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Integrated Management of Sclerotinia Sclerotiorum, An Emerging Fungal Pathogen Causing White Mold Disease

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Abstract

Sclerotinia sclerotiorum, the causal agent for white mold (*Sclerotinia* stem rot), is a devastating fungal pathogen. Currently, *Sclerotinia* is most commonly managed using the chemical fungicide which can lead to *Sclerotinia* resistance development, impacting biodiversity and interfering with key ecosystem services. In this regards, field experiments were conducted during 2017-18 planting seasons to evaluate the efficacy of different components viz. sawdust burning, stable bleaching powder, fungal and bacterial bio-control agents, chemical fungicide Rovral 50 WP and integration of different components for the management white mold disease of bush bean, mustard and garden pea in three different locations viz. in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Regional Agricultural Research Station (RARS), Burirhat, Rangpur and RARS, Ishurdi, Pabna, respectively. The results showed that different treatments displayed varying levels of effectiveness against the disease. All the treatments gave satisfactory reduction of white mold disease development and increased plant growth as well as yield of bush bean, mustard and garden pea. Among the treatments, integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + application fungicide Rovral 50 WP is the best treatment which reduced 97.49%, 77.72%, 72.26% white mold disease incidence and 84.61%, 81.14%, 71.01% white mold disease severity of mustard, bush bean and garden pea, respectively and increasing plant growth parameter as well as 52.16%, 27.74%, 36.97% yield of mustard, bush bean and garden pea, respectively. Application of only fungicide Rovral 50 WP also better treatment in reduction of white mold disease incidence and disease severity and increasing plant growth parameter as well as increasing yield of mustard, bush bean and garden pea. Soil amendment with fungal or bacterial bio-control

agents also gave satisfactory results in reduction of white mold disease incidence and disease severity and increasing plant growth parameter as well as increasing yield of mustard, bush bean and garden pea. It could be concluded from the obtained results that integration between bio-control agents as a soil treatment and foliar application chemical fungicide might be useful as a good tool for controlling white mold disease caused by *S. sclerotiorum* and obtained higher yield of bush bean, mustard and garden pea under field condition.

Introduction

The white mold, caused by the fungus *Sclerotinia sclerotiorum* (Lib.) de Bary, is a disease with worldwide distribution. The *S. sclerotiorum* is a soil-borne and cosmopolitan plant pathogenic fungus that infects more than 500 cultivated and wild plant species [1] and causes substantial damage to its host under favourable environments. Low temperatures, between 18-23 °C and high humidity conditions, favor the occurrence of the pathogen. However, the use of contaminated and/or infected seeds, continuous crops in monoculture, succession of crops with susceptible species or hosts, mild nocturnal temperatures (below 18ºC), prolonged rains during cultivation, excessive nitrogen fertilization and uncontrolled irrigation water supplied cause white mold to spread, assuming great economic and social importance [2] [3] [4]. Plant infection occurs either by myceliogenic germination of sclerotia or by ascospores released from apothecia during carpogenic germination of sclerotia. The myceliogenically germinating sclerotia are the main source of infection on processing tomato crops leading to rotting of aerial parts of the plant in contact with soil [5] [6]. The disease can cause disastrous crop failure as disease incidences have been recorded from 60-80% and variable yield losses ranged from traces to 100% in several economically important crops worldwide [7]. Due to the abundant production of sclerotia, which allow for the survival of the fungus in the soil for more than 10 years, white-mold is considered a disease of difficult control [8]. Currently, *Sclerotinia* is most commonly managed using the chemical fungicide [9] [10]. A sole reliance on chemical fungicides can lead to *Sclerotinia* resistance development, while also impacting biodiversity and interfering with key ecosystem services [11]. As a result, the interest to obtain alternative management options against the disease is to be sought. Recent research has spurred the development of alternatives for chemical fungicides. Soil disinfection through solarization has proven an effective strategy for control of pathogens, such as *Sclerotinia* [12] [13]. Although solarization combined with applications of chemical fungicide yields substantial reductions of *S. minor* incidence [9], efficacy of such practice depends on local climatic conditions. Biological control of *Sclerotinia* has also been investigated, with various antagonistic fungi affecting white mould sclerotia both under in vitro as in field conditions [14] [15] [16]. Although successful biological control of *Sclerotinia* is mainly restricted to greenhouse production systems. Cotes *et al*. [17] reported that *Trichoderma koningiops* (Th003) has shown potential for *Sclerotinia* control. For the particular case of *Sclerotinia*, a single pest management strategy has not yielded satisfactory control and integrated tactics (combining physical, cultural, chemical or biological control) are urgently needed [18]. In this regards Naema *et. al.* [19] reported that the integration between Billis and compost was the most effective treatment where it reduced effectively the white mold disease incidence and disease severity (88.24 and 92.37%) respectively of tomato. In Bangladesh, *S. sclerotiorum* becoming as resurged phytopathogen for various crop including vegetables, fruits and field crops especially in cooler part of the country. First *S. sclerotiorum* was recorded on mustard in 2008 then chili, brinjal and cabbage, country bean in 2011, marigold in 2011, jackfruit in 2012 and lentil in 2014 [20]. Moreover, high infection was observed on mustard, brinjal, cauliflower, garden pea and bush bean. The number of host range for the pathogen is increasing day by day [21] [22]. There is limited information available on chemical control of white mold disease in Bangladesh. Therefore, the development of disease management especially integrated disease management technologies is urgently needed in Bangladesh. In this regards, the

present studies have been design to develop an integrated management technologies against the *S. sclerotiorum* causing white mold disease.

Materials and Methods

For development an integrated management package of white mold disease, three field experiments were conducted in three different locations viz. in the field of Plant Pathology Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Regional Agricultural Research Station (RARS), Burirhat, Rangpur and RARS, Ishurdi, Pabna with three different crops viz. bush bean, mustard and garden pea, respectively during Rabi season of 2017-18. The experiments were laid out in a RCB design with three replications. Eight treatments viz. T_1= Saw dust burning of soil, T_2= Stable bleaching powder (20 kg/ha) in soil, T_3= *Trichoderma* based bio-fungicide in soil, T_4= *Bacillus* based bio-control agent (BCA) in soil, T_5= Fungicidal spray three times with Rovral 50 WP, T_6= T_1 + T_2 + T_3 + T_4, T_7= T_1 + T_2 + T_3 + T_4 + T_5 and T_8= Control were applied in these experiments. The unit plot size was 3 m x 2.5 m. *T. harzianum* isolates collected and isolated previously in Plant Pathology Division was multiplied in the mixture of Grasspea and wheat bran with mustard oilcake substrates. The formulated *Trichoderma* was used to mass multiplication in vermi-compost and it is designated *Trichoderma* based bio-fungicide. *Trichoderma* based bio-fungicide was added @ 3 tha^{-1} 5 days before seed sowing and mixed properly with soil and kept 5 days for *Trichoderma* establishment in soil. The bacteria *Bacillus* was formulated in the liquid culture with the concentration of 2.0 × 10^7 CFU/ml and spraying in soil before seed sowing. Stable bleaching powder was added @20 $kgha^{-1}$ 5 days before seed sowing and properly mixed with the soil. In case of saw dust burning, 6 cm thick layer of dry saw dust cover with plot soil and burned the soil properly. After burning the ash were mixed with the soil. Foliar application of fungicide Rovral 50 WP was started just after phenotypic symptom initiation of disease in the plant. The fungicide Rovral 50 WP was sprayed @ 2 g/l of water and 3 sprays were done at 10-12 days interval. The varieties BARI Sarisha-14, BARIMotorshuti-3 and BARIJharshim-1 were used. Fertilizers, weeding and irrigation were applied as per recommendation of the crop. The experiment was monitored regularly to observe the onset of *Sclerotinia* rot disease in the field.

Data Collection and Analysis

Data on different plant growth parameters viz. plant height and plant weight were taken 45-50 days after seed sowing. Data on disease incidence and disease severity data were started at the time of disease appeared and it was continuing until maturity of the crops. Yield data per unit area was also recorded. In case of garden pea, number of pods per plant, weight of pods per plant and pod yield was also recorded.

The disease incidence of white mold disease that caused by *S. sclerotiorum* was calculated by following formulae:-

Disease incidence= (Number of plant infected per plot/Total number of plant per plot) X100

The disease severity of white mold disease that caused by *S. sclerotiorum* was assessed using disease scale proposed by Grau *et al.* [23] consisted of three categories: 0 to 3, where; (0= no detectable symptoms, 1= appearance of a 1-2 cm water-soaked lesion on the crown region of the plant, 2= appearance of a 2 cm water-soaked lesion covering the stem base of the plant, 3= plant completely dead)

$$\text{Disease Severity \%} = \sum (a \times b) / N \times K \times 100$$

Where: a = Number of infected leaves in each category.

b = Numerical value of each category.

N = Total number of examined leaves.

K = The highest degree of infection category.

The percent data were converted into arcsine transformation values before statistical analysis. Data were analyzed statistically by using the MSTATC program. The treatment effects were compared by applying the least significant different (LSD) test at P=0.05 level.

Results and Discussion

Integrated Management of White Mold Disease of Mustard

Effects of different treatments against white mold disease caused by soil-borne pathogen *S. sclerotiorum* of mustard are presented in table 1, 2 and Figure 1. Significant difference was observed among the treatments. The highest disease incidence 62.56% and disease severity 69.33% was recorded from control and the lowest disease incidence 1.57% and disease severity 10.67% was recorded from integration of sawdust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + Bacillus based bio-control agent + Rovral 50 WP (T7) treatment which was followed by the application Rovral 50 WP (T5) where the white mold disease incidence 5.91% and disease severity 18.67% (Table 1). Other treatment also gave significantly lower white mold disease incidence range from 25.47% to 38.87% and disease severity from 37.33% to 44.00% compared to control but significantly differ from T5 and T7 treatments. Integration of different treatments viz. saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agent + foliar application of fungicide Rovral 50 WP (T7) gave the highest reduction of white mold disease incidence and severity by 97.49% and 84.61%, respectively followed by the foliar application of fungicide Rovral 50 WP where the reduction of disease incidence and severity was 90.55% and 73.07%, respectively. Saw dust burning and soil amendments with *Trichoderma* based bio-fungicide and bacillus based bio-control agent also gave significant reduction of white mold disease incidence range from 37.88 to 56.63% and disease severity range from 36.54 to 46.16% but less effective than T5 and T7 treatments. Integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + application fungicide Rovral 50 WP gave the highest plant height and plant weight followed by Rovral 50 WP, *Trichoderma* based bio-fungicide, bacillus based bio-control agent and saw dust burning treatments. The lowest plant height and plant weight was recorded from control (Table 2).

Regarding the yield of mustard, the highest yield of mustard at 1566 kgha^{-1} was obtained from integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agent + application fungicide Rovral 50 WP treatment which was followed by Rovral 50 WP, *Trichoderma* based bio-fungicide, integration saw dust burning + stable bleaching powder + + Bacillus based bio-control agent, only Bacillus based bio-control agent and saw dust burning treatments where the yield was 1306, 1178, 1156, 1086 and 1073 kgha^{-1}, respectively (Table 2). The lower yield of mustard 749.2 and 825.4 kgha^{-1} were recorded from the stable bleaching powder and control treatments, respectively. Yield was higher 52.16% compared to control due to integration saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP where as it was 42.63% due to application of Rovral 50 WP. Soil amendment with *Trichoderma* based bio-fungicide gave 36.40% higher yield compared to control where it was 35.19%, 31.01% and 30.18 % by the integration saw dust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + Bacillus based bio-control agent, Bacillus based bio-control agent and saw dust burning, respectively compared to control. Soil treatment with stable bleaching power was the least effective treatment in reduction of white mold disease incidence, disease severity and increasing plant growth as well as yield of mustard.

Integrated Management of White Mold Disease of Bush Bean

Effect of different treatments on the incidence and severity of white mold disease and plant growth as well as yield of bush are presented in table 2, 3 and figure 2. Results showed that all the treatments significantly reduced white mold disease incidence, disease severity and increasing plant growth as well as yield of bush bean (Table 3 and 4 and Figure 2). The highest disease incidence 11.13% and disease severity 70.67% was recorded in control and the lowest disease incidence 2.48% and disease severity 33.33% was observed in the treatment when integration of different treatments viz.

Table 1. Effect of different treatments and its integration against white mold disease incidence and disease severity of mustard

Treatments	Disease incidence (%)	Reduction of disease incidence than control (%)	Disease severity (PDI)	Reduction of disease severity than control (%)
T_1= Sawdust burning	25.47 e (30.31)	59.29	38.67 c (38.44)	44.22
T_2= Stable bleaching powder	38.87 b (38.55)	37.88	44.00 b (41.54)	36.54
T_3= *Trichoderma* based bio-fungicide	30.95 cd (33.79)	50.53	37.33 c (37.66)	46.16
T_4= Bacillus based bio-control agent	34.10 bc (35.73)	45.49	40.67 bc (39.62)	41.34
T_5= Rovral 50 WP	5.91 f (13.92)	90.55	18.67 d (25.47)	73.07
T_6= T_1 +T_2 +T_3 +T_4	27.13 de (31.37)	56.63	38.67 c (38.44)	44.22
T_7= T_1 +T_2 +T_3 +T_4+ T_5	1.57 g (7.12)	97.49	10.67 e (19.04)	84.61
T_8= Control	62.56 a (52.28)	-	69.33 a (56.38)	-
LSD	3.125	-	2.393	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

Figure 1. Experimental field view of integrated management of white mold disease of mustard at RARS, Burirhat, Rangpur and white mold disease symptom in control plot and disease free plot in the field

Table 2. Effect of different treatments and its integration on the plant growth and yield of mustard

Treatments	Plant Height (cm)	Plant weight ($gplant^{-1}$)	Yield ($kgha^{-1}$)	Yield higher than control (%)
T_1= Sawdust burning	74.00 de	7.20 d	1073.0 c	30.18
T_2= Stable bleaching powder	72.00 e	7.00 d	825.4 d	9.23
T_3= *Trichoderma* based bio-fungicide	78.93 bc	7.73 c	1178.0 c	36.40
T_4= Bacillus based bio-control agent	75.00 cde	7.27 cd	1086.0 c	31.01
T_5= Rovral 50 WP	82.07 ab	8.27 b	1306.0 b	42.63
T_6= T_1 +T_2 +T_3 +T_4	77.27 cd	7.40 cd	1156.0 c	35.19
T_7= T_1 +T_2 +T_3 +T_4+ T_5	86.20 a	10.73 a	1566.0 a	52.16
T_8= Control	64.27 f	5.60 c	749.2 d	-
LSD	4.142	0.479	120.6	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD.

Table 3. Effect of different treatments and its integration against white mold disease of bush bean

Treatments	Disease incidence (%)	Reduction of disease incidence than control (%)	Disease severity (PDI)	Reduction of disease severity than control (%)
T_1= Sawdust burning	3.91 c (11.38)	64.87	33.33 c (35.26)	52.84
T_2= Stable bleaching powder	4.08 bc (12.01)	63.34	41.33 b (40.00)	41.52
T_3= *Trichoderma* based biofungicide	3.12 c (11.37)	71.97	32.00 c (34.45)	54.72
T_4= Bacillus based biocontrol agent	4.95 b (12.15)	55.53	36.00 bc (36.85)	49.06
T_5= Rovral 50 Wp	3.05 d (10.05)	72.59	18.67 d (25.50)	73.58
T_6= T_1 +T_2 +T_3 +T_4	2.70 de (9.45)	75.74	33.33 c (35.25)	52.84
T_7= T_1 +T_2 +T_3 +T_4+ T_5	2.48 e (9.05)	77.72	13.33 e (21.27)	81.14
T_8= Control	11.13 a (19.46)	-	70.67 a (57.28)	-
LSD	0.7409	-	4.082	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD; values within the parenthesis is the Arcsin Transformed value.

Figure 2. Experimental field view of integrated management of white mold disease of bush bean in Plant Pathology Division, BARI, Gazipur and white mold disease symptom in control plot and disease free plot in the field

Table 4. Effect of different treatments and its integration on the growth and yield of bush bean

Treatments	Plant Height (cm)	Plant weight ($gplant^{-1}$)	Yield (t/ha)	Yield higher than control (%)
T_1= Sawdust burning	15.13 d	9.83 c	14.83 cd	15.85
T_2= Stable bleaching powder	16.07cd	9.43 c	14.22 e	12.24
T_3= *Trichoderma* based bio-fungicide	17.93 bc	9.67 c	15.65 b	20.25
T_4= Bacillus based bio-control agent	17.23 bcd	9.83 c	14.48 de	13.81
T_5= Rovral 50 WP	19.23 ab	12.17 b	15.68 b	20.41
T_6= T_1 +T_2 +T_3 +T_4	18.03 bc	12.17 b	15.17 c	17.73
T_7= T_1 +T_2 +T_3 +T_4+ T_5	20.93 a	13.67 a	17.27 a	27.74
T_8= Control	12.10 e	7.00 d	12.48 f	-
LSD	2.274	1.212	0.387	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD

saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP was used which was followed by the fungicidal treatment Rovral 50 WP, integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents, soil amendment with *Trichoderma* based bio-fungicide and saw dust burning.

Integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP gave the highest reduction of disease incidence 77.72% and disease severity 81.14% compared to control. Application of fungicide Rovral 50 WP reduced 75.74% disease incidence and 73.58% disease severity followed by integration saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents, soil amendments with *Trichoderma* based bio-fungicide and saw dust burning treatments where the reduction of disease incidence 72.59%, 71.97% and 64.87% and disease severity 52.84%, 54.72% and 52.84%, respectively compared to control.

Integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP gave the highest plant height and plant weight followed by the application fungicide Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide and integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agent treatments. Soil and foliar application of different treatments gave appreciable higher yield of bush bean compared to control. The lowest yield of groundnut was recorded under control by 12.48 tha^{-1} (Table 4). The yield was increased to 14.22-17.27 tha^{-1}due to application of different treatments. Integration of saw dust burning + stable bleaching powder + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + foliar application fungicide Rovral 50 WP gave the highest yield 17.27 tha^{-1} followed by foliar application Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide, integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents and saw dust burning treatments where the yield was 15.68, 15.65, 15.17 and 14.83 tha^{-1}, respectively. Soil treatment with Bacillus based bio-control agent gave lower yield 14.48 tha^{-1} followed by the application of stable bleaching powder where the yield was 14.22 tha^{-1} compared to other treatments. The maximum yield increased 27.74% compared to control was obtained by integration of saw dust burning + stable bleaching powder + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + foliar application fungicide Rovral 50 WP followed by foliar application Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide, integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents and saw dust burning treatments where the yield was 20.41%, 20.25%, 17.73% and 15.85%, respectively higher than control (Table 4). The least effective treatment was stable bleaching powder followed by soil treatment with Bacillus based bio-control agent where the yield was 13.81% and 12.24%, respectively higher than control..

Integrated Management of White Mold Disease of Garden Pea

Effect of different treatments on the incidence and severity of white mold disease and plant growth as well as yield of bush are presented in table 4 and 5. Results showed that all the treatments significantly reduced the white mold disease incidence and disease severity as compared to control (Table 4). The incidence (%) and severity (%) of white mold disease of garden pea varied significantly among the treatments. The highest white mold disease incidence 11.43% and disease severity 9.90% was recorded from control treatment. The incidence and severity of white mold disease reduced significantly range from 3.17%-11.43% and 2.87%-6.60%, respectively due to application of different treatments (Table 4). The highest reduction of disease incidence 72.26% and disease severity 71.01% compared to control

was obtained by integration of saw dust burning + stable bleaching powder + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents + foliar application fungicide Rovral 50 WP followed by foliar application Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide, integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents and saw dust burning treatments where the reduction of disease incidence 71.13%, 63.43%, 50.04% and 49.52% and disease severity 70.00%, 67.68%, 58.79% and 55.85%, respectively. (Table 5). All the treatments showed significant effect on yield and yield contributing characters of garden pea except plant height and number of pods per plant (Table 6). The highest weight of pods per plant (16.28) was recorded in T_7 (integration of saw dust burning + stable bleaching powder + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio -control agents + foliar application fungicide Rovral 50 WP) which was followed by integration of saw dust burning + soil amendments with *Trichoderma* based bio-fungicide + bacillus based bio-control agents, foliar application Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide, *Bacillus* based bio-control agent and saw dust burning treatments. Integration of saw dust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP, foliar application Rovral 50 WP and soil amendments with *Trichoderma* based bio-fungicide gave higher yield of garden pea followed by saw dust burning, *Bacillus* based bio-control agent and integration of saw dust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + bacillus based bio-control agent treatments. (Figure 3)

Yield was 36.97% higher compared to control in the integration of saw dust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + bacillus based bio-control agents + Rovral 50 WP treatment followed by foliar application Rovral 50 WP, soil amendments with *Trichoderma* based bio-fungicide, *Bacillus* based bio-control agent, saw dust burning and integration of saw dust burning + stable bleaching powder + *Trichoderma* based bio-fungicide + bacillus based bio-control agent treatments where the yield was 35.01%, 32.91%, 27.42%, 25.62% and 25.39%, respectively higher than control. The least effective treatment was stable bleaching powder where the yield was 16.26% higher than control (Table 6).

From these study it is observed that integration of bio-control agents as soil application with foliar application of chemical fungicide Rovral 50 WP (Iprodione) is the best treatment for management of white mold disease caused by *S. sclerotiorum* and increasing plant growth as well as yield of different crops viz. mustard, bush bean and garden pea. Soil treatment with only *Trichoderma* based bio-fungicide or *Bacillus* based bio-control agent or foliar application of only chemical fungicide Rovral 50 WP (Iprodione) also better for significant reduction in incidence and severity of white mold disease caused by *S. sclerotiorum* and increasing plant growth as well as yield of different crops viz. mustard, bush bean and garden pea. Different workers reported the antagonistic activity of the mycoparasitic fungi viz. *Coniothyrium minitans*, *Trichoderma* spp., *Gliocladium* spp. *Sporidesmium sclerotivorum*, *Fusarium*, *Hormodendrum*, *Mucor*, *Penicillium*, *Aspergillus*, *Stachybotrys*, and bacterial bio-control agents viz. *Bacillus* species, *Pseudomonas* spp. *P. chlororaphis* against *S. sclerotiorum* [24] [25] [26] [27]. Simon and John [28] reported that disease caused by *S. sclerotiorum* was significantly reduced by a combination of bio-control agents and a single application of Iprodione fungicide. They also reported that only bio-control agent or Iprodione fungicide also effective against the disease caused by *S. sclerotiorum* but differ than integrated approaches. Shivpuri *et al.* [29] observed that fungicides, carbendazim, thiophenate methyl and phenylpyrrole had completely inhibited the growth of *S. sclerotiorum* at all tested concentrations *in vitro*. Eisa *et al.* [30] recorded that under field conditions combining the fungicide Folicur with compost has enhanced the control of white rot of onion and bulb yield compared with using alone.

Table 5. Effect of different treatments against incidence and severity of white mold disease of garden pea

Treatments	Disease incidence (%)	Reduction of disease incidence than control (%)	Disease severity (PDI)	Reduction of disease severity than control (%)
T_1= Sawdust burning	5.77 c (2.40)	49.52	4.37 c (2.08)	55.85
T_2= Stable bleaching powder	8.36 b (2.89)	26.86	6.60 b (2.57)	33.33
T_3= *Trichoderma* based bio-fungicide	5.71 c (2.39)	50.04	4.08 cd (2.02)	58.79
T_4= Bacillus based bio-control agent	7.66 b (2.76)	32.98	6.55 b (2.55)	33.83
T_5= Rovral 50 WP	3.30 d (1.81)	71.13	2.97 de (1.72)	70.00
T_6= T_1 +T_2 +T_3 +T_4	4.18 d (2.04)	63.43	3.20 cde (1.78)	67.68
T_7= T_1 +T_2 +T_3 +T_4+ T_5	3.17 d (1.78)	72.26	2.87 e (1.69)	71.01
T_8= Control	11.43 a (3.38)	-	9.90 a (3.14)	-
LSD (p≥0.05)	0.2538		0.2930	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD. Values in the parentheses indicated as square root transform value

Figure 3. Experimental field view of integrated management of white mold disease garden pea at RARS, Ishurdi, Pabna and white mold disease symptom in the field

Table 6. Effect of different treatments on plant height, yield and yield contributing characters of garden pea

Treatments	Plant height (cm)	No. of pods/ plant	Weight of pods/ Plant (g)	Pod yield (t/ha)	Yield higher than control (%)
T_1= Saw dust burning of soil	59.20	3.46	12.27 bc	6.60 ab	27.42
T_2= Stable bleaching powder (20 kg/ha) in soil	58.93	3.80	11.49 bc	5.72 bc	16.26
T_3=*Trichoderma* based bio-fungicide in soil	62.80	3.35	13.27 abc	7.14 a	32.91
T_4= *Bacillus* based biocontrol agent (BCA) in soil	58.93	3.30	12.47 bc	6.44 ab	25.62
T_5= Fungicidal spray three times with Rovral 50 WP	59.80	3.44	13.20 abc	7.37 a	35.01
T_6= T_1 + T_2 + T_3 + T_4	57.40	4.42	14.51 ab	6.42 ab	25.39
T_7= T_1 + T_2 + T_3 + T4 + T_5	58.27	4.53	16.28 a	7.60 a	36.97
T_8= Control	57.07	2.96	10.12 c	4.79 c	-
LSD	NS	NS	2.882	1.236	-

Values in a column having same letter did not differ significantly (P=0.05) by LSD. NS = Not Significant

Abdel-Kader *et al*. [31] found that combination of compost + *T. harzianum* + thyme and compost + *T. harzianum* + lemon grass reduced the peanut crown rot disease incidence at both pre- and post-emergence growth stages, respectively compared with untreated control. Therefore, it could be concluded from the obtained results that integration between bio-control agents as a soil treatment and foliar application chemical fungicide might be useful as a good tool for controlling white mold disease caused by *S. sclerotiorum* and obtained higher yield of bush bean, mustard and garden pea under field condition. Foliar application of only fungicide Rovral 50 WP also better treatment in reduction of white mold disease incidence and disease severity and increasing plant growth parameter as well as increasing yield of mustard, bush bean and garden pea. Based on findings of the present investigation these two treatments may be recommended for controlling white mold disease caused by *S. sclerotiorum* of bush bean, mustard and garden pea under field condition in Bangladesh.

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