MANAGEMENT OF FOOT AND ROOT ROT OF EGGPLANT CAUSED BY *Sclerotium rolfsii*

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JUNE, 2014

MANAGEMENT OF FOOT AND ROOT ROT OF EGGPLANT CAUSED BY *Sclerotium rolfsii*

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REGISTRATION NO. 13-05749

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE
IN
PLANT PATHOLOGY
SEMESTER: JANUARY-JUNE, 2014

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This is to certify that the thesis entitled, "**MANAGEMENT OF FOOT AND ROOT ROT OF EGGPLANT CAUSED BY *Sclerotium rolfsii***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in PLANT PATHOLOGY,** embodies the result of a piece of *bona fide* research work carried out by **MOHAMMAD NURAY ALAM SIDDIQUE** Registration No. **13-05749** 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 sources of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: 31th May, 2015

Place: Dhaka, Bangladesh

_____

(Prof. Dr. Md. Rafiqul Islam)

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DEDICATED TO MY BELOVED PARENTS

ACKNOWLEDGEMENTS

*All admiration and praises are solely to "**Almighty Allah**" Whose mercy absolutely enabled the author to pursue the higher education in Agriculture discipline and complete M.S. courses and research work successfully for the degree of M.S. in Plant Pathology.*

*The author expresses his immense respect and deepest sense of gratitude and heartfelt thanks to his most reverend teacher and research Supervisor, **Professor Dr. Md. Rafiqul Islam**, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for his untiring and scholastic guidance, timely instructions, valuable advices and encouragement throughout the research work and completion of this thesis.*

*The author is grateful to his research Co-supervisor, **Abu Noman Faruq Ahmmed**, Associate Professor, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, keen interest, valuable advices and continuous encouragement regarding this research work.*

*The author also wishes to pay his deep respect to **Dr. F. M. Aminuzzaman**, Chairman, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for his keen interest, continuous effort and valuable advice throughout the study and research period. The author also wishes to express his sincere gratitude to all other respected teachers of the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for their cooperation and help during the entire study period.*

The author is also grateful to the staff members of the farm, office and laboratory of Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka for their responsible help during the experimental work. Finally, the author expresses his immense gratefulness to his beloved parents, sisters and well wishers whose inspirations, sacrifices, moral support and continuous blessings opened the gate and paved the way to higher studies.

The Author

MANAGEMENT OF FOOT AND ROOT ROT OF EGGPLANT CAUSED BY *Sclerotium rolfsii*

ABSTRACT

Experiments were conducted at the Plant Pathology Laboratory and Farm of Sher-e-Bangla Agricultural University, Dhaka during November 2013 to May 2014 to find out the effective IDM components against foot and root rot disease of eggplant. The field experiment was carried out in Randomized Complete Block design with three replications. In laboratory condition, the highest reduction of mycelium growth (74.44 %) and sclerotia formation (77.13 %) was recorded in Bavistin 50 WP followed by Topgan 50 WP (68.88 %, 76.03 %) and Ridomil Gold (64.07, 59.16 %), respectively. In net house experiment, application of Bavistin 50 WP showed profound effects in reducing the disease incidence and severity (stem lesion area) with increasing yield compared to other treatments. Application of fungicides, plant extracts, organic manure and bio-agent also showed variation in reduction of foot and root rot disease caused by *Sclerotium rolfsii* and influenced yield and yield contributing characters of eggplant. Among the treatments, Bavistin 50 WP appeared to be the best in controlling the disease. In field experiment, significantly the higher yield (25.17 ton/ha) was found under the treatment Bavistin 50 WP followed by Topgan (22.87 ton/ha) and Ridomil gold MZ 68 WG (22.23 ton/ha). The lowest disease incidence (0.710 %) was recored in case of Bavistin 50 WP (0.71 %) which was statistically similar to Topgan 50 WP (1.963 %) and Ridomil Gold (1.963 %) .

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LIST OF SYMBOLS AND ABBREVIATIONS

%	Per cent
et al.	And others
spp.	Species
viz.	Namely
etc.	Etcetera
^{0}C	Degree Celsius
cm	Centimeter
gm	Gram
No.	Number
&	And
pv.	Pathovar
i.e.	That is
Ha	Hectre
J.	Journal
T	Treatment
LSD	Least Significant Difference
CRD	Complete Randomized design
CV	Co-efficient of Variance
SAU	Sher-e-Bangla Agricultural University
BAU	Bangladesh Agricultural University
IRRI	International Rice Research Institute
BBS	Bangladesh Bureau of Statistics

INTRODUCTION

Eggplant (*Solanum melongena* L.) is the second most important vegetable crop next to potato in Bangladesh in respect of acreage and production (BBS, 2011). The total area of eggplant cultivation was 28815.69 ha with 7 707.21 kg/ha yield and total production of 222110 metric tons in winter season and 17812.27 ha with 6227.06 kg/ha yield and total production of 110910 metric tons in summer (BBS, 2011).

The ancient ancestors of eggplant grew wild in India and were first cultivated in China in the 5th century B.C. Eggplant was introduced to Africa before the middle ages and then into Italy, the country with which it has long been associated, in the 14th century. It subsequently spread throughout Europe and the Middle east and centuries later was brought to the Western Hemisphere by European explorers. Today Italy, Turkey, Egypt, China and Japan are the leading growers of eggplant.

In Bangladesh eggplant is being cultivated in almost all districts and consumed as a cooked vegetable in various ways. It is a small short lived perennial herb belonging to the family solanaceae of dicot angiosperm. It contains various biologically important elements such as amino acids, sugars and vitamins etc. It is grown at homestead area and kitchen garden because of its popularity especially to the urban people. There are several varieties of eggplant grown in Bangladesh such as, Kazla, Jhumka, Nayantara, Islampuri, Singnath, Uttata, Luffa, Bholanath, Dohajari, ISD-006, Dhundul etc. Some of high yielding varieties found to be cultivated are BARI Bagoon-2 (Tarapuri), BARI Bagoon-4 (Kajla) and BARI Bagoon-5 (Nayantara). About 8 million farm families are involved in eggplant cultivation (Islam, 2005). This gives small, marginal and landless farmers a continuous source of income and provides employment

facilities for the rural people. For most of the times, market price of eggplant remains high compared to other vegetables in the market. In Bangladesh foot and root rot may cause up to 30-50 % loss in fruit yield in eggplant (Bari, 2001).

In Bangladesh, production and quality of eggplant are reduced by a number of pathogens and pests including phytoparasitic nematodes (Talukdar, 1974; Mian, 1986). The crop is attacked by a number of fungal species which put adverse effect on both the yield and the quality. More than ten diseases of eggplant have been reported from this country. Among them, foot and root rot is most common disease of eggplant caused by *Sclerotium rolfsii.*

Sclerotium rolfsii is a serious soil borne pathogenic fungus and harmful to many crops which are economically valuable in most of the tropical and subtropical region of the world (Aycock, 1966). It has a wide host range and it has been referred as an almost omnipathogenic organism (Talukdar, 1974). The fungus *Sclerotium rolfsii* is a facultative parasite and can maintain continuity of generation under adverse situation by the formation of sclerotia (Ahmed, 1980). As the fungus *Sclerotium rolfsii* is soil borne and omnipathogenic, it is very difficult to control even by the use of chemical fungicides. Some fungicides such as Bavistin 50 WP, Topgan 50 WP, Dithane M-45 and Bordeaux mixture reported to be effective to control foot and root rot disease of eggplant caused by *Sclerotium rolfsii* (Patil *et al.*, 1986). But indiscriminate uses of chemicals are hazardous to living being and also disrupt the natural ecological balance by killing the beneficial and/or antagonists microorganisms exist in the soil.

The continuous and spontaneous chemical application also induced the development of resistant isolates of the pathogens, which sometimes become more virulent. Hence, efforts have to be made to retain pathogen activity below economic threshold level by choosing methods alternative to of chemicals only. Biological control could be successful alternative to chemicals.

Biological control of soil borne pathogens offer environmentally safe, durable and cost effective alternative to chemicals. Many species of fungi and bacteria are reported to be effective as bio-control agents against soil borne plant pathogens (Mukhopadhyay, 1994). *Trichoderma* spp. are known to be antagonists of plant pathogenic fungi and have been shown to be very potential bio-control agent against several soil borne plant pathogenic fungi under both green house and field conditions.

Botanical extracts are biodegradable (Devlin and Zettel, 1999) and their use in crop protection is practically a sustainable alternative. Few works have been done by using tobacco, neem, garlic, and some other plant extracts to control different fungi. Different natural bio-fungicides also used separately or in combination with plant extracts to control some other fungi by the farmers. Antifungul activities of garlic, neem, alamanda, have been reported by many researchers (Islam, 2005; Rahman *et al*., 1999; Arun *et al*., 1995; Mohanty *et al.*, 2000). Botanicals or plant extracts are also widely used for pest control in organic cultivation.

Considering the above facts, the present study was undertaken:

1. To isolate and identify the causal pathogen of foot and root rot disease of eggplant;
2. To screen selected chemicals, plant extracts, organic manure and bio-agent against the pathogen; and
3. To find out the effective IDM components for management of foot and root rot disease of eggplant.

MATERIALS AND METHODS

3.1 Experimental site

The experiment was conducted in the laboratory, net house and farm field of the Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Sher-e- Bangla Nagar, Dhaka- 1207.

3.2 Experimental period

The experiments were conducted from November 2013 to May 2014.

3.3 Laboratory experiment

3.3.1 Collection of diseased specimens

Diseased samples of Eggplant (*Solanum melongena* L.) were collected from the field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka- 1207. Collected samples were put in polyethylene bags immediately after collection to protect them from drying. Then the samples were preserved in refrigerator at 4 $^{\circ}$C for future use.

3.3.2 Sterilization of materials and equipments

Liquid materials, such as PDA media and distilled water were sterilized in an autoclave following the method (Hazra, 1988) at 121 $^{\circ}$C under 15 pound per square inch (PSI) for 30 min. For surface sterilization, 0.1 % sodium hypochlorite (NaOCl) was used for plant materials such as leaf, stem, seed etc., and rectified spirit was used for sterilization other equipment's like inoculation-needles, forceps, inoculation chamber, hands etc.

3.3.3 Isolation of causal organism

The pathogens associated with the foot and root rot disease of eggplant were isolated following tissue planting method.

3.3.3.1 Isolation of causal organism (*Sclerotium rolfsii*) by tissue planting method

3.3.3.1.1 Moist blotter method

The pathogen associated with the diseased plant parts of eggplant were cut into several pieces by scissors and placed on the moist filter paper (Whatman no.1). Three pieces of filter paper were moistened by dipping in sterile water were placed in each of the petri dish. The petri dishes with the diseased specimens were incubated at 22±2 °C under 12/12 alternating cycles of NUV and darkness in the incubation room of the Pathology Laboratory of Sher-e-Bangla Agricultural University (SAU) for 5-7 days. After incubation, the plates were examined under stereomicroscope for primary identification of the organisms (fungi).

3.3.3.1.2 Preparation of potato dextrose agar (PDA) media

In all the experimental studies, the standard potato dextrose agar medium was used. Two hundred grams of cleaned, washed and peeled potato tubers were chopped into pieces. Later pieces were boiled in distilled water and the extract was collected by filtering through muslin cloth. Dextrose (200 gm) and agar (30 gm) were dissolved in the potato extract and the volume was made upto 1000 ml by adding distilled water. Known quantity of medium was dispensed into number of conical flasks. The pH of the medium was adjusted at 6.5 by using pH meter with adding HCL or NaOH. After adjusting pH flask plugged with non absorbent cotton and finally wrapped with brown paper. The flasks containing dispensed

medium was sterilized at 121 °C temperature with 15 PSI pressure for about 30 minutes.

3.3.3.1.3 Tissue planting method

At first the diseased plant parts (stem) were thoroughly washed to remove soil and sand particles. Then infected plant parts were cut into small pieces (5 mm) from advancing end of the lesions. The cut portion was surface sterilized with 0.1% NaOCl for 5 minutes, and rinsed with sterilized water for 3 times. Surface sterilized plant pieces were placed on PDA media in 9 cm petri dishes and incubated at 22± 2 °C for 7-10 days. During incubation plant pieces were examined daily to investigate fungal growth. After incubation, the inoculated plates were observed to identify the causal organism. After 20-30 days mustard seed like brown sclerotia are formed.

3.3.3.2 Isolation of *Sclerotium rolfsii* from soil dilution method

For isolation of soil microbes dilution plate technique (Warcup, 1955) was followed.

3.3.3.2.1 Preparation of working area

Since the bacteria and fungi are always present as contaminants in the soil, it is important to exclude them as much as possible from the surface of the working area and the equipment to be used. The surface of the working area was disinfected with cotton soaked in methylated spirit (70%). The hands were disinfected by the same. The glass wares (Test tubes, Petri dishes, Pipettes, Beakers etc.) were sterilized in dry oven and then placed in laminar flow cabinet.

3.3.3.2.2 Preparation of working samples

For every dilution of soil samples, working sample was prepared from the composite sample that was made after collection of soil sample from the infected field.

3.3.3.2.3 Making suspension (soil dilution)

A. 1gm of the soil was placed in test tube containing 9 ml of sterile water and stirred thoroughly for few minutes in order to obtain a uniform 1:10 dilute soil suspension and was used as stock suspension.

B. 1ml of that 1:10 stock suspension was transferred with the help of sterile pipette into the 2nd test tube containing 9 ml sterile water and shaken thoroughly thus resulting 10^{-1} dilution.

C. 1ml of the dilution was transferred to 3rd test tube containing 9 ml sterile water by sterile pipette thus making 10^{-2} dilution. In this way dilution was made up to 10^{-4} (Figure 1).

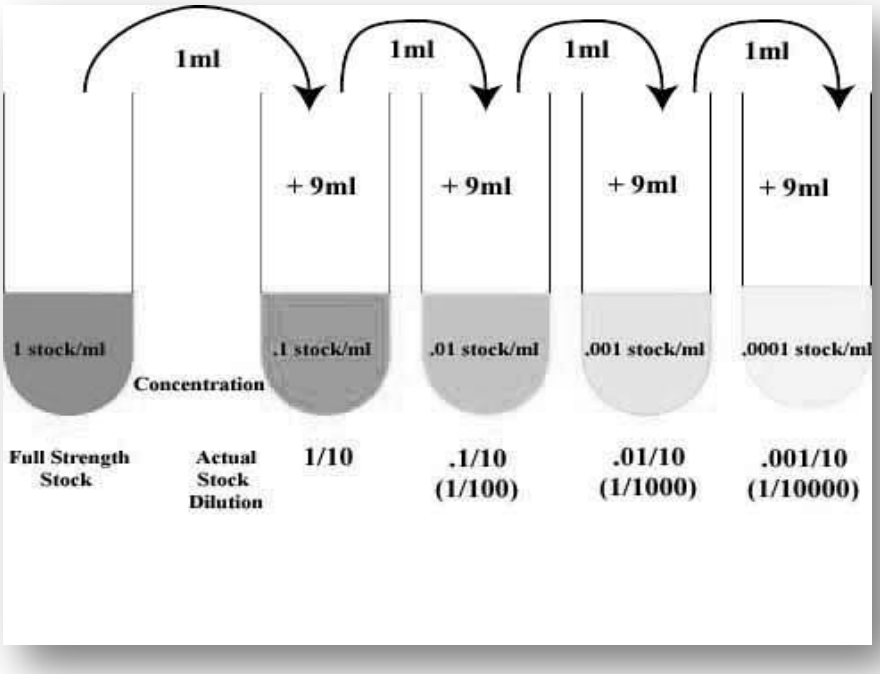

Figure 1. Preparation of soil dilution series

3.3.3.2. 4 Isolation procedures

A. 20 ml of warm melted PDA medium was (approx. 45 $^{\circ}$C) poured in each sterile petri plate.

B. 1 ml of diluted soil sample (10^{-4}) was placed at the center of PDA and spreaded. Four petri dishes each were inoculated with 1 ml of diluted sample.

C. The inoculated PDA plates were incubated at room temperature for 7-10 days.

D. After incubation period the colonies were grown on PDA. Sub cultures were made by transferring a single colony to a new petri dish. For more purification, further transfers were made and the contaminated plates discarded.

3.3.4 Identification, multiplication and preservation of the pathogen

Pure culture of the isolates were prepared following hyphal tip methods (Tuite, 1969; Mian, 1995) and subsequently transferred to fresh PDA slants in test tubes and petri dishes. Petri dishes and test tube slants containing pure culture of *Sclerotium rolfsii* were stored at 4 $^{\circ}$C.

3.3.5 Bioassay following growth inhibition technique

3.3.5.1 Cup method

From a PDA plate three 5 mm discs of the medium were scooped from three places maintaining an equal distance from the centre by a sterilized disc cutter. One milliliter of fungicide/plant extract solution was put into each hole and the plates were stored overnight in refrigerator for diffusion of the input in the medium around the hole before resumption of fungal growth. The next day, one 5 mm block of 7 days old fungal culture

(pathogen) was cut by sterilized disc cutter and was placed at the centre of the plate. The linear growth (cm) of mycelium of *S. rolfsii* was recorded at 24hrs. Interval until the control plates were filled (Islam, 2005; Nene and Thaplial, 1993; Mckeen *et al*., 1986).

3.3.5.2 Measurement of radial growth

After 70 hours of incubation, radial growth (cm) of *S. rolfsii* in petri dishes was measured. The radial growth (cm) of mycelium of each plate was measured by taking average of the two diameters taken right angles for each colony and then plates were kept for 30 days for sclerotia formation.

Inhibition of radial growth was computed based on colony diameter on control plate using the following formula (Sunder *et al*., 1995).

$$\% \text{ growth inhibition} = \frac{X-Y}{X} \times 100$$

X= Average radial mycelium growth (cm) of *S. rolfsii* in control plate.
Y= Average radial growth (cm) of *S. rolfsii* in treated petri dishes.

3.4 Net house experiment

3.4.1 Soil collection

Soil was collected from the experimental fields of Sher-e-Bangla Agricultural University, Dhaka-1207.

3.4.2. Sterilization of soil

Collected soil mixed with cowdung properly in 1:3 ratio. Soil was dripped with 40% formalin solution @ 200 ml/cft soil and kept covered

with polyethylene sheets for 2-3 days. Then the soil was uncovered and pulverized enough and kept for two days to release the gas of formalin.

3.4.3 Preparations of pots

Sterilized soil was dispensed at the rate of desired amount per pot. Then the pots were arranged according to experimental design.

3.4.4 Transplanting of seedlings

Seedlings were uprooted carefully from the seed bad and only one plant was transplanted to each pot in the net house. Sufficient irrigation was given just after transplantation. Watering was continued till the seedlings were established.

3.5 Field experiment

3.5.1 Variety

There are several varieties of eggplant grown in Bangladesh. Singnath variety was used for this experiment.

3.5. 2 Design of the experiment

The experiment was carried out in Randomized Complete Block Design (RCBD) with three replications.

3.5.3 Land preparation

A piece of medium high land with well drainage system was selected. The experimental field was first ploughed on 20 November 2013. The land was ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilt. The clods of the land were hammered to make the soil into small pieces. Weeds, stubbles and crop residues were cleaned from the land. The final plugging and land preparation was done on 25 November 2013.

3.5.4 Layout

The layout was done as per experimental design on 26 November 2013. The field was divided into three blocks each of which representing a replication. The unit plot size was 1m × 3.5 m and plot to plot distance was 0.5 m and block to block distance was 1 meter.

3.5.5 Plantation of eggplant

Selected healthy and disease free seedlings were planted in the experimental field. Planting was done with the help of *khurpi* (a hand operated implement). For planting, a hole was made with *khurpi*, so that the seedling of eggplant is dipped in soil, but must be touching with surface soil. The hole was completely packed with the help of thumb finger. This planted eggplant need to be watered twice a day with the help of watering cane or sprinkler. Two months after plantation inoculums of the *S. rolfsii* were inoculated to the soil in the base of each plant.

3.5.6 Inoculums preparation

Seven petri plates (9 cm) of pure culture of *S. rolfsii* were cultured.

3.5.7 Inoculation of pathogen

After establishment of plant in field, the soil in the base of each plant was inoculated with *S. rolfsii* inoculums.

3.5.8 Treatments

T_1 = Control

T_2 = Bavistin 50 WP @ 0.2%

T_3 = Topgan 50 WP @ 0.2%

T_4 = Ridomil Gold MZ 68 WG @ 0.4%

T_5 = Bordeaux mixture @ 1:1:2 (w/v)

T_6 = Dithane M-45 @ 0.2%

T_7 = Neem leaf extract @ 1:2 (w/v)

T_8= Alamanda leaf extract @ 1:2 (w/v)

T_9= Poultry manure @ 25g/plant

T_{10}= *Trichoderma harzianum* @ 1.35 x 10^9 spores/plant

3.5.9 Intercultural Operation

3.5.9.1 Shading

News paper shade was use for save the eggplant seedling from high intensity of sunlight.

3.5.9. 2 Gap filling

Gap filling is important intercultural operation for plantation crop. After planting some seedling was died for many reasons. For maintain optimum plant population gap filling was done.

3.5.9.3 Irrigation

During dry season irrigation was done at 10-15 days interval.

3.5.9.4 Weeding

Weeding was done fourth time in the experimental period at 20 days after planting, 40 days after planting, 55 days after planting and 70 days after planting.

3.5.10 Application of fertilizers and manures

The following dose of fertilizers and manures were applied for the eggplant cultivation.

Table 1. Application dose of fertilizers and manures in the field experiment

Fertilizers / Manures	Dose /ha
Urea	300 kg
TSP	150 kg
MOP	250 kg
Gypsum	40 kg
Cow dung	10 tons

The 1/3rd urea and whole amount of other fertilizers were applied as basal dose and rest 2/3rd urea was applied at 30 DAT and fruit setting followed by an irrigation.

3.5.11 Evaluation of fungicides, plant extracts and bio-agent against *Sclerotium rolfsii*

Five fungicides (Bavistin 50 WP, Topgan 50 WP, Ridomil gold MZ 68 WG, Bordeaux mixture, and Dithen M-45), two plant extracts (Neem and Allamanda leaf), organic manure (Poultry manure) and bio-agent (*Trichoderma harzainum*) were tested following poisoned food technique (Dhingraand Sinclair, 1985) to evaluate their effect on colony growth and sclerotia formation of *Sclerotium rolfsii*. The details of the fungicides are presented in the Table 2.

Table 2. Fungicides used in the bio-assay study against *Sclerotium rolfsii.*

Trade name	Common name	Active ingredient	Conc. Used
Bavistin 50 WP	Mythyl—Benzimidazole Carbamate	50 % Carbendazim	0.2%
Topgan 50 WP	Copper-oxychloride	50% Copper-oxychloride	0.2%
Ridomil gold	Metalaxyl+Mancozeb	68% Metalaxyl	0.4%
Bordeaux mixture	---	---	---
Dithane M-45	Manganous ethylene bisdithiocarbamate-ion	80% Mancozeb	0.2%

Table 3. The particulars of plant extracts used in this study

Common name	English name	Scientific name	Plant parts	Conc. Used
Neem	Margosa tree	*Azadirachta indica*	Leaf	1:2
Allamanda	Allamanda	*Allamanda cathertica*	Leaf	1:2

3.5.12 Collection of fungicides, plant extracts, organic manure and bio-agent

Five fungicides namely Bavistin 50 WP, Topgan 50 WP, Ridomil gold MZ 68 WG, Bordeaux mixture, and Dithane M-45 were collected from local market. Leaf of neem and allamanda were collected from Sher-e-Bangla Agricultural University campus. Poultry manure was collected from the Agargoan market, Tejgoan, Dhaka. Bio-control agent

Trichoderma harzainum were collected from IPM laboratory of Bangladesh Agricultural University (BAU).

3.5.13 Preparation of plant extracts

The extracts were prepared by using the method of Ashrafuzzaman and Hossain (1992). For preparation of extracts, collected leaves were weighted in an electric balance and then washed in the water. After washing the big leaves were cut into small pieces. For getting extract, weighted plant parts were blended in a mortar & pastel and then distilled water was added into the mortar. The pulverized mass was squeezed through 3 folds of fine cotton cloth. For getting 1:2 (w/v) ratio 200 ml of distilled water was added with 100 g plant parts. The particulars of the botanicals used for the experiment are listed in Table 3.

3.5.14 Preparation of bio-agent

Pure culture of *Trichoderma harzianum* were cultured and spores collected from pure culture by scraping with the help of camel hair brush and blended with the help of electric blender to make spore suspension. Then pure spore suspension was prepared mixing 1 liter of sterile water with each spore masses got from 1 petri dish (9 cm) of 15 days old culture.

3.5.15 Application of fungicides, plant extracts, organic manure and bio-agent

The fungicides, plant extracts, organic manure and bio-agent were applied at root zone of eggplants by hand sprayer with 7 days interval. Precautions were taken to avoid drifting of spray materials from plant to neighboring plants.

3.6 Data collection

The data were recorded on the following parameters at an interval of 30 days.

1. Disease Incidence (%)
2. Stem lesion area (cm)
3. Height of plant (cm)
4. No. of branch/plant
5. No. of leaf/branch
6. Yield (t/ha)

3.7 Assessment of disease incidence

Percent disease incidence was calculated using the following formula:

$$(\%) \text{ disease Incidence} = \frac{\text{Number of diseased plant}}{\text{Number of total plants inspected}} \times 100$$

3.8 Statistical analysis

Completely Randomized Design (CRD) was followed for the laboratory and net house experiments. Randomized Completely Block Design (RCBD) was followed for field experiments. The data were statistically analyzed by using computer package program (MSTAT-C).

Figure 2. Collection of diseased specimens

Figure 3. Pure culture of *Sclerotium rolfsii*

Figure 4. Preparation of Allamanda leaf extract

Figure 5. Preparation of Neem leaf extract

Figure 6. Seedling of Singnath variety raised in the net house

Figure 7. Solution of different fungicides

RESULTS

The present experiment was conducted for the management of foot and root rot disease of eggplant caused by *Sclorotium rolfsii.* Effect of the treatments in controlling foot and root rot disease of eggplant was assessed in laboratory, net house and field condition. The results were compiled based on the inhibition of radial mycelium growth, number of sclerotia, plant height, number of branch/plant, number of leaf/plant, stem lesion area, disease incidence and yield.

4.1 Laboratory experiment

4.1.1 *In vitro* evaluation of different treatments against radial mycelium growth of *Sclerotium rolfsii*

Efficacy of different treatments on radial mycelium growth of *Sclerotium rolfsii* is shown in Table 4. Fungicides, plant extracts, organic manure and bio-agent have profound effect on reduction of radial mycelium growth of the fungus. All the tested treatments significantly reduced radial mycelium growth of the fungus. Radial mycelium growth for all the tested treatments ranged from 2.3 to 9.0 cm recorded 4 days after inoculation. The lowest radial mycelium growth (1.03, 1.73, 2.06 and 2.30 cm) of *Sclerotium rolfsii* was recorded in case of Bavistin 50 WP at 1 day, 2 days, 3 days and 4 days after inoculation. The performance of Bavistin 50 WP in reduction of radial mycelium growth was the best followed by Topgan 50 WP, Ridomil Gold MZ 68 WG, Bordeaux mixture and Dithane M-45 irrespective of days after incubation. The highest radial mycelium growth (9.00 cm) was recorded in untreated

control preceded by Alamanda leaf extract (7.90 cm) at 4 days after inoculation.

All the tested fungicides, plant extracts, organic manure and bio-agent have strong effect on inhibition of mycelium against *Sclerotium rolfsii* in culture media. The highest percent inhibition (74.44 %) was recorded in case of Bavistin 50 WP and the lowest in Alamanda leaf extract (12.2 %) at 4 days after inoculation.

Table 4. *In vitro* evaluation of different treatments against radial mycelium growth of *Sclerotium rolfsii*

Treatment	Radial Mycelium Growth (cm)				% Inhibition of mycelium growth over control (4 DAI*)
	1 DAI	2 DAI	3 DAI	4 DAI	
Control	2.00 a	4.20 a	7.33 a	9.00 a	-
Bavistin 50 WP	1.03 d	1.73 e	2.06 g	2.30 h	74.44
Topgan 50 WP	1.30 c	1.80 e	2.23 g	2.80 g	68.88
Ridomil Gold	1.40 bc	1.93 e	2.63 f	3.23 f	64.07
Bordeaux mixture	1.50 bc	2.66 d	3.63 d	4.30 d	52.22
Dithane M-45	1.60 b	2.90 c	3.66 d	4.16 d	53.70
Neem leaf extract	1.50 bc	3.10 c	5.46 c	6.73 c	25.18
Alamanda leaf extract	1.53 bc	3.60 b	5.86 b	7.90 b	12.22
Trichoderma harzianum	1.33 c	2.46 d	2.96 e	3.46 e	61.47
LSD (0.05)	0.21	0.22	0.24	0.22	-
CV (%)	8.50	4.81	3.55	2.76	-

DAI = Days after inoculation

4.1.2 *In vitro* evaluation of different treatments against sclerotia formation of *Sclerotium rolfsii*

Efficacy of fungicides, plant extracts, organic manure and bio-agent on sclerotia formation of *Sclerotium rolfsii* is shown in Table 5. All the tested treatments have profound effect on decreasing sclerotial formation of the fungus. Number of sclerotia for all the treatments ranged from 124.7 to 545.3 recorded after inoculation of 30 days. The lowest number of sclerotia (124.7) of *Sclerotium rolfsii* was recorded in case of Bavistin 50 WP that was statistically similar with the number of sclerotia (130.7) of Topgan 50 WP. The highest number of sclerotia (545.3) of *Sclerotium rolfsii* was recorded in case of untreated control treatment preceded by *Trichoderma harzianum*, Dithane M-45 and Topgan. The highest reduction of number of sclerotia (77.13 %) was recorded in case of Bavistin 50 WP preceded by Topgan 50 WP (76.03 %), Ridomil Gold MZ (59.16 %) and *Trichoderma harzianum* (42.41 %).

Table 5. *In vitro* evaluation of different treatments against sclerotia formation of *Sclerotium rolfsii*

Treatment	**Number of sclerotia (30DAI)**	**% Reduction of number of sclerotia over control (30 DAI*)**
Control	545.3 a	-
Bavistin 50 WP	124.7 h	77.13
Topgan 50 WP	130.7 h	76.03
Ridomil Gold MZ 68WG	222.7 g	59.16
Bordeaux mixture	295.0 e	45.90
Dithane M-45	272.0 f	50.11
Neem leaf extract	354.0 c	35.08
Alamanda leaf extract	386.0 b	29.21
Trichoderma harzianum	314.0 d	42.41
LSD (0.05)	16.83	-
CV (%)	3.34	-

***DAI = Days after inoculation**

4.2 Net house experiment

4.2.1 Effect of different treatments on disease incidience of eggplant in net house condition

Data recorded on percent disease incidence of foot and root rot disease of eggplant as affected by the application of different fungicides, plant extracts, organic manure and bio-agent were summarized and presented in Table 6. The effects of different treatments recorded at 120 days after transplanting (DAT) differed significantly as compared to control. The spraying of Bavistin 50 WP gave the lowest disease incidence that were (7.10 %) which was statistically similar to Topgan 50 WP (19.6 %) and Ridomil Gold MZ 68WG (25.9 %). The highest disease incidence was recorded in control treatment (64.9 %) which was statistically similar to Alamanda extract (47.8 %) and poultry manure (62.5 %). Among the treatments, Bavistin 50 WP gave the best result for reducing percent disease incidence (89.06 %) of eggplant.

Table 6. Effect of different treatments on disease incidence of eggplant in net house condition

Treatment	**Disease incidence**	**% Reduction of disease incidence over control**
Control	64.90 a	-
Bavistin 50 WP	7.10 e	89.06
Topgan 50 WP	19.63 de	69.75
Ridomil Gold	25.90 cde	60.09
Bordeaux mixture	25.90 cde	60.09
Dithane M-45	41.53 abcd	36.00
Neem leaf extract	38.43 bcd	40.78
Alamanda leaf extract	47.80 abc	26.34
Poultry manure	62.53 ab	3.65
Trichoderma harzianum	31.93 cd	50.80
LSD (0.05)	22.40	-
CV (%)	35.97	-

4.2.2 Effect of different treatments on stem lesion area (cm) of eggplant in net house condition

The effect of all the fungicides, plant extracts, organic manure and bio-agent on stem lesion area of eggplant was determined and presented in Figure 8. Stem lesion area under fungicides, plant extracts, organic manure and bio-agent was found to differ significantly any the treatments. The lowest stem lesion area of eggplant was found which applied with Bavistin 50 WP (0.71 cm) followed by Topgan 50 WP (0.99 cm). The highest lesion area was recorded in the untreated control (2.23 cm). Neem leaf extract (1.59 cm) and bio-agent *Trichoderma harzianum* (1.40 cm) showed better performance compared to control.

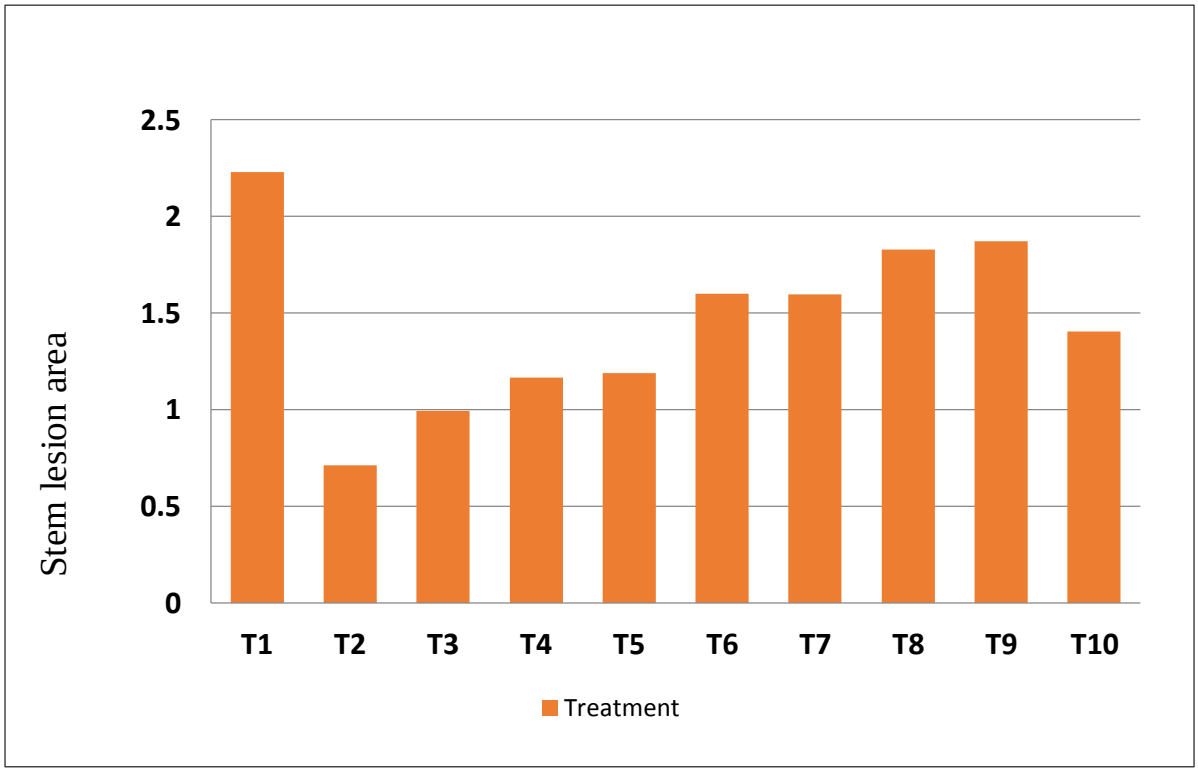

Figure 8. Effect of different treatments on stem lesion area (cm) of eggplant in net house condition

T_1 = Control

T_2 = Bavistin 50 WP

T_3 = Topgan 50 WP

T_4 = Ridomil Gold MZ 68WG

T_5 = Bordeaux mixture

T_6 = Dithane M-45

T_7 = Neem leaf extract

T_8= Alamanda leaf extract

T_9= Poultry manure

T_{10}=*Trichoderma harzianium*

4.2.1 Effect of different treatments on yield of eggplant in net house condition

Data recorded on yield of eggplant by the application of different fungicides, plant extracts, organic manure and bio-agent were summarized and presented in Table 7. Yield of eggplant differed statistically due to the effect of different fungicides, plant extracts, organic manure and bio-agent against *Sclerotium rolfsii* in net house condition. Mean yield of eggplant ranged from 18.07 (ton/ha) to 4.86 (ton/ha). The highest yield (18.07 ton/ha) was recorded in the plot treated with Bavistin 50 WP followed by Topgan (15.79 ton / ha) and Ridomil gold MZ 68WG (13.41 ton/ha). The lowest yield (4.86 ton/ha) was recorded in control plot. Application of alamanda leaf extract (9.42 ton/ha), neem leaf extract (10.66 ton/ha) and *Trichoderma harzianum* (11.58 ton/ha) gave moderate yield compared to control.

Table 7. Effect of different treatments on yield of eggplant in net house condition

Treatment	**Yield (ton/ha)**	**% Yield increase over control**
Control	4.867 h	-
Bavistin 50 WP	18.07 a	271.27
Topgan 50 WP	15.79 b	224.42
Ridomil Gold MZ 68WG	13.41 c	175.52
Bordeaux mixture	12.40 d	154.77
Dithane M-45	10.95 e	124.98
Neem leaf extract	10.66 e	119.02
Alamanda leaf extract	9.420 f	93.54
Poultry manure	7.660 g	57.38
Trichoderma harzianum	11.58 de	137.92
LSD (0.05)	0.9483	-
CV (%)	4.85	-

4.3 Field experiment

4.3.1 Effect of different treatments on disease incidence of eggplant in field condition

Data recorded on percent disease incidence of foot and root rot disease of eggplant as affected by the application of different fungicides, plant extracts and bio-agent were summarized and presented in Table 8. The effects of different treatments recorded at 120 days after transplanting (DAT) differed significantly as compared to control. The spraying of Bavistin 50 WP gave the lowest disease incidence (7.1 %) which was statistically similar to Topgan 50 WP (19.6 %) and Ridomil Gold MZ 68WG (19.6 %) . The highest disease incidence was recorded in control treatment (62.5 %) which was statistically similar to Alamanda leaf extract (50.87 %) and poultry manure (50.90 %) . Among the treatments, Bavistin 50 WP gave the best result for reducing percent disease incidence (88.64 %) of eggplant.

Table 8. Effect of different treatments on disease incidence of eggplant in field condition

Treatment	**Disease incidence**	**% reduction of disease incidence over control**
Control	62.50 a	-
Bavistin 50 WP	7.10 c	88.64
Topgan 50 WP	19.63 bc	68.59
Ridomil Gold	19.63 bc	68.59
Bordeaux mixture	32.17 abc	48.52
Dithane M-45	32.17 abc	48.52
Neem leaf extract	35.27 abc	43.56
Alamanda leaf extract	50.87 ab	18.60
Poultry manure	50.90 ab	18.56
Trichoderma harzianum	38.43 abc	38.51
LSD(0.05)	29.58	-
CV(%)	49.45	-

4.3.2 Effect of different treatments on stem lesion area (cm) of eggplant in field condition

The effect of all the fungicides, plant extracts, organic manure and bio-agent on stem lesion area of eggplant was determined and presented in Figure 9. Stem lesion area under fungicides, plant extracts, organic manure and bio-agent was found to differ significantly any the treatments. The lowest stem lesion area of eggplant was found while applied Bavistin 50 WP (0.71 cm) followed by Topgan 50 WP (1.04 cm). The highest lesion area was recorded in the untreated control (2.45 cm). Neem leaf extract (1.48 cm) and bio-agent *Trichoderma harzianum* (1.80 cm) showed better performance compared to control.

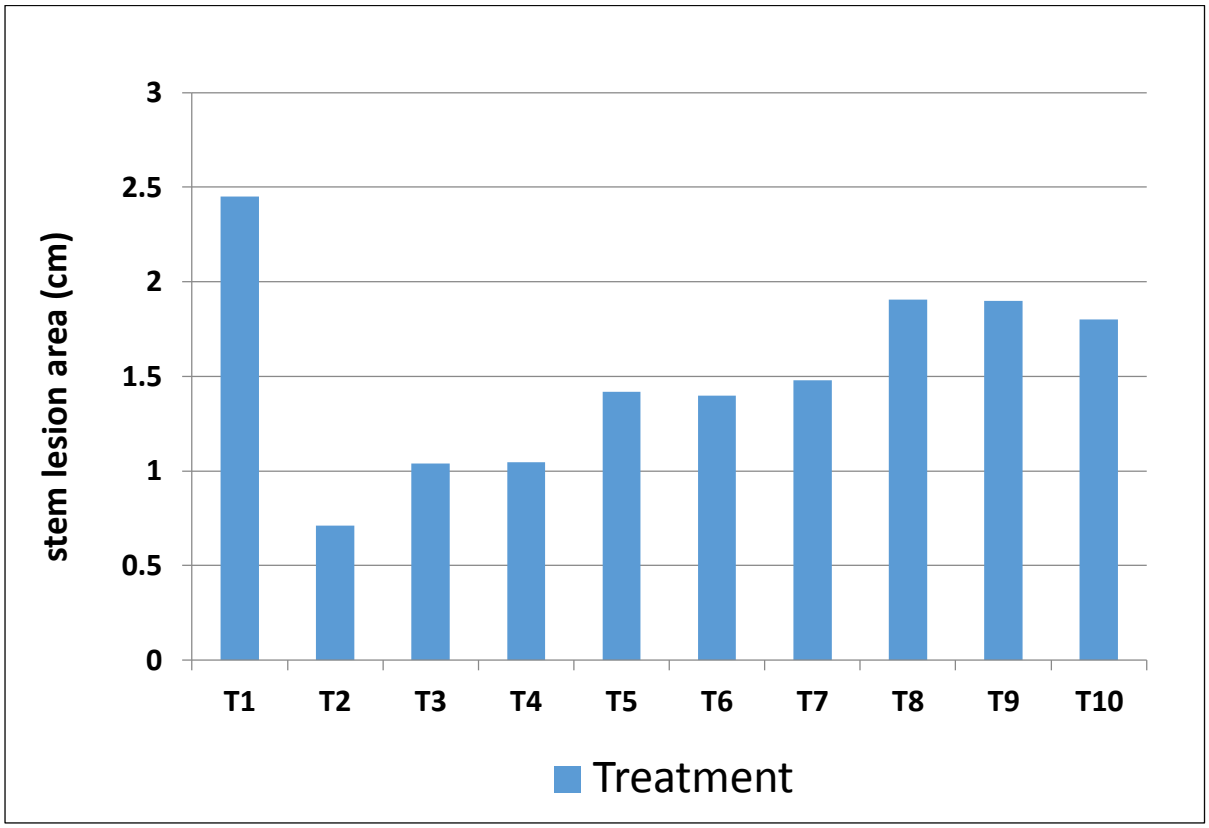

Figure 9. Effect of different treatments on stem lesion area (cm) of eggplant in field condition

T_1 = Control

T_2 = Bavistin 50 WP

T_3 = Topgan 50 WP

T_4 = Ridomil Gold MZ 68WG

T_5 = Bordeaux mixture

T_6 = Dithane M-45

T_7 = Neem leaf extract

T_8= Alamanda leaf extract

T_9= Poultry manure

T_{10}= *Trichoderma harzianum*

4.3.3 Effect of different treatments on plant hight of eggplant in field condition

The effect of fungicides, plant extracts, organic manure and bio-agent on plant hight was determined and presented in Figure 10. All the treatments have strong effect to increasing the plant hight with the increase of the age of the plant. The highest plant hight (88 cm) was found in Bavistin 50 WP treated plot followed by Topgan 50 WP (85 cm) and the lowest plant hight (61 cm) was found in untreated control condition at 120 DAT.

4.3.4 Effect of different treatments on number of branch/plant of eggplant in field condition

The effect of the treatments on number of branch/plant was determined and presented in Figure 11. All the treatments have remarkable effect in increasing the number of branch/plant with the increase of the age of the plant. The highest number of branch/plant (7.33) was found in Bavistin 50 WP treated plot followed by Topgan 50 WP (6.66) and the lowest number of branch/plant (4.33) was found in untreated control condition at 120 DAT. Number of branch/plant in poultry manure and Alamanda leaf extract treated plots were 5.00 and 5.33, respectively.

4.3.5 Effect of different treatments on number of leaf/branch of eggplant in field condition

The effect of the treatments on number of leaf/branch was determined and presented in Figure 12. All the treatments have remarlable effect to increasing the number of leaf/branch with the increase of the age of the plant. The highest number of leaf/branch (25.33) was found in Bavistin 50 WP treated plot followed by Topgan 50 WP (23.33) and the lowest number of leaf/branch (12.00) was found in untreated control condition at 120 DAT. Number of leaf/branch in case of poultry manure and alamanda leaf extract treated plots were 14.33 and 16.00, respectively.

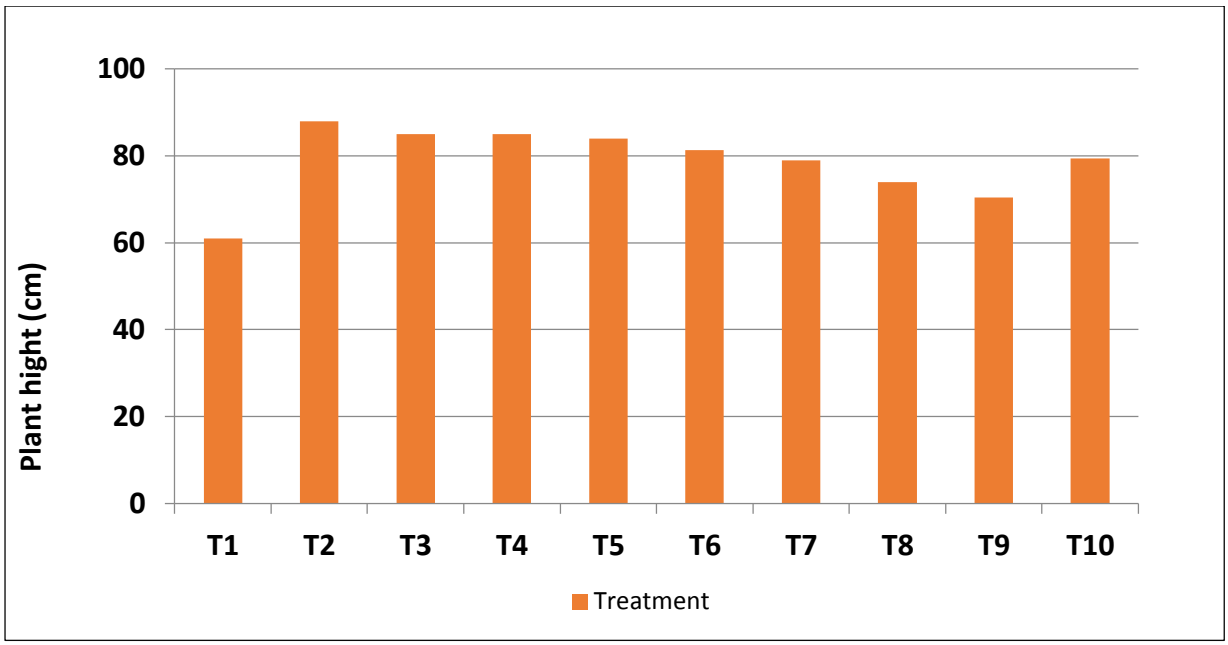

Figure 10. Effect of different treatments on plant hight of eggplant in field condition

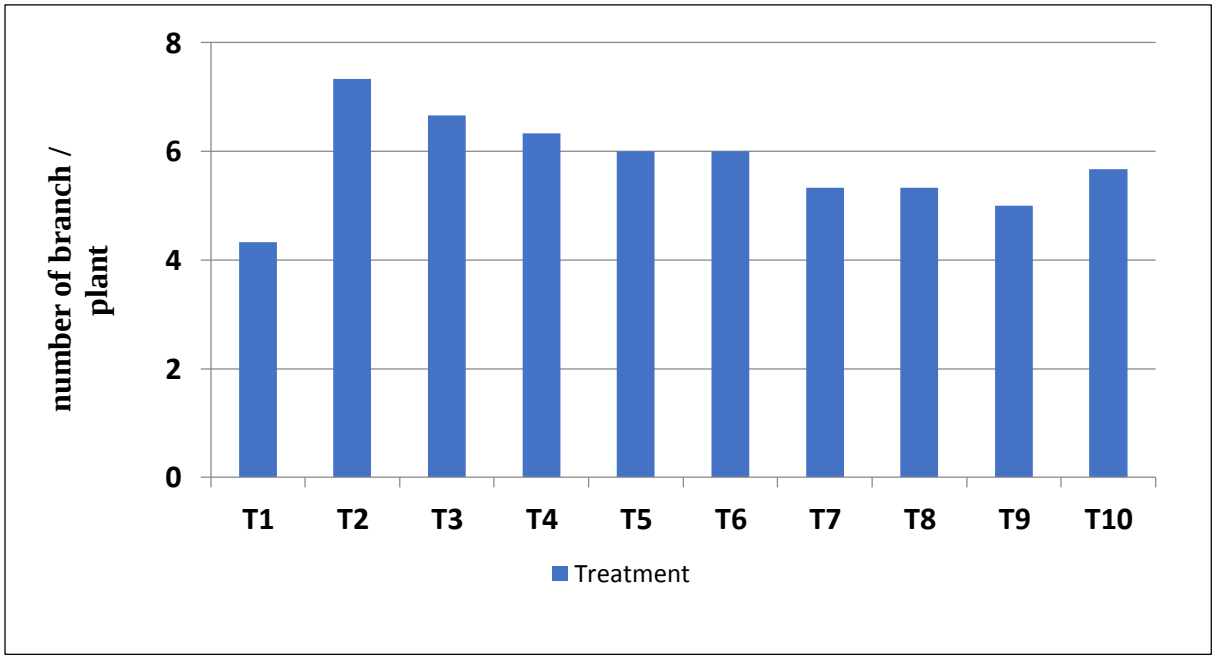

Figure 11. Effect of different treatments on number of branch/plant of eggplant in field condition

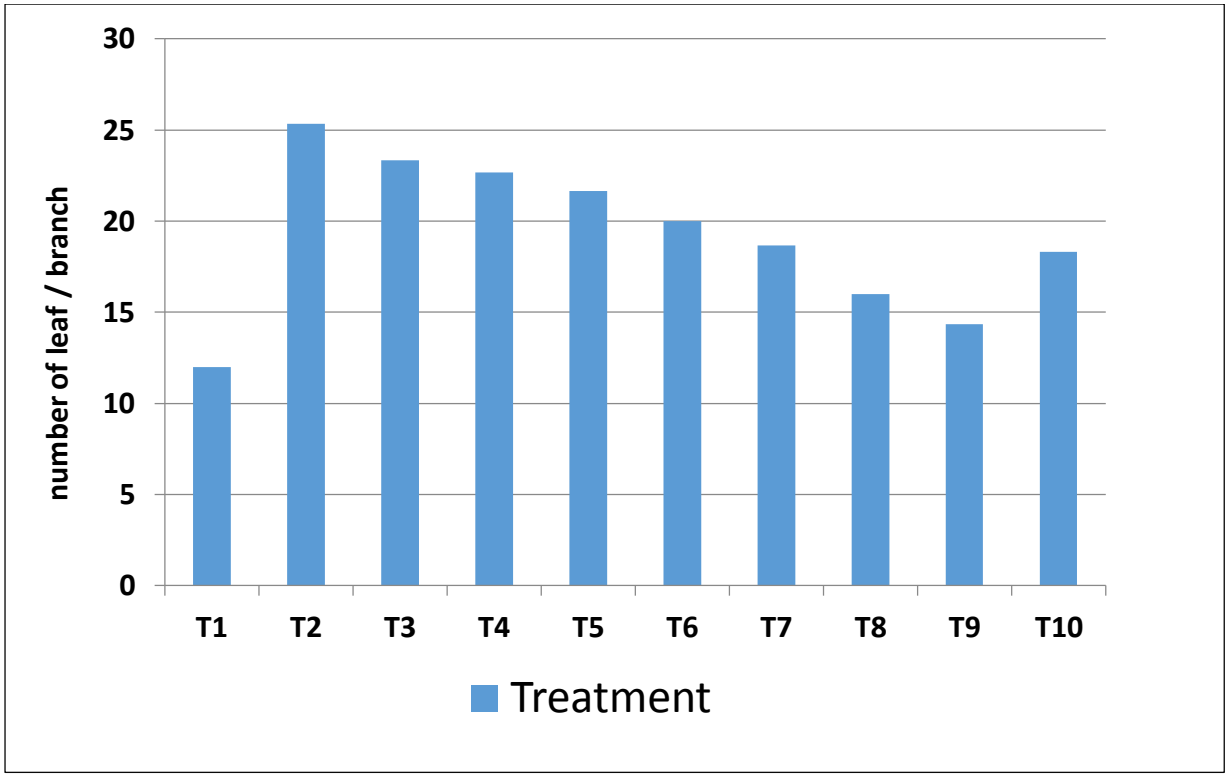

Figure 12. Effect of different treatments on number of leaf / branch of eggplant in field condition

T_1 = Control

T_2 = Bavistin 50 WP

T_3 = Topgan 50 WP

T_4 = Ridomil Gold MZ 68WG

T_5 = Bordeaux mixture

T_6 = Dithane M-45

T_7 = Neem leaf extract

T_8= Alamanda leaf extract

T_9= Poultry manure

T_{10}= *Trichoderma harzianum*

4.3.6 Effect of different treatments on yield of eggplant in field condition

Data recorded on yield of eggplant by the application of different fungicides, plant extracts, organic manure and bio-agent were summarized and presented in Table 9. Yield of eggplant differed statistically due to the effect of different fungicides, plant extracts, organic manure and bio-agent in field condition. Mean yield of eggplant ranged from 25.17 (ton/ha) to 8.70 (ton/ ha). The highest yield (25.17 ton/ha) was recorded in the plot treated with Bavistin 50 WP followed by Topgan 50 WP (22.87 ton/ha) and Ridomil gold MZ 68WG (22.23 ton/ha). The lowest yield (8.70 ton/ha) was recorded in control plot. Application of Alamanda leaf extract (13.40 ton/ha) and *Trichoderma harzianum* (17.80 ton/ha) showed moderate effect compared to control.

Table 9. Effect of different treatments on yield of eggplant in field condition

Treatment	Yield (ton/ha)	% Yield increase over control
Control	8.700 f	-
Bavistin 50 WP	25.17 a	189.31
Topgan 50 WP	22.87 b	162.87
Ridomil Gold	22.23 b	155.51
Bordeaux mixture	19.43 cd	123.33
Dithane M-45	19.82 c	127.81
Neem leaf extract	18.00 d	106.89
Alamanda leaf extract	13.40 e	54.02
Poultry manure	12.30 e	42.18
Trichoderma harzianum	17.80 d	104.59
LSD(0.05)	1.622	-
CV(%)	5.26	-

Figure 13. Bioassay following growth inhibition technique using fungicides, plant extracts and bio-agent.

T_1 = Control

T_2 = Bavistin 50 WP

T_3 = Topgan 50 WP

T_4 = Ridomil Gold MZ 68WG

T_5 = Bordeaux mixture

T_6 = Dithane M-45

T_7 = Neem leaf extract

T_8= Alamanda leaf extract

T_{10}= *Trichoderma harzianum*

Figure 14. Different growth stage of healthy eggplant

A. Seedling stage
B. Vegetative stage
C. Fruting stage

Figure 15. Infected eggplant caused by *Sclerotium rolfsii*

A. Infected seedling

B. Infected plant

C. Stem lesion

Figure 16. Healthy stem (splited) of eggplant

Figure 17. Infected stem (splited) of eggplant

Figure 18. Scleratia form in infection area

REVIEW OF LITERATURE

Sclerotium rolfsii causing foot and root rot of eggplant is a well known polyphagous, ubiquitous and a non-target pathogens. It is one of the most destructive soils inhibiting pathogen reported so far. The disease results in an uneven crop stand loss of plant population and subsequently yield of crop plants.

2.1 The pathogen

Islam (2005) reported that, eggplant (*Solanum melongena* L.) is prone to attack of many diseases at all stages of growth. The diseases of eggplant have been studied in Bangladesh to a limited extent. Humid and moist shaded conditions are favorable for its growth. The serious diseases viz. foot and root rot caused a huge loss yield of eggplant. Foot and root rot of eggplant caused by *Sclerotium rolfsii* is the most common in eggplant garden and this disease is endemic and cause serious problem all over the eggplant growing regions in Bangladesh. Foot and root rot of eggplant caused by *Sclerotium rolfsii* is also a devastating soil borne pathogenic fungus with a wide host range of agricultural and horticultural crops and very much difficult to control. The fungus *Sclerotium rolfsii* is also a facultative saprophyte and can maintain continuity of generation under adverse situation by the formation of sclerotia.

It is a well known polyphagous, ubiquitous, omnivorous and most destructive soil borne fungus. This was first time reported by Rolfs (1892) as a cause of tomato blight from Florida in USA. *Sclerotium rolfsii* is a serious soil borne pathogenic fungus and harmful to many economically valuable crops in most of the tropical and subtropical

region of the world (Aycock, 1966). However, later studies showed that, the fungus involved was *S. rolfsii* (Ramakrishnan, 1930).

Shaw and Ajrekar (1915) isolated the fungus from rotted potatoes and identified as *Rhizoctonia destruens* Tassi. Later, Saccardo (1911) named the fungus as *S. rolfsii*.

2.2 Importance and distribution

Palakshappa (1986) studied the effect of different soil moisture levels on foot rot of betel vine caused by *S. rolfsii* and reported that, the fungus survived better at low soil moisture than at higher levels. The survival ability was the highest between 20 and 40 % soil moisture. However, higher saprophytic activity of the fungus was observed at 40 % moisture level and the least was at 60 and 70 % soil moisture where the saprophytic activity of the fungus was found to be very less.

Kulkarni *et al*. (1994) reported the tuber rot or wilt of potato as major problem in rainy season of transitional belt of Karnataka. Sporadic incidence of fungal wilts caused by either *S. rolfsii* or *Verticillium* sp. was found in Karnataka, North Gujarat and Sapura plateau.

Lingaraju (1977) reported that, the saprophytic activity of the *S. rolfsii* was more at 10 % soil moisture and the fungus did not survive when the soil moisture was raised to 50 % and above.

Dutt *et al*. (1971) reported 5-40 % damage due to this disease with more damage in kharif than in rabi crop. The disease also reported from Punjab cold stores, Madhya Pradesh and Karnataka. It was minor in Punjab but causes heavy losses both in the field and stores in areas of Deccan plateau.

Since 1961 the disease is of annual occurrence at Rajgurunagar (Pune), especially during kharif season and recorded less than one per cent in 1964 and three per cent in 1968. In a badly affected crop, more than 50 per cent plants showed *Sclerotium* rot. The disease was quite serious in Satara region with an average incidence of 5 % wilt and 1-3 % tuber infection during 1968. It was destructive in stores and upto 1 % tuber may rot every day (Khanna and Sharma, 1993).

Foot and root rot is a disease of tropics and subtropics crops. It is common where high temperature exists during the rainy season. It is a serious disease on eggplant in Bangladesh. The pathogen *S. rolfsii*, cannot survive in low temperate for long time, hence, it is not important in cold temperate regions. In India, it has been reported from Bengal and Bombay (Shaw and Ajrekar, 1915); Tamil Nadu (McRae, 1928) and Western India (Ajrekar, 1924).

2.3 Symptom of the disease

Dasgupta *et al*. (2000) reported the highest intensity of foot and root rot and leaf rot of eggplant have been recorded in Midnapore and Nadia district.

Kulkarni *et al*. (1995) reported that, the pathogen *Sclerotium rolfsii* damaged stem, root or tuber and infected the stem and produced dark brown lesion at collar region causing wilt and ultimately plants get dried. Brownish sclerotia like mustard seed, developed at later stages on the root and collar region of the infected plants. Afterwards tubers get infected and rotten in field condition.

Maiti and Sen (1982) reported that, the high temperature, high relative humidity and rainfall played an important role in the development of foot rot and diseases of betel vine.

Dastur (1935) gave a well accepted description of the symptom of foot rot disease of eggplant. In *Sclerotium rolfsii* induced foot rot, wet rot associated with wilting of vines is common. In the diseased plants fine young roots are infected first. In case of foot and root rot of betel vine, the leaves and shoots turn yellow, wither and finally dry out to a pale brown color. The fungus attacks the roots and stem near the soil level. Black lesion develops following necrosis of the plant cells. The mycelium invades the stem and rots the affected portions. As a result, the plant become wilt and gradually dies. Abundant white mycelium and small light brown sclerotia form on the rotted plants. Gradually the rotting spreads through older roots and ultimately reaches the foot or collar region of the plant. In a diseased plant, the whole underground portion gets more or less completely rotten.

2.4 Pathogenicity Studies

Uma Singh and Thapliyal (1998) reported inoculums density levels of 2.5 to 10 g/kg soil significantly increased the emergence rot which was ranged from 36.70 to 90 % in seed and seedling rot of soybean caused by *S. rolfsii*.

Kulkarni *et al*. (1994) while studying the most susceptible growth stage of groundnut to *S. rolfsii*, maximum mortality was recorded in 15 days old plants and the least mortality in 105 days old plants.

Palakshappa *et al*. (1988) observed considerable foot rot infection, when betel vine were inoculated with two and three per cent inoculums and they recorded 100 % infection at four per cent and above inoculums levels.

Harlapur (1988) reported that, 2 % inoculums were essential for infection. But, maximum infection (100 %) was noticed in inoculums level of more than 4 % in foot rot disease of wheat.

Siddaramaiah and Chandrappa (1988) proved the pathogenicity of *S. rolfsii* on cardamom in pot culture studies by inoculating 25 days old sclerotial cultures which was grown on sand corn meal medium and observed the symptoms a week after inoculation.

Siddaramaiah (1988) confirmed the pathogenicity of *S. rolfsii* on *Desmodium uncimatum* Desv and *Cotonoris bainesii* Eckl and Zeyh, two important forage legumes of hill zone by similar procedure.

Mishra and Bais (1987) used 15 days old fungal culture grown on sand corn meal medium for studying pathogenicity of root rot of barley caused by *S. rolfsii*, by mixing upper 4-5 cm layer of soil with inoculums at the rate of one flask per pot.

Datar and Bindu (1974) proved the pathogenicity of *S. rolfsii* on sunflower by soil inoculation method under glasshouse condition. The inoculums was prepared by growing the fungus on sterilized maize bran medium and mixed with the sterilized soil one week before sowing. Typical symptoms were produced within a week of inoculation in the field.

Sengupta and Das (1970) studied the cross inoculation of isolates of *S. rolfsii* from groundnut, wheat, potato, guava and bengal gram. They concluded that bengal gram was the most susceptible host against *S. rolfsii*. Although isolates were most virulent to their appropriate hosts.

Kilpatrick and Merkle (1967) reported the effect of different levels of *S. rolfsii* inoculums on foot rot of wheat and found that, 0.5 and 1.0 % inoculums was superior to 3, 5 and 10 %. However, considerable amount of infection was recorded in two per cent inoculums and 100 % disease in 6 % and above inoculums level.

Garret (1956) defined inoculums potential as the energy for growth of a parasite available for infection of a host, at the surface of the organ to be infected. For development of root rot diseases, certain number of fungal propagules should always survive in soil.

Difference in morphology and pathogenicity were reported as early as in 1923 by Edson and Shapovalov for the isolates of *S. rolfsii* from North Caralina and Arkansas. One of those two isolates was found to be more virulent in potato seed decay.

2.3 Effect of chemicals against *Sclerotium rolfsii*

Dasgupta and Maiti (2008) reported that the foot rot caused by *Sclerotium rolfsii* was claimed to be ameliorated by soil application of Bordeaux mixture (BM).

Johnson and Reddy (2008) evaluated *in vitro* efficacy of fungicides (hexaconazole, propiconazole, mancozeb, Chlorpyriphos and Quinalphos) against *S. rolfsii*. Among the five pesticides, hexaconazole at a concentration of 1000, 1500 and 2000 ppm and propiconazole at a

concentration of 500, 750 and 1000 ppm completely inhibited the growth of *S. rolfsii*.

Sheoraj *et al.* (2005) studied the efficacy of mancozeb, thiram, carboxin, dithane M-45, sulfur dust, carbendazim, ziram, streptocycline, thiophanate methyl and blue copper at 2500 ppm in controlling *S. rolfsii* causing collar rot of lentil *in vitro*. Mancozeb, thiram and carboxin performed 100 % control against the pathogen.

Tiwari and Ashok (2004) reported that, fungicides like carboxin, epoxiconazole, hexaconazole, propiconazole and triadimefon which were found highly effective against *Rhizoctonia solani* and *S. rolfsii*, and can be formulated as seed dresser either with thiram or mancozeb to control both collar rot and root rot as well as seed mycoflora effectively.

Vanitha and Suresh (2002) reported that, seed treatment with carbendazim recorded significantly the lowest incidence (10.83 %) of collar rot of brinjal caused by *S. rolfsii* compared to control (39.30 %).

Rahman *et al*. (1994) demonstrated that the effect of Vitavax-200, Apron-TZ, Dithane M-45, Thiram, Captan and Baytan 100-S [Triadimeno] on foot and root rot disease on cowpea (*Vigna unguiculata*) caused by *Corticium rolfsii*. Seeds of a susceptible variety were treated before sowing. Vitavax-200 was the best fungicides in respect to controlling seedling mortality.

Harlapura (1988); Vyas and Joshi (1977) reported the efficacy of thiram in inhibiting the growth of *S. rolfsii*, the casual agent of foot rot of wheat.

Harlapur (1988) noticed complete inhibition of mycelium growth of *Sclerotium rolfsii* by Agallol and Dithane M-45.

Dasgupta *et al.* (1988) showed that fosetyl-Al and Bordeaux mixture were effective in controlling foot rot and leaf rot of betel vine.

Mishra and Bais (1987) found that soil treatment with thiram (2000 ppm) minimized pre and post-emergence mortality of barley caused by *S. rolfsii* and reported the efficacy of different fungicides hexaconazole (0.1 % and 0.2 %), carbendazim (0.2 %), and thiophanate-methyl (0.2 %) under *in vivo* conditions against *S. rolfsii* of gram and sunflower. Hexaconazole was found to be highly effective.

Pan and Sen (1987) demonstrated soil drenches with benodanil and seed treatments with campogram M were also highly effective in reducing wheat seedling mortality caused by *Sclerotium rolfsii.*

Soil drenching with dithane M-45, captan, difolatan and boredeux mixture were found highly effective in reducing the mortality of *Piper betel* L. due to *S. rolfsii* (Patil *et al*., 1986).

Wokocha and Ebeneb (1986) used six fungicides Aatopam-N, Aldrex-T, Calixin-M, PCNB [Quintozene], Captan and Captafol at 200 mg a.i. litter in green house tests against *Sclerotium rolfsii* on tomato completely suppressed the disease when applied as soil drenches up to 4 d before inoculation, but only Quintozene was effective when applied 10 d before and post-inoculation treatments were all effective.

Patil *et al*. (1986) reported that, in field trials against the foot rot disease on the *Piper betel* caused by *Sclerotium rolfsii* were control by soil drenches with Cupravit, Dithane M-45, Copper oxychloride , Difolatan and Bordeaux mixture were very effective.

Punja *et al*. (1982) found that, eruptive and hyphal germination of dried seed sclerotia of two isolates of *Sclerotium rolfsii* at 1 % Noble and Bacto water agar was totally inhibited by Carboxin, Cycloheximide, Oxycarboxin and experimental fungicides CGA-64251 in the agar @ 100 and 200µg ai. /ml.

Kulkarni (1980) found that, in field trials foot rot of wheat caused by *Sclerotium rolfsii* was controlled effectively by seed treatment with panoram, brassicol, panoctine-35 [Guazatine]. Vitavax and calixin [Tridemorph] were less effective. Seed treatments with 0.2 % of these chemicals protect wheat seedlings for up to 35 days even in heavily infested soil.

Saksena (1977) reported that the foot rot of betel vine caused by *Sclerotium rolfsii* was completely checked when cuttings were dipped in streptomycin solution and the plants were sprayed with BM (1 %) twice a month.

Vyas and Joshi (1977) screened several fungicidal compounds (including both systemic and non-systemic) against collar rot of wheat caused by *S. rolfsii* and recorded that, Mertect and Triforine completely inhibited the growth of the fungus at 200 and 100 ppm, respectively.

Maiti and Choudhary (1975) reported the effectiveness of carboxin in inhibiting *S. rolfsii* under laboratory conditions. Pan and Sen (1977) reported the effectiveness of campogram-M (50 % 2.5 dimethylfuron-3-carbamix acid anlide + zinc manganese ethylene bisdithiocarbamate) in inhibiting sclerotial germination and mycelia growth of the *S. rolfsii.*

Dutta (1975) found that, soil application of fungicides such brassicol (0.1%), Bavistin (0.5-0.7%) three times at 20 days interval has been effective in controlling foot and tuber rot disease of tuberose.

2.4 Effect of plant extracts against *Sclerotium rolfsii*

Gurjar *et al.* (2003) reported that, collar rot of chilli caused by *Sclerotium rolfsii* and studied the effect of organic amendments like FYM, vermin compost, cotton oil, mustard oil, castor oil, neem oil and groundnut oil against the disease. All amendments were found significantly superior compared to control. Neem cake was found most effective with the least disease incidence of 18.50 per cent.

Seshakiran (2002) reported that, *Eupatorium odoralum* L., *C. occidentalis* and *Azadirachta indica* were highly antifungal to mycelia growth of *S. rolfsii*. However, root extract of *Patheniumhy sterophorus* L. exhibited maximum inhibition of mycelium growth of *S. rolfsii.*

Morteza and Mohammed (2001) applied some plants products to control some soil borne fungal pathogens. More than 15 plants species were tested for their antifungal effects on radial growth and spore germination of *Fusarium oxysporum* f. sp. *cumini* causing cumin wilt and *Fusarium equisetii* causing dry rot of potato tubers and *Rhizoctonia solani* causing sugar beet root rot.

Enikuomehin *et al*. (1998) worked on the evaluation of ash from some tropical plants of Nigeria for the control of *S. rolfsii o*n wheat (*Trichodermam aestivum* L.). Nine tropical plants were screened for their abilities to inhibit mycelium growth and sclerotial germination of Nigerian isolate of *Corticium rolfsii* on agar and in soil. Of the 11

samples tested 10 showed some activity against mycelia growth of *C. rolfsii in vitro.*

Pani and Patra (1997) utilized some phyto-extracts for controlling *S. rolfsii* during paddy straw mushroom (*Volvariella volvacea*) cultivation. *In vitro* and in vivo studied were conducted to determine the effect of extracts of *Azadirachta indica, Psidium guagava, Lantana camara, Sopindus trifoliate, Tamarindus indica,* the mycelium growth of *Volvariella volvacea*and *S. rolfsii.* Paddy straw mushroom inoculated with *S. rolfsii* and treated with *Tamarindus indica* leaf extract resulted in the highest yield followed by *Sopindus trifoliate* seed extract and *Moringa oleifera* root extract.

Dayaram and Tewari (1994) found that, the soil application of green leaves of *Adathoda vasica, Aegle marchelos*, *Anisomeles ovata*, *Azadirchta indica*, *Cymbopogon flexuous*, rhizomes of *Curcuma amada* and resin of *Ferula foetida* at 2 to 5 per cent concentration reduced both pre and post emergence collar rot of chickpea caused by *Sclerotium rolfsii* . Five per cent *Ferula foetida* resin applied 48 hours before sowing of seeds in artificial inoculation of soil provided nearly 100 per cent protection.

Ram and Tewari (1994) reported that, soil application of green leaves of *Adhatoda vasica, Acgle marmelos, Anisomeles ovata, Azadirachta indica, Cymtopogan flexuosus*, rhizomes of *Curcuma amada* and resin of *Ferula fostida* at two and five per cent concentration reduced both pre and post-emergence collar rot of chickpea caused by *Sclerotium rolfsii.* Five per cent *F. fortida* resin applied 48 hours before sowing of seeds in artificially inoculated soil proved nearly 100 per cent protection.

Singh and Dwivedi (1987) observed that, hyphal dry weight and sclerotial production of *Sclerotium rolfsii* were significantly reduced by bark extracts of *Acacia arabica.*

Palakshappa (1986) found that, the maximum suppression of the saprophytic activity of *S. rolfsii* causing foot rot of betel vine by groundnut and safflower oil cake, and FYM, paddy hulls and wheat bran were less effective.

Punja (1985) reported that, the addition of organic amendments such as compost, oats or corn straw to soil limited the disease caused by *S. rolfsii*, possibly due to release of toxic ammonia or increased in the level of resident antagonistic soil micro organisms.

Lingaraju (1977) reported that of all the organic amendments tried, groundnut oil cake was the most effective in suppressing the saprophytic activity of *S. rolfsii* followed by FYM. While plant residue like paddy hull and wheat bran were equally effective in keeping the saprophytic activity of the fungus at a low level.

Mathur and Sinha (1970) reported reduced infection due to *S. rolfsii* in case wilt of gram (*Cicer arietinum* L.) by the application of FYM.

Chaudhary (1946) reported that, application of manure reduced the death of betel vine plants due to infection of *Sclerotium rolfsii.* Among the organic amendments tested the mustard oil cake was found to be effective.

2.5 Effect of bio-agent against *Sclerotium rolfsii*

Saralamma and Vithal Reddy (2003) observed and reported that seed treatment @ 10 conidia ml^{-1} and soil application @ 5g kg^{-1} soil with *Trichoderma harzianum* were found to be optimum in increasing percent seedling emergence to an extent of 80 and 84, reducing disease incidence to 26.6 and 13.0% with an increasing yield of 1373 and 1413 kg /ha.

Pranab Datta and Das (2002) conducted experiments for the management of collar rot of tomato by using chemicals and *T. harzianum*, *T. viride* and *T. koningii*. Among the bio-agents, *T. harzianum* was found to be inhibitorier to *S. rolfsii* in dual culture technique.

Vanitha and Suresh (2002) observed that application of the inoculums *T. harzianum* in the seed treatment and soil application of adathoda leaf powder and FYM exhibited, the lowest collar rot of brinjal (9.44%) caused by *Sclerotium rolfsii.*

Bari *et al*. (2000) reported significant reduction on radial growth of *S. rolfsii* by *Trichoderma* spp. in dual culture on PDA plate. Significant effect of *T. harzianum* and *T. viride* were observed by Morshed (1998) in reducing the vegetative growth of *Fusarium oxysporum* and *S. rolfsii in vitro* in dual culture on PDA.

Biswas and Sen (2000) reported the dual culture of the 11 isolates of *T. harzianum*, isolates viz. T_8, T_{10} and T_{12} were effective against *S. rolfsii* and they over grew the pathogen up to 92 %, 85 % and 79 %, respectively *in vitro*. Both the T_8 and T_{10} isolates reduced stem rot incidence significantly when delivered as seed dressing or soil application in the pot trials of groundnut. Disease reduction through seed dressing by the isolates T_8 and T_{10} were 33 % and 50 %, respectively while disease

reduction through soil dressing were 72 % and 83 %, respectively over control.

Desai and Schlosser (1999) collected 44 isolates of *Trichoderma* belonging to eight species were tested for their ability to infect, macerate and kill the sclerotia of *S. rolfsii*. Of them 14 isolates infected and killed the sclerotia of *S. rolfsii.*

Mondal (1999) tested 55 isolates of *T. harzianum*, isolate TF-24 showed 93% inhibition of mycelia growth of *S. rolfsii* on PDA. Akhter (1999) reported similar observation where the isolate TF-24 of *T. harzianum* was found to be the most effective against *S. rolfsii.*

Virupaksha *et al*. (1997) tested the antagonistic organisms against *Sclerotium rolfsii*. Among them, *Trichoderma harzianum* and *Trichoderma viride* were found to be effective in inhibiting the mycelium growth and reducing production of sclerotial bodies irrespective of inoculation periods. He also observed inhibition zone and reduction in size of sclerotial bodies in presence of antagonists.

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Iqbal *et al*. (1995) tested the micro-organisms for antagonism to *Sclerotium rolfsii*. All the organisms viz., *Trichoderma harzianum*, *Trichoderma koningii* Ouden, *Trichoderma viridae*, *Gliocladium virens*

Miller, *Aspergillus canditus* Link, and *Bacillus* spp. significantly inhibited the mycelia growth of *S. rolfsii*, *Trichoderma harzianum*, *Trichoderma koningii* and *Trichoderma viride* overlapped the pathogen and suppressed growth by 63.6 %, 54.9 % and 51.89 %, respectively.

Iqbal *et al*. (1995) tested the micro-organisms for antagonism to *Sclerotium rolfsii*. All the organisms viz., *Trichoderma harzianum*, *Trichoderma koningii* Ouden, *Trichoderma viride*, *Gliocladium virens* Miller, *Aspergillus candidus* Link, *Paecilomyces lilacinus* (Thom) Samson and *Bacillus spp*. significantly inhibited the mycelium growth of *S. rolfsii*, *Trichoderma harzianum*, *Trichoderma koningii* and *Trichoderma viride* overlapped the pathogen and suppressed growth by 63.6 per cent, 54.9 per cent and 51.89 per cent, respectively.

Kulkarni and Kulkarni (1994) and Virupaksha Prabhu *et al.* (1997) showed that, seed and soil treatment with *T. viride* and *T. harzianum* were the most effective in reducing the mortality percentage of groundnut and cotton seedlings. *T. harzianum* helped to increase the seedling emergence of groundnut.

Kulkarni (1994) showed that, seed and soil treatment with *T. viride* and *T. harzianum* were the most effective in reducing the mortality percentage of groundnut incited by *S. rolfsii.*

Chamswarng and Sangkaha (1988) collected 147 isolates of *Trichoderma* and *Gliocladium* group. In vitro test of bio-control potential of all isolates indicate that 123 were antagonistic to *S. rolfsii*.

D'Ambra and Ferrata (1984) observed the reduction of mycelium growth, sclerotial formation, sclerotial germination and number of sclerotia of

Sclerotium rolfsii when inoculated with different inoculums concentration of *Trichoderma harzianum.*

Eliad *et al*. (1983) studied the parasitism of *Trichoderma harzianum* to the soil borne plant pathogen, *S. rolfsii* .They observed that hyphae of the parasites contact with their host either producing aspersorium like bodies or coiling around the hyphae, enzymatically digest host cell walls. Parasite organelles (mitochondria, vesicles and dark osmiophillicinclusion) accumulate in the parasitizing cells. In response to invasion, the host produces a sheath matrix which encapsulates the penetrating hyphae and the host cells become empty of cytoplasm.

Arora (1999) found that, *T. harzianum* significantly depressed the growth of *S. rolfsii*, the causal organism of root disease of lentil (*Lens esculenta*) on agar.

Mehrotra and Tiwari (1976) showed that dipping of cutting in a *Trichoderma viride* cell suspension effectively reduced the foot rot disease of betel vine.

SUMMARY AND CONCLUSION

Experiments were conducted at the Plant Pathology Laboratory and Farm of Sher-e-Bangla Agricultural University, Dhaka during November 2013 to May 2014 to find out the effective IDM components against foot and root rot disease of eggplant. The field experiment was carried out in randomized complete block design with three replications.

In laboratory condition, the highest reduction of mycelium growth (74.44 %) was recorded in Bavistin 50 WP followed by Topgan 50 WP (68.88 %) and Ridomil Gold MZ 68 WG (64.07 %), respectively. In case of sclerotium formation, the highest reduction of sclerotium was recorded in Bavistin 50 WP (77.13 %) followed by Topgan 50 WP (76.03 %) and Ridomil Gold MZ 68 WG (59.16 %), respectively.

In net house experiment, application of Bavistin 50 WP showed profound effects to reducing the disease incidence compared to control and other treatment. Bavistin 50 WP showed the highest reduction of disease incidence (89.06 %) which reduced foot and root rot disease of eggplant compared with Topgan 50 WP (69.75 %) and Ridomil Gold MZ 68 WG (60.09 %), respectively. The lowest stem lesion area was recorded in Bavistin 50 WP (0.71 cm) followed by Topgan 50 WP (0.99 cm). Application of fungicides, plant extracts and bio-agents also showed variation in reduction of foot and root rot disease caused by *Sclerotium rolfsii* and influenced yield and yield contribution characteristics of eggplant. The highest yield was recorded in Bavistin 50WP (18.07 ton/ha) followed by Topgan 50WP (15.79 ton/ha) and

Ridomil Gold MZ 68 WG (13.41 ton/ha), respectively. Among the treatments, Bavistin 50 WP appeared to be the best in controlling the disease.

In field experiment Bavistin 50 WP showed the highest reduction of disease incidence (88.64 %) which reduced foot and root rot disease of eggplant compared with Topgan 50 WP (68.59 %), respectively. The lowest reduction of disease incidence was recorded in control treatment. Application of Bavistin 50 WP (0.71 cm) showed profound effects to reducing stem lesion area compared to Topgan 50 WP (1.04 cm) and other treatments. The higher yield (25.17 ton/ha) was found under the treatment Bavistin 50 WP followed by Topgan 50 WP (22.87 ton/ha) and Ridomil gold MZ 68 WG (22.23 ton/ ha). The highest plant hight, number of branch/plant and number of leaf/branch was found in Bavistin 50 WP (88 cm, 7.33 and 25.33) followed by Topgan (85 cm, 6.66 and 23.33) and the lowest plant hight, number of branch/plant and number of leaf/branch (61 cm, 4.33 and 12) was found in untreated control treatment.

DISCUSSION

Eggplant (*Solanum melongena* L.) is a small short perennial herb belonging to the family solanaceae. The major constraint of cultivation of eggplant is foot and root rot disease that severely damage. The climate of Bangladesh harbors plant pathogens and provides luxuriant environment for the growth and reproduction of pathogens (Fakir, 2001).The present experiments were carried out for the management of foot and root rot disease of eggplant during November 2013 to May 2014.

From the results of the experiments it is revealed that the chemical fungicides, plant extracts, organic manure and bio-agent proved to be effective against *Sclerotium rolfsii* causing foot and root rot disease of eggplant in laboratory, net house and field condition. Among the treatments, the fungicide Bavistin 50 WP remarkably reduced the mycelium growth and sclerotia formation in laboratory condition. The fungicide Topgan 50 WP also found to be effective against *Sclerotium rolfsii* next to Bavistin 50 WP.

In net house as well as field condition Bavistin 50 WP showed profound effects in reducing the disease incidence of foot and root rot disease of eggplant increasing the yield and yield contributing characters like plant height, number of branches/plant and number of leaf. The present findings corroborate with the findings of the previous researchers (Sheoraj *et al.*, 2005; Vanitha and Suresh, 2002; Mishra and Bais, 1987; Dutta, 1975).

Sheoraj *et al*. (2005), while working on collar rot of Lentil caused by *Sclerotium rolfsii*, reported that Carbendazim (Bavistin) completely controlled the pathogen. Vanitha and Suresh (2002) studied on the collar rot of brinjal caused by *Sclerotium rolfsii* and reported that Carbendazim (Bavistin) significantly reduced the incidence of disease. Mishra and Bais (1987) worked on barely, gram and sunflower mortality caused by *Sclerotium rolfsii* and reported that Carbendazim (Bavistin) effectively controlled the pathogen. Dutta (1975) studied on different chemicals against *Sclerotium rolfsii* caused foot and tuber rot disease of tuberose and reported that Bavistin (0.5-0.7 %) effectively controlled the disease. Among the fungicides used in the experiment Topgan also found to be very effective in controlling *Sclerotium rolfsii* both in *in vitro* and *in vivo* conditions.

Among the plant extracts assayed in the experiment, neem leaf extract found promising against the *Sclerotium rolfsii* causing foot and root rot disease of eggplant. Alamanda leaf extract should comparatively lower performance than neem leaf extract but was better than control. This finding also keep in with the findings of previous researcher (Seshakiran, 2002; Dayaram and Tewari,1994).

Seshakiran (2002) reported that neem leaves (*Azadrachta indica*) were highly antifungal to mycelium growth of *Sclerotium rolfsii.* Dayaram and Tewari (1994), studied on the collar rot of chickpea caused by *Sclerotium rolfsii* and reported that neem leaf (*Azadrachta indica*) reduced the pathogen. Neem leaf extract should comparatively highest performance than other leaf extract but was better than control.

The bio-agent *Trichoderma harzainum* found to be very promising in controlling *Sclerotium rolfsii* causing foot and root rot disease of eggplant. As an eco-friendly component *Trichoderma harzainum* is presently using worldwide in

controlling plant disease without harming the agro-ecological environment. It is reported that *Trichoderma harzainum* captured the root rhizosphere zone of the crop plants by its vigorous growth and thus the pathogenic micro-organisms cannot keep face in competition with *Trichoderma harzainum* for food and space. Thus, the pathogenic micro-organisms naturally suppressed by *Trichoderma harzainum.* It is also reported that *Trichoderma harzainum* did not cause diseases in crop plant rather it contributes in growth performance of the plant by inhibiting pathogenic micro-organisms (Islam, 2005).

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