

Research Article

Optimising Bio-Fortified Compost for Effective Suppression of Soil-Borne Diseases and Boosting Tomato Yield

Mahmudul Sultan¹, Md. Khurshed Alam Bhuiyan¹, Md. Giashuddin Miah², Md. Abu Ashraf Khan¹, Shaikh Sharmin Siddique¹, Md. Tanbir Rubayet^{1*}

¹Department of Plant Pathology, Gazipur Agricultural University, Gazipur, Bangladesh.

²Department of Agroforestry and Environment, Gazipur Agricultural University, Gazipur, Bangladesh.

Article history:

Received 07 June 2025

Revised 28 November 2025

Accepted 15 December 2025

Published 27 April 2026

Keywords:

Plant growth promotion

Soil-borne disease suppression

Trichoderma-fortified compost

*Corresponding author:

E-mail:

tanbir86plp@gmail.com

Abstract

Soil-borne fungal pathogens are a major constraint in tomato cultivation, often causing severe yield losses. This study aimed to optimise the dosage of Trichoderma-fortified compost (*TFC*) as an eco-friendly strategy for disease management and growth promotion. The antagonistic potential of *Trichoderma harzianum* isolate PABT-22 (*TP-22*) was validated *in vitro*, showing >90% inhibition against *Fusarium oxysporum* f. sp. *lycopersici* (*Fo*), *Sclerotium rolfsii* (*Sr*), and *Rhizoctonia solani* (*Rs*). The most effective isolate was incorporated into poultry manure compost and tested in field experiments with eight treatments, including five *TFC* dosages (100–500 g per 6 m² plot). All *TFC* treatments significantly improved plant growth compared with controls, with the greatest benefits recorded in T₈ (500 g per plot ~833 kg ha⁻¹). In T₈ plots, disease incidence was reduced to 12.5% for Fusarium wilt and southern blight and 14.0% for Rhizoctonia root rot, compared with high incidence in pathogen-only controls. Yield increased by 27.3% (*Fo*), 29.6% (*Sr*), and 29.1% (*Rs*) under T₈. These results confirm that a standardised dose of 500 g *TFC* per plot provides effective pathogen suppression and substantial yield, supporting its adoption as a low-cost, sustainable solution for tomato production.

How to cite:

Sultan, M., Bhuiyan, M. K. A., Miah, M. G., Khan, M. A. A., Siddique, S. S., & Rubayet, M. T. (2026). Optimising Bio-Fortified Compost for Effective Suppression of Soil-Borne Diseases and Boosting Tomato Yield. *Journal of Agriculture and Applied Biology*, 7(1): 32 - 45. doi: 10.11594/jaab.07.01.03

1. Introduction

Tomato (*Solanum lycopersicum* L.), a widely cultivated vegetable crop, belongs to the Solanaceae family. Its global popularity continues to rise due to its diverse uses, including fresh consumption, processing into sauces, juices, and as a flavor enhancer in various food products. Despite a gradual increase in cultivated area and production in Bangladesh, tomato productivity remains low at 6.46 t/ha, significantly below the global average of 26.29 t/ha (FAOSTAT, 2021). Several factors contribute to this low productivity, with soil-borne diseases being among the most critical constraints. Tomato plants are highly susceptible to soil-borne pathogens such as *Sr*, *Rs*, *Fo*, and *Pythium* spp., which affect seedlings and mature plants in the field. The initial symptom is often a yellowing of the plant, followed by vascular blockage that disrupts nutrient and water transport. Infected seedlings develop black discoloration or rot at the collar region of the stem, which extends to the roots. In advanced stages, affected plants exhibit wilting, drying, and ultimately death. The pathogen identification is based on characteristic symptoms; *Fo* produces cotton-like mycelia at the infection site, *Sr* develops white mycelia with mustard seed-like sclerotia, while *Rs* presents dark brown to blackish sclerotia. The transmission of these pathogens varies; *Sr* and *Rs* spread through mycelia and sclerotia, while *Fo* disperses via mycelia, conidia, and chlamydospores.

To manage these diseases, chemical fungicides are widely used despite their adverse environmental and health effects. Excessive pesticide use leads to contamination of agricultural produce, ecological imbalances, and biodiversity threats. Alternatively, *Trichoderma* spp. has emerged as a promising biocontrol agent against plant pathogens. *Trichoderma* species employ multiple antagonistic mechanisms, including mycoparasitism, antibiosis, resource competition, and induction of plant defense responses. Several studies (Nitu et al., 2016; Rubayet and Bhuiyan, 2016; Rubayet et al., 2020; Bhuiyan and Rubayet, 2023) have demonstrated that *TFC* effectively reduces tomato diseases while enhancing yield. One major limitation of *T. harzianum* application is the lack of a standardised method for its multiplication and field application. Developing an efficient mass production technique would enable farmers to adopt *Trichoderma*-based biocontrol methods effectively. This research aimed to standardise the optimal dose of *TFC* for managing soil-borne diseases, promoting plant growth, and improving tomato yield while evaluating *Trichoderma* population dynamics in field conditions. These mechanisms such as competition, antibiosis, and induced systemic resistance are likely to explain the reduced incidence observed.

2. Materials and Methods

2.1 Isolation of *Trichoderma* spp. and pathogens

Trichoderma isolates were collected from vegetable fields at Gazipur Agricultural University and the Bangladesh Agricultural Research Institute. The isolates were obtained using the standard soil dilution plate and the root washing method. A total of 100 *T. harzianum* isolates were identified using standard morphological keys (Barnett and Hunter, 1972). Pathogenic isolates of *Sr* 2, *Rs* 13, and *Fo* 7 were sourced from the Plant Pathology laboratory stock culture at Gazipur Agricultural University. The specific isolate used was *T. harzianum* PABT-22, collected from tomato rhizosphere soil.

2.2 In vitro screening of *Trichoderma* isolates

The antagonistic activity of *Trichoderma* isolates against the test pathogens was evaluated on PDA medium using standard dual culture techniques (Bell et al., 1982; Sundar et al., 1995). Based on these screenings, *TP 22* was selected for further study.

2.3 Preparation of TFC

Compost was prepared using poultry refuse (40 kg per pit) in six designated pits (1.0m × 1.0m × 1.5m). The decomposed poultry refuse was inoculated with wheat grain-colonised *Trichoderma* inoculum at five different concentrations (4, 6, 8, 10, and 12%). A control pit was maintained without *Trichoderma* inoculum. The compost was covered with polythene sheets for 45 days to ensure proper decomposition and *Trichoderma* proliferation.

2.4 Field experiment and treatment application

A randomized complete block design (RCBD) with three replications was implemented, using 2m × 3m plots. Healthy tomato seedlings from the Horticulture Research Centre (BARI) were transplanted with a spacing of 70 cm between plants and 90 cm between rows. Test pathogens were introduced into designated plots, followed by the application of TFC at varying doses. The trial included three replications per treatment with 10 plants per plot.

2.5 Observations

Disease incidence was recorded at different growth stages (30, 55, 85, 105, and 120 days after transplanting) based on characteristic symptoms (Shamshiri et al., 2018). Growth parameters, including plant height, number of leaves, fresh/dry shoot weight, and root weight, were recorded. Yield was assessed at harvest, and percentage increases were calculated relative to the control.

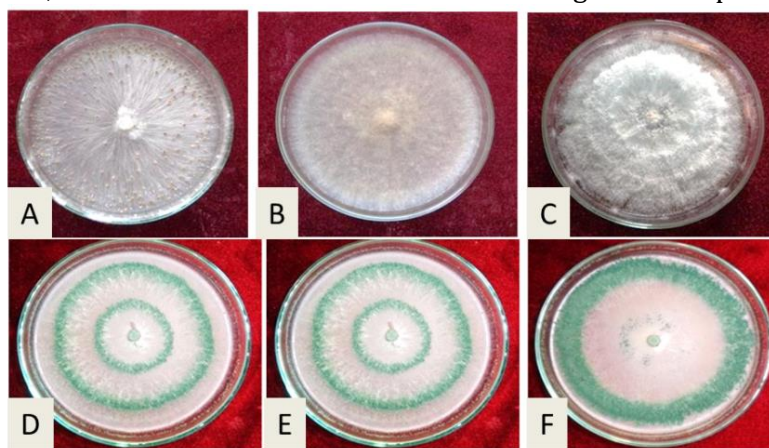
2.6 Data analysis

Data were analysed using ANOVA (STATISTIX 10) and means separated by Duncan's Multiple Range Test (DMRT) at $\alpha=0.05$.

3. Results

3.1 Screening of *Trichoderma* spp. against the selected test pathogens

Several isolates of *T. harzianum* demonstrated antagonistic effects against the tested soil-borne pathogens in vitro (Figure 1 and Tables 1-3). All tested isolates exhibited antagonism above 55%, corresponding to Bell's Scale 3 or higher against the three pathogens. Three isolates such as, BU 7, PABT 22, and PABT 24 were identified as highly antagonistic, ranking as Bell's Scale 1 against all tested pathogens (Table 1). Against *Fo*, 35 isolates were categorised in Bell's Scale 2, while 60 isolates were classified under Bell's Scale 3 (Table 1). Similarly, against *Rs*, 60 isolates were placed in Bell's Scale 2, and 37 in Bell's Scale 3. For *Sr*, 8 isolates were grouped into Bell's Scale 2, and 85 into Bell's Scale 3. Only four isolates, ComT-14, GAZT-53, GBRT-4, and GBRT-31 were classified under Bell's Scale 4 for *Sr*, while no isolates fell into Bell's Scale 4 for *Fo* and *Rs*. The antagonistic activity of the stock culture isolates was consistent with observations reported by Salam (2017). Based on these results, the PABT 22 isolate was selected for using in field experiments.



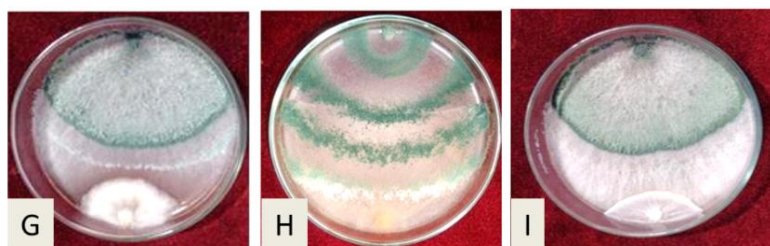


Figure 1. Dual culture of the virulent pathogenic isolates with highly antagonist *T. harzianum* isolates. Virulent pathogen isolates were A) *Sr*; B) *Rs*; and C) *Fo*. Three highly antagonist *T. harzianum* isolates, such as D) PABT 22; E) PABT 24; F) BU 7. Antagonism of selected pathogen and TP 22, such as G) *Sr* vs TP 22; H) *Rs* vs TP 22; and I) *Fo* vs TP 22.

Table 1. Antagonism of *Trichoderma* isolates *Fo*, *Sr*, and *Rs* following dual Plate culture technique on PDA

Name of the pathogen	Antagonism Bell's Scale	No.	<i>Trichoderma</i> isolates
<i>F. oxysporum</i> f. sp. <i>lycopersici</i>	1	3	BU 7, PABT-22, PABT-24
	2	35	BU 1, BU 2, BU 6, BU 8, BU 9, BI 1, BI 2, BI 3, BBUT- 70, GAZT-55, PABT-16, BBUT-77, COMT-6, BBUT-78, GAZT-54, BBUT-89, PABT-18, GAZT-41, BBUT-69, BBUT-73, BBUT-72, GAZT-51, Ran 9, BBUT-91, GAZT-56, BBUT-83, PABT-31, BBUT-84, BBUT-76, NOAT-63, GAZT-42, BBUT-74, COMT-8, PABT-29, PABT-34
	3	62	BI 4, BI 5, BI 6, BI 7, BI 8, BI 9, BI 10, BU 3, BU 4, BU 5, BU 10, COMT-5, GAZT-58, PABT-19, GAZT-53, GAZT-49, COMT-3, BBUT-75, Syl 06, Jes 2, Far 6, AZT- 45, GAZT-59, GAZT-38, PABT-27, PABT-28, GAZT-50, COMT-14, Far 4, BBUT-81, Raj 9, NOAT-61, GAZT- 40, COMT-12, PABT-32, COMT-9, GBRT-31, Din 4, BBUT-68, PABT-23 , COMT-13, GAZT-48, COMT-1, COMT-11, PABT-33, Ran 8, GAZT-60, PABT-25, Syl 07, BBUT-79, COMT-2, BBUT-71, PABT-26, GAZT-46, BBUT-80, COMT-10, BBUT-86, BBUT-88, BBUT-66, JES 10, GAZT-43, BBUT-85,
	4		
	5		
<i>Rhizoctonia solani</i>	1	3	BU 7, PABT-22, PABT-24
	2	60	BI 1, BI 2, BI 3, BI 4, BI 5, BI 6, BI 10, BU 1, BU 2, BU 6, BU 8, BU 9, BBUT-83, PABT-23, Raj 9, BBUT-80, BBUT-87, PABT-16, PABT-19, PABT-27, GAZT-60, GAZT-51, COMT-12, PABT-18, PABT-25, PABT-26, GAZT-58, BBUT-82, BBUT-85, , COMT 70, COMT-14, SYL 07, GAZT-41, NOAT-63, COMT-13, GAZT-59, Far 4, Ran 9, PABT-33, GAZT-38, GAZT-55, PABT-32, PABT-34, GAZT-42, BBUT-88, PABT-31, GAZT-56, Ran 8, GAZT-39, GAZT-50, COMT-6, GAZT-45, NOAT-61 COMT-8, BBUT-76, Din 4, COMT-9, JES 10, GAZT-43, BBUT-74
	3	37	BI 7, BI 8, BI 9, BU 3, BU 4, BU 5, BU 10, SATT-65, BBUT-72, BBUT-78, BBUT-68, BBUT-81, GAZT-40, GAZT-47, GAZT-49, BBUT-71, BBUT-84, GAZT-46, PABT-28, BBUT-73, Far 6, GAZT-53, Syl 06, BBUT-75, BBUT-77, OMT-3, BBUT-66, BBUT-69, GAZT-54, GBRT-31, COMT-10, COMT-2, Jes 2, GAZT-48, COMT-11, BBUT-91, BBUT-70,

Name of the pathogen	Antagonism Bell's Scale	No.	Trichoderma isolates
<i>Sclerotium rolfsii</i>	4		
	5		
	1	3	BU 7, PABT-22, PABT-24
	2	8	BI 1, BI2, BU2, BBUT-77, COMT-13, PABT-16, PABT-24, COMT-70
	3	85	BI 3, BI 4, BI 5, BI 6, BI 7, BI 8, BI 9, BI 10, BU 1, BU 3, BU 4, BU 5, BU 6, BU 8, BU 9, BU 10, BBUT-86, COMT-12, GAZT-60, Raj 9, Ran 8. PABT-26, BBUT-75, PABT-28, COMT-6, PABT-27, PABT-33, BBUT-89, PABT-32, BBUT-83, BBUT-85, Far 4, BBUT-88, Far 6, Ran 9, PABT-18, COMT-8, PABT-23, PABT-25, GAZT-41, GAZT-56, COMT-3, COMT-9, PABT-19, Jes 10, , GAZT-50, GAZT-55, BBUT-72, BBUT-84, BBUT-74, BBUT-81, BBUT-91, GAZT-59, GAZT-40, GAZT-42, GAZT- 59, BBUT-69, BBUT-78, GAZT-58, BBUT-80, COMT-2, GAZT-45, GAZT-43, NOAT-61, BBUT-68, BBUT-79, Din 4, GAZT-49, BBUT-73, GAZT-38, SATT-65, BBUT-66, , BBUT- 71, Jes 2, GAZT-46, GAZT-48, GAZT-51, COMT-1, COMT-5, Syl 07, GAZT-54, COMT-10, Syl 06, COMT-11, GAZT-57
	4	4	COMT-14, GAZT-53, GBRT-4, GBRT-31
	5		

3.2 Seedling mortality of tomato by different pathogens

Significant variation was recorded in the % seedling mortality at different doses of TP 22 fortified compost. The highest seedling mortality (35.8, 35.5 and 16.7% for *Fo*, *Rs*, and *Sr*, respectively) was observed in Control 2 (artificial pathogen inoculated plot). Whereas the lowest seedling mortality (8.4, 8.3 and 6.5% for *Fo*, *Rs*, and *Sr*, respectively) was recorded in treatment T₈ (Figure 2). Interestingly, similar seedling mortality was recorded for T₇ applied plots where *Rs*, and *Sr*, respectively were artificially inoculated. However, this dose was not effective in the *Fo* applied plot. Minimum mortality was also observed in treatment T₇ where 400 g wheat grain colonized *TFC* was applied. In the treatment T₃ and T₄ where only poultry refuse and only 200 g wheat grain colonized *Trichoderma* were applied seedling mortality was also abruptly low in comparison to control 2. The highest dose of *TFC* in the treatment T₈ was significantly superior in controlling seedling mortality caused by all the pathogens. Similar observations were also recorded by Rahman et al. (2024).

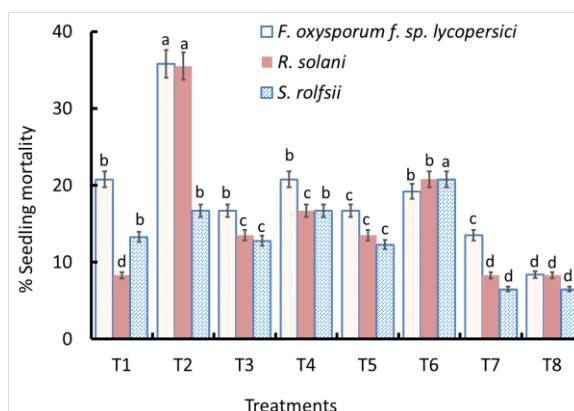


Figure 2. Percent seedling mortality at different of TFC applied field after artificial inoculation of three specific soil-borne pathogen

3.3 Disease incidence

Different *TFC* significantly reduced the selected three disease incidences (Collar rot and southern blight, *Rhizoctonia* dry root rot, *Fusarium* wilt) compared to Control 2 (Figure 3A). Therefore, the % reduction of those selected diseases over Control 2 also significantly varied accordingly (Figure 3B). The lowest collar rot and southern blight incidence (12.5%) was recorded from T₈ and T₇ applied plots. The highest disease incidence (58.3%) was recorded in an artificially inoculated plot (T₂). Whereas the disease incidence of the naturally infected plots (T₁ and T₃) was significantly lower (37.5 and 29.2%, respectively) than the T₂ plot. The T₆ also reduced the disease incidence (16.7%) compared to all three controls (29.2 to 58.3%) but was statistically higher than T₇ and T₈. The collar rot and southern blight incidence in T₅ (29.2%) was statistically like the naturally infected control. Whereas the T₄ (54.2%) did not reduce the specific disease symptoms compared to the other fortified composts (Figure 3C).

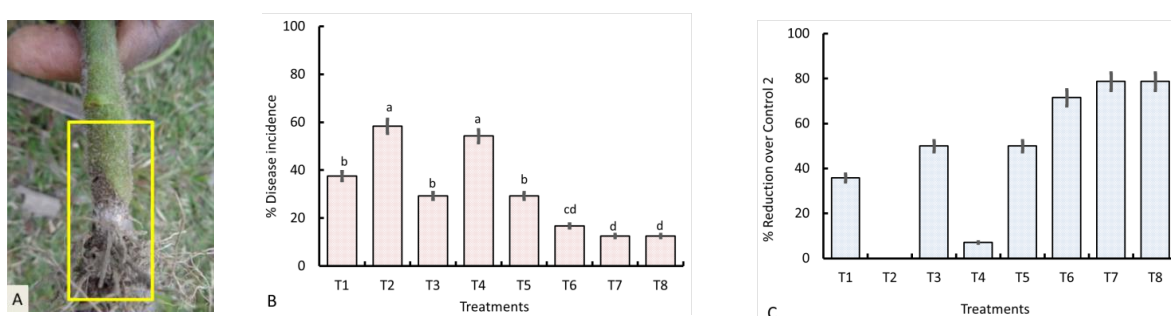


Figure 3. Effect of different *TFC* on collar rot and southern blight incidence in an artificially *Sr* inoculated plot. A) Collar rot and southern blight symptom in the experimental field, B) Collar rot and southern blight incidence of different plot and, C) %reduction of collar rot and southern blight symptom over artificially *Sr* inoculated control plot T₂. Note, T₂= artificially *Sr* inoculated plot, T₁=Naturally infected plot, and T₃= Naturally infected and *TFC* applied plot

Similarly, three doses of *TFC* reduced *Rhizoctonia* dry root rot incidences compared to the controls (Figure 4A). The lowest disease incidence (16.7%) was recorded from T₈ plot. The disease incidence recorded from T₆ and T₇ (20.8 and 25.0%, respectively) was also lower compared to the controls, and it is statistically similar with the former plot. All the three control plots provided higher disease incidence (37.5 to 50.8%), of which the highest incidence was recorded from the artificially inoculated plot (50.8%) (Figure 4B). Likewise, the highest % of *Rhizoctonia* dry root rot control of T₂ was also recorded from the T₈ plot. Data was recorded for all the test pathogens in the treatment T₈ where 500 g wheat grain colonised *TFC* was applied in the pathogen-inoculated field.

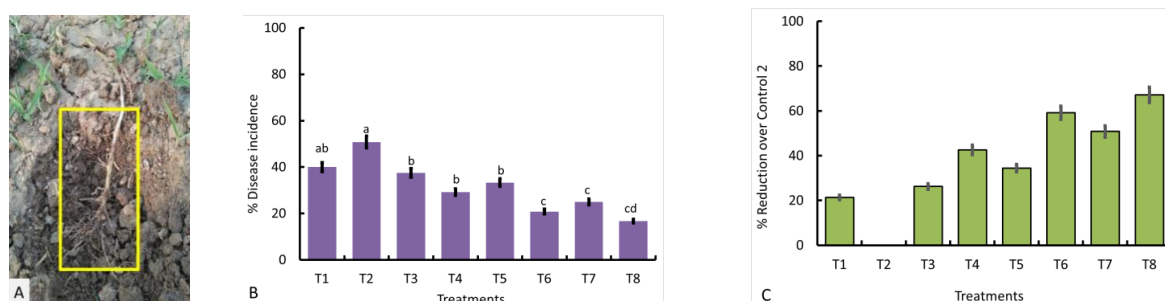


Figure 4. Effect of different *TFC* on *Rhizoctonia* dry root rot incidence in an artificially *R. solani* inoculated plot. A) *Rhizoctonia* dry root rot symptom in the experimental field, B) *Rhizoctonia* dry root rot incidence of different plot and, C) %reduction of *Rhizoctonia* dry root rot symptom over artificially *Rs* inoculated control plot T₂. Note, T₂= artificially *Rs* inoculated plot, T₁=Naturally infected plot, and T₃= Naturally infected and *TFC* applied plot

In the experiment with *Sr* inoculation, treatment T₈, where 500 g of wheat grain colonised with *TFC* was applied, showed the greatest effectiveness in minimising sclerotial diseases. The incidence of collar rot, southern blight, and sclerotial rot on tomato plants was significantly reduced in treatments T₁, T₃, and T₅, which were on par with each other. These treatments outperformed T₆, where 300 g of wheat grain colonised *TFC* was applied. On the other hand, treatment T₄, which consisted solely of wheat grain and *Sr*, did not demonstrate any notable effect in reducing these sclerotial diseases and showed similar results to Control 2. This pattern was consistent in the other two experiments, where only *R*s and *F*o were used as pathogen inoculants in Control 2. In the *R*s inoculated experiment, the most significant reduction in *Rhizoctonia* dry root rot (67.1%) was seen in T₈. T₆ and T₇ treatments showed similar disease reduction, both significantly more effective than treatments T₁, T₃, T₄, and T₅. Disease incidence was consistently lower in all treated plots compared to Control 2 (which was inoculated with only *R. solani*).

A similar trend was observed in the *Fusarium* wilt experiment. The lowest disease incidence (12.5%) occurred in the T₈ treatment. In contrast, Control 2 (inoculated only with *F*o) showed the highest *Fusarium* wilt incidence (54.2%). Treatment T₁ had a 33.3% disease incidence. Interestingly, *TFC* applied in T₁ also exhibited lower disease incidence (20.8%) compared to Control 2. While treatments T₄, T₅, T₆, and T₇ reduced *Fusarium* wilt compared to Control 2, they were not significantly different from T₁ and T₃. The highest reduction in *Fusarium* wilt was recorded in T₈ (76.9%) and T₃ (61.6%).

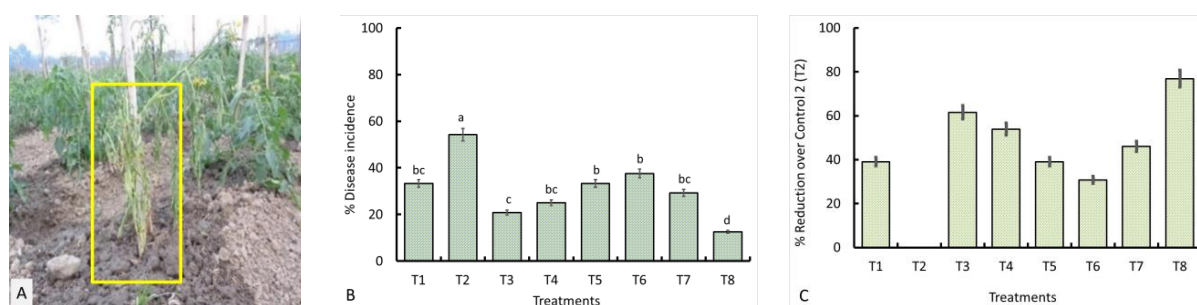


Figure 5. Effect of different *TFC* on *Fusarium* wilt incidence in an artificially *Fo* inoculated plot. A) *Fusarium* wilt symptom in the experimental field, B) *Fusarium* wilt incidence of different plot and, C) %reduction of *Fusarium* wilt symptom over artificially *Fo* inoculated control plot T₂. Note, T₂= artificially *Fo* inoculated plot, T₁=Naturally infected plot, and T₃= Naturally infected and *TFC* applied plot



Figure 6. Sclerotium fruit rot of disease tomato (middle) and *Sr* infected tomato fruits at soil level (Right) in the field

In the field inoculated with *Fo*, all treatments showed a significant improvement in growth parameters compared to the untreated controls (T₁ and T₂). The greatest increase in all recorded growth parameters, including plant height (cm), number of branches, number of leaves, fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), and dry root weight (g), was observed in treatment T₈. This treatment involved the highest amount of wheat grain colonised with *Trichoderma* mixed into the compost. Treatments T₆ and T₇, where 300 g and 400 g of TFC were applied, showed similar results. The growth parameters for treatments T₁, T₃, T₄, and T₅ were comparable, with most parameters showing significant improvement compared to Control 2, which was inoculated with only the pathogen (Table 2).

Table 2. Effect of (TFC) on growth parameters of tomato for *Fo* inoculated field

Treatments	Plant height (cm)	No. of branch	No. of leaf	Fresh Shoot wt. (g)	Dry Shoot wt. (g)	Fresh Root wt. (g)	Dry Root wt. (g)
T ₁	21 c	13.1 c	5.67 bc	290.2 c	92.4 bc	39.2 c	10.1 bc
T ₂	17 d	11.2 d	5.43 c	227.9 d	85.2 c	32.12 d	8.1 d
T ₃	20.1 bc	14.2 bc	6.1 ab	306.7 bc	93.2 b	41.2 bc	9.9 c
T ₄	22.5 bc	16.3 ab	6.34 ab	333.6 bc	96.9 ab	44.1 b	10.2 bc
T ₅	24.2 b	15.9 bc	5.9 b	342.8 b	98.1 ab	43.2 bc	10.3 bc
T ₆	26.1 ab	17.4 ab	6.1 ab	352.9 ab	104.2 ab	47.5 ab	11.8 ab
T ₇	27.9 ab	19.4 a	6.2 ab	359.6 a	105.1 a	49.2 a	12.6 a
T ₈	30.2 a	19.8 a	6.9 a	358.9 a	106.7 a	50.2 a	12.8 a

In the *Rs* inoculated field (Table 3), similar results to those observed in the *Fo* and *Sr* inoculated fields were found. All treatments significantly improved growth parameters compared to the untreated controls (T₁ and T₂). The highest increases in growth parameters, including plant height (cm), number of branches, fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), and dry root weight (g), were observed in treatment T₈, which involved the highest amount of wheat grain colonized with *Trichoderma* mixed into the compost. Treatments T₇, T₆, T₅, T₄, and T₃ also showed similar improvements in growth parameters. Control 2 (T₂) exhibited the lowest plant growth parameters when compared to all other treatments.

Table 3. Effect of *Trichoderma* fortified compost on growth parameters of tomato for *Rhizoctonia* inoculated field

Treatments	Plant height (cm)	No. of branch	No. of leaf	Fresh Shoot wt.(g)	Dry Shoot wt.(g)	Fresh Root wt.(g)	Dry Root wt.(g)
T ₁	19.1 bc	12.4 c	5.12 c	299.6 c	91.3 c	37.3 c	7.2 c
T ₂	18 c	12.1 d	6.1 b	244.6 d	89.2 d	34.7 d	6.9 d
T ₃	21.9 bc	15.6 bc	5.9 bc	309.5 bc	93.01 bc	40.7 bc	9.7 bc
T ₄	23.9 b	16.4 bc	6.9 a	331.2 bc	97.1 bc	45.1 b	9.8 bc
T ₅	24.1 b	17.6 ab	6.7 a	345.4 ab	98.3 ab	44.4 bc	11.3 ab
T ₆	26.4 ab	18.7 ab	6.2 ab	337.2 ab	98.2 ab	47.3 ab	11.2 ab
T ₇	26.9 ab	19.7 a	5.8 d	370.2 a	108.1 a	49.3 ab	11.6 a
T ₈	29.1 a	20.4 a	6.3 ab	372.4 a	108.6 a	57.8 a	11.1 ab

In the *Sr* inoculated field (Table 4), all treatments significantly improved growth parameters compared to the untreated controls (T₁ and T₂). The greatest increases in growth parameters, including plant height (cm), number of branches, fresh shoot weight (g), dry shoot weight (g), fresh

root weight (g), and dry root weight (g), were recorded in treatment T₈, where the highest amount of wheat grain colonized with *Trichoderma* was incorporated into the compost. Treatments T₇, T₆, T₅, and T₄ showed similar improvements in growth parameters. Control 2 (T₂) exhibited the lowest growth parameters for most traits, except for plant height, where T₂ showed slightly higher values than some treatments. Treatment T₁ had the lowest plant height compared to all other treatments.

Table 4. Effect of *Trichoderma* fortified compost on growth parameters of tomato for *S. rolfsii* inoculated field

Treatments	Plant height (cm)	No. of branch	No. of leaf	Fresh Shoot wt.(g)	Dry Shoot wt.(g)	Fresh Root wt.(g)	Dry Root wt.(g)
T ₁	20.1 d	11.9 c	4.81 bc	295.3 c	93.7 c	38.6 c	8.2 c
T ₂	21 c	11.4 d	4.34 c	248.4 d	87.4 d	30.2 d	7.2 d
T ₃	22.4 bc	15.1 bc	6.3 ab	308.1 bc	92.6 c	40.8 bc	8.7 bc
T ₄	24.3 ab	16 b	6.34 a	301.4 bc	95.9 bc	43.2 b	10.6 b
T ₅	23.9 b	17.2 ab	6.2 ab	344.9 ab	99.9 bc	45.3 ab	11.1 ab
T ₆	25.8 ab	18.3 ab	6.3 ab	354.7 ab	104.2 ab	43.4 b	10.8 ab
T ₇	28.8 a	19.6 a	6.2 ab	363.4 a	106.7 a	50.7 a	12.1 a
T ₈	30.8 a	19.8 a	5.99 b	367.4 a	107.2 a	51.6 a	11.7 a

3.4 Harvesting and yield

Tomatoes were harvested at four different times based on their maturity. After harvesting, fruit size and weight were used to grade the tomatoes and compare the different treatments. The total weight of fruits from each treatment was recorded to assess the overall yield. Based on disease management and total yield, the optimal dose of *TFC* was determined. In general, all treatments in the three experiments resulted in increased tomato yields. The highest yield increase was observed in treatment T₈, which used 500 g of wheat grain colonised *TFC* (Figure 7). The yield increased as the amount of *Trichoderma*-colonized wheat grain mixed with poultry refuse increased.

3.5 Effect of *TFC* on tomato yield

3.5.1 *Fusarium* inoculated field

The largest yield increase (27.27%) was observed in treatment T₈, followed by 21.40% in treatment T₇, and 18.18% in treatment T₆ (Table 5). The yield increases in treatments T₈, T₇, and T₆ were similar, but all were significantly higher compared to controls T₁ and T₂. Treatments T₇, T₆, T₅, T₄, and T₃ showed identical yield increases and were significantly higher than control treatments T₁ and T₂. The smallest yield increase (5.72%) was recorded in treatment T₁ (healthy tomato seedlings without any amendments) (Figure 7). The yield increased with the increasing amount of wheat grain colonised *Trichoderma*-fortified compost. All treatments with amendments resulted in significantly higher yields than Control 2, where only the pathogen was inoculated without any amendments.

Harvesting occurred at four different times, as tomatoes ripened at different rates. The largest quantity of tomatoes was harvested during the third harvest for all treatments. The size, uniformity, and colour of the tomatoes also varied depending on the treatment. Tomatoes grown under treatments T₈, T₇, and T₆ were larger, more uniform, and predominantly red, while those from the untreated control were smaller, with variable sizes and colours ranging from yellowish to red-dish.

Table 5. Effect of (TFC) on the yield of tomato for *Fusarium* field

Treatments	Fruit wt. (kg) per plot				Total yield (kg/plot)	Yield (t/ha)
	1 st harvest	2 nd harvest	3 rd harvest	4 th harvest		
T ₁	6.4	11.3	13.2	9.8	40.7	67.83 c
T ₂	6.1	12.4	14.2	5.8	38.5	64.16 d
T ₃	8.8	14.7	16.1	5.7	43.3	72.16 bc
T ₄	7.9	10.2	15.9	8.9	42.9	71.5 bc
T ₅	5.2	13.2	15.2	10.3	44.2	73.6 b
T ₆	5.3	13.5	16.9	9.1	45.5	75.83 ab
T ₇	7.1	13.7	17.8	8	46.6	77.67 ab
T ₈	7.8	16.2	16.3	8.7	49	81.67 a

3.5.2 *Rhizoctonia* inoculated field

The highest tomato yield of 84.33 tons per hectare was observed in treatment T₈, followed by 83.16 tons per hectare in treatment T₇, 75.32 tons per hectare in treatment T₆, and 74.5 tons per hectare in treatment T₅ (Table 6). The yield of tomatoes increased with the amount of *Trichoderma*-fortified compost, although no significant differences in yield were observed among treatments with increasing doses. The lowest yield increase (5.10%) was recorded in treatment T₁, which had no pathogen or amendments (Figure 7). The tomato yield increased with the increasing amount of wheat grain colonized *Trichoderma*-fortified compost. All treatments with amendments resulted in significantly higher yields compared to Control 2, where only the pathogen was inoculated without any amendments. The highest quantity of tomatoes was harvested during the third harvest for all treatments, except for treatments T₇ and T₆. The size, uniformity, and color of the tomatoes also varied depending on the treatment. Tomatoes from treatments T₈, T₇, and T₆ were larger, more uniform, and predominantly red, while tomatoes from the untreated control were smaller and showed greater variation in size and color, ranging from yellowish to reddish, like the other experiments.

Table 6. Effect of (TFC) on the yield of tomato for *Rhizoctonia* field

Treatments	Fruit wt. (kg) per plot				Total yield (kg/plot)	Yield (t/ha)
	1 st harvest	2 nd harvest	3 rd harvest	4 th harvest		
T ₁	6.7	9.2	18.2	7.8	41.9	69.83 c
T ₂	3.4	14.3	15.8	5.7	39.2	65.33 d
T ₃	5.3	14.9	15.62	8.2	44.02	73.36 bc
T ₄	7.7	14.3	16.2	6.1	44.3	73.83 bc
T ₅	6.1	16.9	17.2	4.5	44.7	74.5 ab
T ₆	8.2	17.6	13.79	5.6	45.19	75.32 ab
T ₇	8.7	17.2	16.8	7.2	49.9	83.16 a
T ₈	7.9	15.4	18.2	9.1	50.6	84.33 a

3.5.3 *Sclerotium* inoculated field

The highest yield increase (29.57%) was observed in treatment T₈, followed by 26.10% in treatment T₇ and 18.40% in treatment T₆. However, the yield increases in the top three treatments were similar (Table 7). The lowest yield increase (5.35%) was recorded in control treatment T₁, although this was still significantly higher than Control 2 (treatment T₂), where only the pathogen was inoculated without any amendments (Figure 7). Tomato yield increased with the increasing dose of wheat grain colonised *TFC* though no significant differences were found among the top

three doses. In the *S. rolfsii* inoculated field, the highest yield was harvested during the third harvest for all treatments. The size, colour, and uniformity of tomatoes were like those observed in the *Fo* inoculated field.

Table 7. Effect of (TFC) on the yield of tomato for *Sclerotium field*

Treatments	Fruit wt. (kg) per plot				Total yield (kg/plot)	Yield (t/ha)
	1 st harvest	2 nd harvest	3 rd harvest	4 th harvest		
T ₁	7.2	8.65	18.4	6.1	40.35	67.25 c
T ₂	6.2	9.2	15.4	7.5	38.3	63.83 d
T ₃	5.4	14.06	15.5	7.9	42.86	71.43 bc
T ₄	6.9	11.37	17.3	7.1	43.27	72.12 b
T ₅	7.7	12.3	18.1	5.6	43.7	72.83 b
T ₆	4.3	17.4	18.55	5.4	45.65	76.08 ab
T ₇	5.1	19.1	19.8	4.3	48.3	80.5 a
T ₈	7.1	17.4	18.2	6.9	49.6	82.67 a

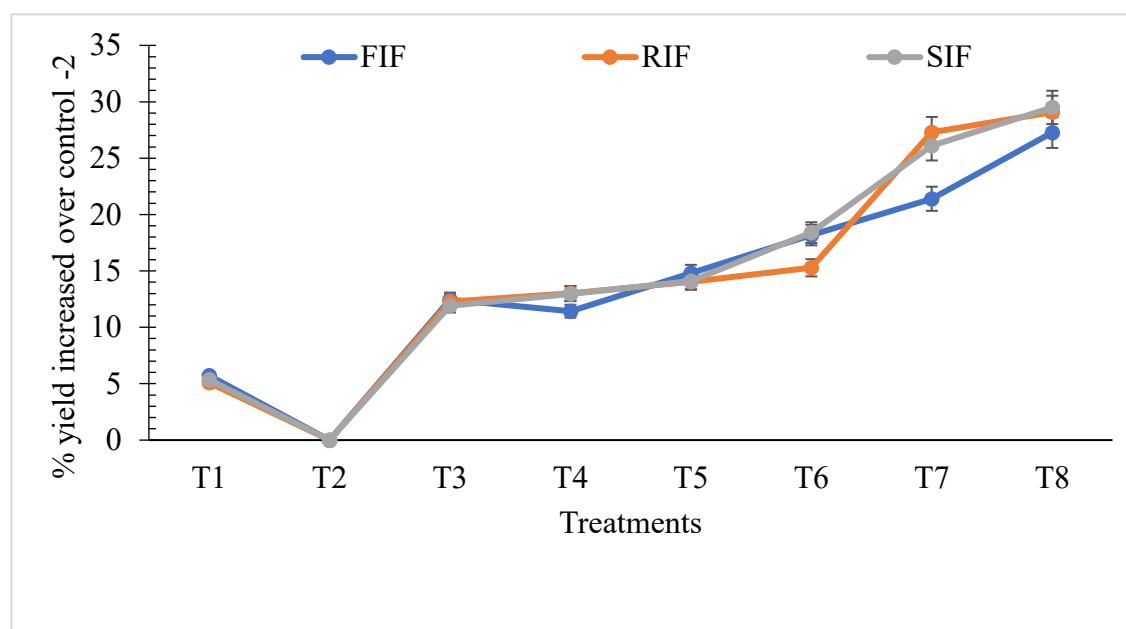


Figure 7. Impact of TFC on percent yield increased over control -2 in the test pathogens (FIF= *Fusarium* inoculated field, RIF= *Rhizoctonia* inoculated field, and SIF= *Sclerotium* inoculated field) inoculated fields

3.6 Discussion

The higher doses of TFC proved to be effective in reducing three major tomato diseases (collar rot, southern blight, *Rhizoctonia* dry root rot, and *Fusarium* wilt) in both naturally infected and artificially inoculated field conditions.

The results of this study align with Rahman et al. (2024), who found that *Trichoderma harzianum* fortified with poultry refuse significantly increased tomato yield and reduced disease incidence. In the present study, the application of wheat grain alone in the pathogen-inoculated fields, without any compost or *Trichoderma*, also contributed to a notable reduction in disease incidence and increased tomato yield. This could be attributed to improved soil structure and fertility, as wheat grain decomposition acts as an organic amendment, like other organic inputs, which can

reduce the incidence of soil-borne diseases. The application of composts, particularly poultry manure, has been well established as an effective organic amendment to improve soil health and suppress diseases caused by soil-borne pathogens. *Trichoderma* thrives in such composts, enhancing microbial activity and providing a sustainable means for biocontrol. Hoitink and Boehm (2009) emphasized that compost serves as an ideal feeding medium for biocontrol agents, helping them establish and thrive in the soil, which supports long-term disease control. Salam (2017) explored the use of various composts, including poultry refuse, to suppress soil-borne diseases in tomatoes, finding that poultry refuse was particularly effective when combined with *Trichoderma harzianum*. The present study extends these findings by optimizing the dose of *Trichoderma* and developing a poultry refuse-based compost that was more effective in controlling major soil-borne tomato diseases. This study is unique in its integrated approach, as prior research mainly used composts and antagonists separately, with limited integration (Akter, 2016; Salam, 2017; Ahmed et al., 2019; Das et al., 2019; Liton et al., 2019; Simi et al., 2019; Rahman et al., 2020; Rahman et al., 2021; Roy et al., 2022; Chowdhury et al., 2024). In this study, several doses of *Trichoderma*-fortified poultry refuse compost (200, 300, 400, and 500 g per 6 m² plot, equivalent to 333, 500, 667, and 833 kg per hectare) were tested. The highest dose showed the most significant reduction in disease incidence and promoted better growth and yield, aligning with Rahman et al. (2024) findings, where 667 kg/ha of *Trichoderma*-fortified poultry refuse compost was most effective in reducing disease incidence. Beneficial microorganisms like *Trichoderma* produce antibiotic compounds that help control various fungal pathogens, such as *R. solani* and *S. rolfsii* (Hoitink and Boehm, 2009). However, the biocontrol mechanisms of (*TFC*) were not explored in this study, which could be a potential area for future research. The improvement in tomato growth and yield through the application of (*TFC*) supports findings from Hoitink and Keener (2013), and Salam (2017), who reported similar benefits in various vegetables after applying *Trichoderma*-enhanced compost. Additionally, composts produced from bio-solids are widely used as peat substitutes in horticulture, reducing production costs, and this approach could be applicable for sustainable crop production in Bangladesh. *Trichoderma* is commonly found in soil, making it readily available and easy to cultivate. It can be mixed with compost and marketed in a packaged form or formulated as a liquid spray for foliar diseases (Arefin et al., 2019). *Trichoderma* has a proven ability to control both seed and soil-borne fungal pathogens during crop cultivation. Recent research has also highlighted that the effectiveness of *Trichoderma* in the field depends not only on the strain and dose, but also on the mode of application and the resulting shifts in the rhizosphere microbiome. Bandara and Kang (2024) reported that while post-transplant application of *T. virens* resulted in the highest rhizosphere colonisation, at-transplant application most effectively promoted tomato growth and enhanced soil suppressiveness against *F. oxysporum* pathogens. They further demonstrated that volatile compounds produced by rhizosphere microbes and metabolites extracted from soils after at-transplant treatments significantly suppressed pathogen growth and spore germination. These findings suggest that microbiome-mediated mechanisms contribute to the disease-suppressive effects of *Trichoderma* and that application timing can be critical for maximising benefits. Our results, which confirm that an optimised dose of *T. harzianum*-fortified compost (*TFC*) suppressed multiple pathogens and improved yield, complement these insights by demonstrating that dose standardisation also plays a decisive role. Together, these studies underscore that both the application method and the dose of *Trichoderma*-based formulations should be considered when designing reliable, farmer-friendly strategies for sustainable tomato production.

4. Conclusion

This study demonstrated that *Trichoderma*-fortified compost (*TFC*) is an effective and eco-friendly strategy for managing soil-borne diseases in tomato while enhancing plant growth and yield. The optimised dose of 500 g per 6 m² plot (~833 kg ha⁻¹) of *T. harzianum* isolate PABT-22

consistently reduced disease incidence to 12.5–14.0% and increased yield by 27–30% compared with pathogen-only controls. These findings provide a standardised, residue-free alternative to chemical fungicides, supporting sustainable and organic tomato production. From a practical standpoint, the adoption of *TFC* at the recommended dose offers farmers a low-cost, farmer-friendly solution for integrated disease management. Future research should focus on validating these results under multi-location and multi-season field conditions, across different tomato varieties and soil types, and with attention to rhizosphere microbiome dynamics to ensure broad applicability and long-term sustainability.

Acknowledgments

The authors acknowledge the National Agricultural Technology Program- Phase II Project (NATP-2), BARC, Dhaka-1215, Bangladesh, for its financial assistance in conducting this research.

References

- Ahmed, M. U., Bhuiyan, M. K. A., Hossain, M. M., Rubayet, M. T., & Khaliq, Q. A. (2019). Efficacy of chitosan and bio-agent in controlling southern blight disease of carrot caused by *Sclerotium rolfsii* and improvement the crop production. *Research in Agriculture and Veterinary Science*, 3(3): 113-125.
- Akter, M. (2016). Trichoderma-fortified compost on disease suppression and yield of onion. MS thesis, BSMRAU, Salna, Gazipur, Bangladesh, 43p.
- Arefin, M. N., Bhuiyan, M. K. A., & Rubayet, M. T. (2019). Integrated use of fungicide, plant extract and bio-agent for management of alternaria blight disease of radish (*Raphanus sativus* L.) and quality seed production. *Research in Agriculture and Veterinary Science*, 3(1): 10-21.
- Bandara, A. Y., & Kang, S. (2024). *Trichoderma* application methods differentially affect the tomato growth, rhizomicrobiome, and rhizosphere soil suppressiveness against *Fusarium oxysporum*. *Frontiers in microbiology*, 15, 1366690. [CrossRef](#)
- Barnett, H. L., & Hunter, B. B. (1972). Illustrated genera of imperfect fungi. (3rd ed), Burgess Publication Co., Minneapolis, 241p.
- Bell, D. K., Wells, H. D., & Markham, C. R. (1982). *In vitro* antagonism of *Trichoderma* species against six fungal plant pathogens. *Phytopathology* 72: 379–382.
- Bhuiyan, M., & Rubayet, M. T. (2023). Population dynamics of *Trichoderma harzianum* in bio-fortified compost against soil-borne potato diseases. *Annals of Bangladesh Agriculture*, 27(1): 81–92. [CrossRef](#)
- Chowdhury, R., Bhuiyan, M. K. A., Siddique, S. S., Rahman, M. A., & Rubayet, M. T. (2024). Integration of *Trichoderma harzianum* with organic amendments for controlling major soil-borne diseases in chickpea. *Egyptian Journal of Agricultural Research*, 102(1): 67-78.
- Das, I. R., Bhuiyan, M. K. A., Jannat, R., Kayesh, E., Rubayet, M. T., & Arefin, M. N. (2019). Effect of bio-fortified compost in controlling soil-borne diseases of lentil (*Lens culinaris* L.) and enhance the crop growth and yield. *Advances in Biology & Earth Sciences*, 4(2): 93-106.
- FAOSTAT. (2021). World Food and Agriculture - Statistical Yearbook, Rome, Italy.
- Hoitink, H. A. J., & Keener, H. M. (2013). Science and Engineering of Composting: Design, Environmental, Microbiological and Utilization Aspects. Worthington, OH, Renaissance Publication. p. 728.
- Hoitink, H. A. J., & Boehm, M. J. (2009). Biocontrol within the context of soil microbial communities: A substrate-dependent phenomenon. *Annual Review of Phytopathology*, 37: 427-446.
- Liton, M. J. A., Bhuiyan, M. K. A., Jannat, R., Ahmed, J. U., Rahman, M. T., & Rubayet, M. T. (2019). Efficacy of (*TFC*) in controlling soil-borne diseases of bush bean (*Phaseolus vulgaris* L.) and sustainable crop production. *Advances in Agricultural Science*, 7(2): 123-136.

- Nitu, N. J., Masum, M. M. I., Jannat, R., Sultana, S., & Bhuiyan, M. K. A. (2016). Application of chitosan and *Trichoderma* against soil-borne pathogens and their effect on yield of tomato (*Solanum lycopersicum* L.) *International Journal of Bioscience*, 9 (1): 10-24.
- Rahman, M. T., Rubayet, M. T., & Bhuiyan, M. K. A. (2020). Integrated management of rhizoctonia root rot disease of soybean caused by *Rhizoctonia solani*. *Nippon Journal of Environmental Science*, 1(7), 1018.
- Rahman, M. T., Rubayet, M. T., Khan, A. A., & Bhuiyan, M. K. A. (2021). Integrated management of charcoal rot disease of soybean caused by *Macrophomina phaseolina*. *Egyptian Journal of Agricultural Research*, 99(1), 10-19. doi: [CrossRef](#)
- Rahman, M. T., Rubayet, M. T., Khan, A. A., & Bhuiyan, M. K. A. (2020). Integrated management of fusarium root rot and wilt disease of soybean caused by *Fusarium oxysporum*. *International Journal of Biosciences*, 17(2): 83-96. [CrossRef](#)
- Rahman, R., Bhuiyan, M. K. A., Khan, M. A. A., Hossain, M. M., & Rubayet, M. T. (2024). Trichoderma-fortified compost in controlling diseases and increasing yield of tomato. *International Journal of Environment, Agriculture and Biotechnology*, 9(1), 165–174. [CrossRef](#)
- Roy, K., Khan, A. A., Rubayet, M. T., & Haque, M. M. (2022). Production of quality seeds of chilli using soil amendments. *Asian Journal of Agriculture*, 6(1): 7-14. doi: [CrossRef](#)
- Rubayet, M. T., & Bhuiyan, M. K. A. (2016). Integrated management of stem rot of potato caused by *Sclerotium rolfsii*. *Bangladesh Journal of Plant Pathology*, 32(1&2): 7-14.
- Rubayet, M. T., & Bhuiyan, M. K. A. (2023). Trichoderma spp.: A bio-agent for sustainable management of *Macrophomina phaseolina*. In P. Kumar & R. C. Dubey (Eds), *Macrophomina Phaseolina* Ecobiology, Pathology and Management. (pp. 265-290). Academic Press. [CrossRef](#)
- Rubayet, M. T., Prodhan, F., Hossain, M. S., Ahmed, M., Mamun, M. A. A., & Bhuiyan, M. K. A. (2020). Use of non-chemical methods for the management of southern blight disease of carrot incited by *Sclerotium rolfsii*. *Journal of Agriculture and Applied Biology*, 1(2): 74 – 85. doi: [CrossRef](#)
- Salam, M. A. (2017). *Trichoderma* fortified compost for the suppression of soil-borne pathogens and improvement of plant growth and yield of tomato. PhD Dissertation. Department of Plant Pathology, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur 1706, Bangladesh, 137p.
- Shamshiri, R. R., Jones, J. W., Thorp, K. R., Ahmad, D., Man, H. C., & Taheri, S. (2018). Review of optimum temperature, humidity, and vapor pressure deficit for microclimate evaluation and control in greenhouse cultivation of tomato: a review. *International Agrophysics*, 32: 287-302
- Simi, S. A., Jannat, R., Rubayet, M. T., & Bhuiyan, M. K. A. (2019). Efficacy of bio-fortified compost in controlling anthracnose disease of chilli caused by *Colletotrichum capsici* and improve the crop production. *Scholars Academic Journal of Bioscience*, 7(12): 482-489.
- Sundar, A. R., Das, N. D., & Krishnaveni, D. (1995). *In-vitro* Antagonism of *Trichoderma* spp. against two fungal pathogens of Castor. *Indian Journal of Plant Protection*, 23(2): 152-155.