and 1000 ppm. Whereas at higher concentration 1000 ppm of all the fungicides completely inhibited the mycelia growth of the tested pathogen respectively. It was noted that as the concentration of fungicides increased, the mycelial growth inhibition is also increased for all tested fungicides exhibited control over the mycelia growth of the pathogen. At 500 ppm concentration Tilt 250 EC, Contaf 5 EC, Folicur 250 EC, Score 250 EC, Combi 230 EC, Filia 525 SE, Amister Top 325 SC, Acibin 28 SC, Nativo 75 WP and Autostin 50 WP above all the fungicides completely inhibited the mycelia growth of the pathogen over the control plate. Awal 72 WP (92.16%), Dithane M-45 (64.59%), Sunvit 50 WP (85.12%) inhibited the mycelia growth of the pathogen over the control plate. At 500 ppm concentration Dithane M-45 (64.59%) that gave the lowest inhibition of the pathogen over the control plate. At 250 ppm concentration Tilt 250 EC, Contaf 5 EC, Folicur 250 EC, Score 250 EC, Nativo 75 WP and Autostin 50 WP fungicides completely inhibited the mycelia growth of the pathogen over the control plate. Those were significantly superior in comparison to the other fungicides inhibiting the mycelial growth and Dithane M-45 (27.84%) that gave the lowest inhibition of the pathogen over the control plate.

The results of the present study revealed that, all the thirteen fungicides tested inhibited the mycelial growth of the pathogen when compared to the control. Of these, Contaf 5 EC, Tilt 250 EC, Folicur 250 EC, Score 250 EC, Nativo 75 WP and Autostin 50 WP exhibited the highest level of inhibition of *R. solani* even at very low concentration (250 ppm). Similarly, Brown *et al.* (1989) reported that hexaconazole was highly effective against *R. solani* by way of inhibiting mycelial growth and conidial germination at lower concentrations in *in vitro* and *in vivo* conditions. Dubey and Toppo (1997), Lore *et al.* (2012) also reported that hexaconazole was most effective in reducing the rice sheath blight disease intensity and increased the yield. There are several works reported on the efficacy of hexaconazole against *R. solani* (Dinakaran *et al.* 2012; Vishal Gupta et al., 2013; Johnson *et al.*, 2013). The above results lend support to the present findings. Hunjan *et al.* (2012) reported that fungicides viz., trifloxystrobin+ tebuconazole, tebuconazole and propiconazole showed higher level of efficacy against *R. solani* of rice in laboratory conditions. Among the new formulations, Nativo and Bavistin were individually effective against the pathogen in inhibiting the mycelia growth and sclerotial production at lower concentration (Sriraj *et al.* 2014). Tiwari *et al.* (2002) reported that propiconazole and hexaconazole at 1000 ppm concentration completely inhibit the radial growth *R. solani*.

Plate 15: Effect of different fungicides on mycelia growth of *R. solani* by poisoned food technique under *in vitro* condition at 1000 ppm concentration

Here,

A= Tilt 250 EC, B=Contaf 5 EC, C=Folicur 250 EC, D=Score 250 EC, E=Combi 230 EC, F=Filia 525 SE, G=Amister Top 325 SC, H=Acibin 28 SC, I=Awal 72 WP, J=Nativo 75 WP, K=Autostin 50 wp, L=Dithae M-45, M=Sunvit50 WP and N=Cotrol

Plate 16: Effect of different fungicides on mycelia growth of *R. solani* by poisoned food technique under *in vitro* condition at 500 ppm concentration

Here,

A= Tilt 250 EC, B=Contaf 5 EC, C=Folicur 250 EC, D=Score 250 EC, E=Combi 230 EC, F=Filia 525 SE, G=Amister Top 325 SC, H=Acibin 28 SC, I=Awal 72 WP, J=Nativo 75 WP, K=Autostin 50 wp, L=Dithae M-45, M=Sunvit50 WP and N=Control

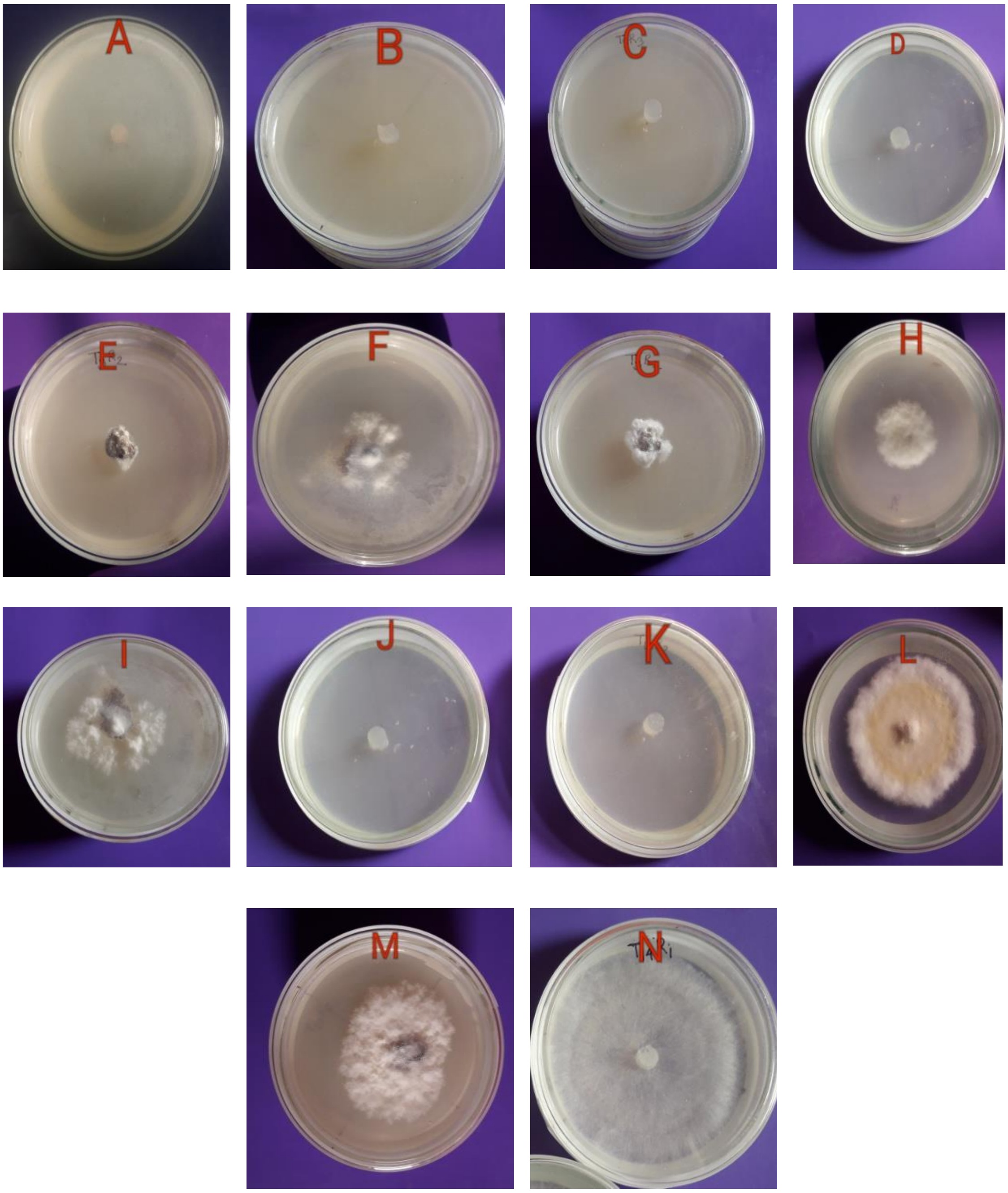


Plate 17: Effect of different fungicides on mycelia growth of *R. solani* by poisoned food technique under *in vitro* condition at 250 ppm concentration

Here, A= Tilt 250 EC, B=Contaf 5 EC, C=Folicur 250 EC, D=Score 250 EC, E=Combi 230 EC, F=Filia 525 SE, G=Amister Top 325 SC, H=Acibin 28 SC, I=Awal 72 WP, J=Nativo 75 WP, K=Autostin 50 wp, L=Dithae M-45, M=Sunvit50 WP and N=Cotrol

Table 9: *In vitro* evaluation of various fungicides against the mycelial growth of *R. solani* by poisoned food technique

Name of Fungicide	Concentration (ppm)	Radial mycelia growth at 7 DAI (mm)	Percent inhibition (%)
T_1 (Tilt 250 EC)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_2 (Contaf 5 EC)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_3 (Folicur 250 EC)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_4 (Score 250 EC)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_5 (Combi 230 EC)	1000	0.00	100
	500	0.00	100
	250	5.33	93.5
T_6 (Filia 525 SE)	1000	0.00	100
	500	0.00	100
	250	16.33	80.09
T_7 (Amister Top 325 SC)	1000	0.00	100
	500	0.00	100
	250	6.44	92.5
T_8 (Acibin 28 SC)	1000	0.00	100
	500	0.00	100
	250	9.27	88.69
T_9 (Awal 72 WP)	1000	0.00	100
	500	6.43	92.16
	250	26.07	68.20
T_{10} (Nativo 75 WP)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_{11} (Autostin 50 WP)	1000	0.00	100
	500	0.00	100
	250	0.00	100
T_{12} (Dithane M-45)	1000	0.00	100
	500	29.03	64.59
	250	59.17	27.84
T_{13} Sunvit 50 WP)	1000	0.00	100
	500	12.20	85.12
	250	31.47	61.62
T_{14} (Control)	-	88	0.00
	-	88	0.00
	-	88	0.00

In this experiment, two controls ($Control_1$ with artificial inoculation of pathogen and $Control_2$ without inoculation) were used to compare disease progress under natural epiphytic and inoculated conditions. However, there was no statistically dissimilarity observed between in these two treatments. This is because; *R. solani* is a soil borne pathogen and prevailed in the soil of experimental field that can spread very quickly under favorable conditions.

Due to this disease, plant tissue become blighted and reduces the total green area of plant. The pathogen destroyed the cholorophyllous tissue of plant that reduces food production of the plant. Ultimately the disease impact on the yield and yield contributing characters of crop. Thus the more disease gave lower yield and less disease gave comparatively higher yield of rice.

The sclerotia of *R. solani* developed the blight symptoms on the sheath of rice plant. It is a soil-borne pathogen and initial infection develops on sheath of the plants. The sclerotia of *R. solani* was being produced in the plant at very severe stage and mycelium, mycelial ball, sclerotia could be seen in the naked eye. It destroyed the total plant and damaged the quality of the grain. The infection was in the leaf sheath initially and later progress to the leaf blade in severe infections.

Considering the overall performances of treatments applied in management of sheath blight of rice in the field, the best performance was shown by T_2 (Contaf 5 EC) followed by T_3 (Folicur 250 EC) that reduced the disease incidence and severity, influenced the yield contributing characters and increased the yield. Moreover, *In vitro* condition, six fungicides gave the best result that completely inhibited the growth of mycelia of *R. solani* at lower concentration (250 ppm).

Contaf 5 EC is a broad spectrum, highly effective systemic, triazole group fungicides. For its translaminar action it is quickly absorbed and translocated within the rice plant leaf an system resulting in quick and effective disease control tripal action, protective, curative and eradicative. It works within and provide long lasting effect. Folicur 250 EC is a systemic, protective, curative and eradicative action, triazole group fungicide. It is also rapidly absorbed into the vegetative parts of the rice plants with translocation principally acropetally. It acts as a systemic fungicide where demethylase inhibitors interfere in the process of building the structure of the fungal cell wall. Finally it inhibits the reproduction and further growth of the fungus. Both fungicides gave phytotonic effect and improved the plant visible characteristics (plant height; increase the no. of filled grain, increase yields, straw yield; quickly produce and also improve the quality of the grain compare to the untreated plot.

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was carried out in the Central farm of Sher-e-Bangla Agricultural University, Dhaka-1207 for the management of sheath blight disease of rice (BR 11) during the period of 30 June 2019 to 15 November 2019 in Aus season to find out the prevalence and to evaluate the efficacy of fungicidal management of sheath blight of rice under *In vivo* and *in vitro* conditions. Fifteen treatments viz. T_1 (Tilt 250 EC), T_2 (Contaf 5 EC), T_3 (Folicur 250 EC), T_4 (Score 250 EC), T_5 (Combi 230 EC), T_6 (Filia 525 SE), T_7 (Amister Top 325 SC), T_8 (Acibin 28 SC), T_9 (Awal 72 WP), T_{10} (Nativo 75 WP), T_{11} (Autostin 50 WP), T_{12} (Dithae M-45), T_{13} (Sunvit 50 WP), T_{14} (Control$_1$) and T_{15} (Control$_2$) were evaluated against *R. solani* causing sheath blight of rice (BR 11) in *aman* season. The *in vivo* experiment was laid out in RCBD with three replications and *in vitro* experiment was laid out in CRD with three replications. *In vivo* experiment data were collected on disease incidence, disease severity at different stages and yield contributing characters. *In vitro* experiment data were collected on radial mycelial growth of *R. solani* at different concentrations (viz. 1000 ppm, 500 ppm and 250 ppm) and percent inhibition of mycelial growth of *R. solani* by poisoned food technique.

Regarding the effect of various fungicides on disease incidence per hill at different stages indicated that the minimum disease incidence per hill was found in T_2 and maximum disease incidence per hill was found in T_{14}. Regarding the fifteen treatments on disease incidence per tiller at different stages (panicle initiation stage, flowering stage and soft dough stage) indicated that the minimum disease incidence per hill were found in T_2 that was closely similar to the T_3 and maximum disease incidence per hill were found in T_{14}.

The effect of different treatments in respect of disease severity, the minimum disease severity was obtained from T_2 while the maximum disease severity was recorded from in T_{14} that was artificially innoculated with the pathogen compared to the T_{15} that was naturally attacked by the pathogen.

From the present study it was evident that different treatments resulted in reduction of percent relative lesion height (%RLH) in comparison to other controls. Effect of different treatments on %RLH was studied before and after spray at different growth stages. The %RLH before starting spray was found significantly indifferent with some extent. Comparatively, the lower %RLH were observed in the treatment T_2 while the maximum %RLH was recorded from in T_{14} after the final spray in the field.

Regarding the present study, the effect of fungicidal sprays on the plant height marked differences had been observed. Comparatively the tallest plants (131.07 cm) were recorded in treatment T_2 sprayed plot and shortest plants (109.40 cm) were obtained from the treatment T_{14}.

The sclorotia of *R. solani* developed on the plant of rice (BR 11) under field condition at severity stage specially that plot which were not treated with fungicides .At first pathogen formed mycelia looked like spider net on the sheath and lower part of the leaves that turned into mycelial ball which could be seen in naked eye. Finally that mycelial ball turned into sclerotia looked like mustard seed which surrounded by the sheath of the rice plant.

The effect of different fungicides on number of tiller per hill, effective number of tiller per hill and non effective number of tiller per hill of rice were determined. The highest numbers of tiller $hill^{-1}$ (23.556), effective number of tiller per hill 22.44 and the lowest number of non effective number of tiller per hill 1.003 were recorded in T_2 sprayed plot. The lowest numbers of tiller $hill^{-1}$ (19.33), lowest effective number of tiller per hill 12.77 and highest non effective number of tiller per hill 6.553 of rice were recorded in the $control_1$ plot respectively.

From the present study, in case of panicle length, the smallest length of the panicle (20.34 cm) was observed from $Control_1$ and the highest length of the panicle (27.443) was observed from T_3. In case of, number of filled grain per panicle and reducing the number of unfilled grain per panicle in comparison to control, the highest number of filled grain per panicle (175.440) and the lowest number of unfilled grain per panicle (21) were recorded from T_2 while the lowest number of filled grain per panicle and the highest number of unfilled grain found in untreated plots.

The highest grain yield (6.94 t ha^{-1}) was recorded in the treatment T_2 which was statistically similar with the T_3 (6.72 t ha^{-1}). The highest grain yield (t ha^{-1}) increased (49.71%) over T_{14} and the highest yield (t ha^{-1}) increased (45.10%) over T_{15} were recorded both in the fungicide T_2. After that T_3 gave the better result over T_{14} and T_{15}. The highest straw yield (7.12 t ha^{-1}) were recorded in the treatment T_2 and lowest (4.32 t ha^{-1}) was recorded in the $control_1$ that was statistically similar to the $control_2$ (4.41 t ha^{-1}). The highest straw yield (t ha^{-1}) increased (39.32%) over T_{14} were recorded in the fungicide T_2. T_3 gave the better result (37.93%) after the T_2 over the T_{14} treatment. The highest straw yield (t ha^{-1}) increased (38.06%) over T_{15} were recorded in the fungicide T_2. After that T_3 gave the better result over T_{15}. It was found that all the fungicides gave the better result than the T_{14} and T_{15} for straw production.

The results of the present study under *in vitro* condition revealed that, all the thirteen fungicides tested inhibited the mycelial growth of the pathogen when compared to the control plate. Of these, Contaf 5 EC, Tilt 250 EC, Folicur 250 EC, Score 250 EC, Nativo 75 WP and Autostin 50 WP exhibited the highest level of inhibition of *R. solani* even at very low concentration (250 ppm).

From the present findings it may be concluded that T_2 (Contaf 5 EC) was found to be promising for lowering sheath blight disease incidence, severity and for the highest yield of rice (BR 11) in *aman* season under field condition. In lab condition 6 fungicides viz. Tilt 250 EC, Contaf 5 EC, Folicur 250 EC, Score 250 EC, Nativo 75 WP and Autostin 50 WP were found to be the best that completely inhibited the mycelia growth of the pathogen at lower concentration (250 ppm) over the control plate.

However further investigation need to be carried out incorporating more treatments to authenticate the results against the disease.

Finally it is recommended to conduct field experiments in deferent Agro Ecological Zones (AEZs) in both *aus* and *aman* seasons with including other popular varieties which are mainly cultivate in *aman* and *aus* seasons in Bangladesh. Moreover for *in vitro* evaluation of fungicides, less ppm concentrations should be tested to evaluate the efficacy of fungicides against the pathogen.

CHAPTER 6

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CHAPTER 7

APPENDICES

Appendix I: Monthly mean weather of the experimental site

Monthly mean of average temperature (°C), average Relative humidity (%), Rainfall and Pressure (mbar) from July to November/2019 are given bellow-

Year	Month	Average Temperature (^{0}C)	Relative Humidity (%)	Rainfall (mm)	Air Pressure (mbar)
2019	July	29.3	82	383	1000.4
	August	29.9	79	223	1000.7
	September	29.1	80	161	1006.2
	October	27.6	78	188	1010.1
	November	24.9	74	37	1011.5

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Sher-e-Bangla Nagar, Dhaka-1207

Appendix II: Experimental Lay out

Plot Size: 2m X 1m

Plot to plot distance: 0.5m

Replication to replication distance: 1m

	R_1		R_2		R_3
↕.5m	T_{10}	↔	T_9	↔	T_{11}
	T_{13}	1m	T_7	1m	T_{15}
	T_6		T_5		T_2
	T_{11}		T_1		T_{13}
	T_7		T_{13}		T_5
	T_2		T_{14}		T_{12}
	T_8		T_{11}		T_{10}
	T_1		T_2		T_6
	T_{12}		T_{15}		T_1
	T_4		T_{10}		T_{14}
	T_3		T_{12}		T_9
	T_{15}		T_4		T_3
	T_5		T_8		T_8
	T_{14}		T_3		T_4
	T_9		T_6		T_7
			↕ 0.25m		

Here,

T_1= Tilt 250 EC, **T_2** =Contaf 5 EC, **T_3**=Folicour 250 EW, **T_4**=Score 250 EC, **T_5**=Combi 230 EC, **T_6**=Filia 525 SE, **T_7**=Amister Top 325 SC, **T_8**=Acibin 28 SC, **T_9**=Awal 72 WP, **T_{10}** =Nativo 75 WP, **T_{11}**=Autostin 50 wp, **T_{12}**=Dithae M-45, **T_{13}**=Sunvit50 WP, **T_{14}**=Cotrol$_1$, **T_{15}**=Cotrol$_2$, **R_1**= Replication 1, **R_2**= Replication 2 and **R_3**= Replication 3