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Trichoderma-fortified compost in controlling diseases and increasing yield of tomato

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Abstract— *An attempt was made to reduce the tomato disease severity caused by several fungal pathogens in the field conditions and increase the growth and yield of tomato through the application of different concentrations of Trichoderma-fortified compost. The antagonism of the tested stock culture isolate of TH 7 of T. harzianum was found to be stable in its antagonistic character and observed more than 90% growth inhibition of all the tested pathogens. Based on the confirmation of the repeated antagonism test, the highly antagonist isolate of T. harzianum TH 7 was selected to prepare the Trichoderma-fortified compost. In the field experiment, post-emergence seedling mortality was completely free whereas Trichoderma-fortified compost at 300 g colonized Trichoderma was used in the treatment* T_6*. All other doses of Trichoderma-fortified compost reduced the seedling mortality 60 to 80% and 20% reduction of seedling mortality was observed in the treatment* T_1 *where compost was used without Trichoderma. Early blight, collar rot and southern blight, root rot and Fusarium wilt are also recorded in the field from the growing stage to the last harvesting period. All the diseases were completely controlled with the treatment* T_6 *except early blight, where the highest reduction was 75% with the treatment* T_6 *and* T_5*. A similar trend of reduction of diseases was observed in the case of other treatments. Although, anthracnose was not observed in the tomato plants but at the ripening stage of the crop 2.5% tomato fruits were infected with anthracnose disease. Tomato fruits in the field were completely free from anthracnose fruit rot in the treatment* T_6*. The treatments* T_4 *and* T_5 *reduced 75% and 80% anthracnose fruit rot in the field condition. All the treatments significantly increased the growth-promoting components in comparison to the untreated control in the treatment* T_8 *where no supplements were added. Significantly the highest 28.08% yield was recorded in treatment* T_6 *followed by 21.67% increased yield in Treatment* T_5*. The highest quantity of tomato was harvested at the 3rd harvest in the case of all the treatments.*

Keywords— ***Anthracnose, Collar rot, Early blight, Fusarium wilt, Root rot, Trichoderma, Tomato***

I. INTRODUCTION

Tomato (*Solanum lycopersicum*), a member of the nightshade family (Solanaceae) is one of the popular vegetables in Bangladesh. Tomato and its products are gaining popularity day by day for various uses including salad, soup, sauce, juice, flavour in crackers and biscuits. Over the centuries, however, humans realized the great versatility of the fruit in the culinary realm, as well as the potential health benefits from the fruit's antioxidants. Tomatoes are now grown all over the world throughout the year. A ripe tomato contains around 94% water with higher contents of vitamin A, B, C including calcium and carotene (Bose and Som, 1990). Tomato has ranked 4^{th} in terms of production among major vegetables grown in the country (BBS, 2022). Although the total cultivated area and production of tomato in our country have increased gradually over the last few years but the productivity is still very low 6.46 ton/ha compared to the average of the world yield 40.84 ton/ha (FAOSTAT, 2022). Every year about 10-30% crop loss occurs due to diseases in Bangladesh that causes annual losses of about $120 million but it may be as high as 100% if control measures are not taken properly (Ahmed, 1994).

Disease is a major limiting factor for tomato production. It can be classified into two groups. The first are those caused by infectious microorganisms that include fungi, bacteria, viruses, and nematodes. These diseases are contagious and can spread from plant to plant in a field, often very rapidly when environmental conditions are favorable. Among various diseases of tomato, soil-borne diseases caused by *Sclerotium rolfsii*, *Rhizoctonia solani*, *Fusarium oxysporum* f. s. *lycopersici*, *Pythium* spp. are very serious both in the seedling stage and mature stage in the field. In Bangladesh, other severe tomato plants and fruits damage diseases are anthracnose (*Colletotrichum coccodes*), early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*). Growers can be much benefitted if they can reduce the losses due to diseases and minimize the production cost for chemical pesticides and fertilizers.

Loss of soil organic matter and associated loss of soil microbial activity has contributed to an increase in soil-borne plant diseases. Pests and diseases cause significant economic crop losses to agricultural crops each year, and management of pests and diseases is identified as one of the top farm management issues by growers across the country. Management of tomato disease is very difficult as the causal pathogens are mostly soil-borne as well as seed-borne and survive in the soil for longer time either in the form of sclerotia, chlamydospores or as fragmented mycelium associated with crop residues and also can survive in the seed as dormant stage over a period of time.

Soil-borne fungal and oomycete plant pathogens, among the major factors limiting the productivity of agroecosystems, are often difficult to control with conventional strategies such as the use of resistant host cultivars and synthetic fungicides. The lack of reliable chemical controls, the occurrence of fungicide resistance in pathogens, and the breakdown or circumvention of host resistance by pathogen populations (McDonald and Linde, 2002) are some of the reasons underlying efforts to develop new disease control measures. The ban of methyl bromide, the most effective fumigant used worldwide for soil disinfestations, has further increased the need for alternative control methods (Martin, 2003). In this context, the search for alternatives with high efficiency, low cost and limited environmental impact is a challenge for eco-sustainable modern agriculture. The use of organic amendments such as animal manure, green manure (the incorporation of crop residues into the soil), composts and peats has been proposed, both for conventional and biological systems of agriculture, to improve soil structure and fertility (Cavigelli and Thien, 2003), and decrease the incidence of disease caused by soil-borne pathogens (Noble and Coventry, 2005). Available control measures including cultural and chemical methods are not satisfactory to control several diseases. During past years, pesticides and chemical fertilizers have become the foundation of highly productive forms of agriculture and their indiscriminate use causes the risk of pollution, serious changes in ecological symmetry and poisoning (Danielle and Rai, 2006). However, the high frequency of chemical use, non-target effects, development of resistance to many chemicals, pathogens which remain viable for many years and risk to human health and the surrounding environment have stimulated the development of alternative methods for disease management. Moreover, pesticides are not available for some diseases, and generally pesticides are more effective against aerial plant pathogens than their soil-borne counterparts. It is also technically difficult to treat large amount of soil, and the range of approved chemicals is declining as active compounds are withdrawn for toxicological and environmental. The current trend to near-zero market tolerance for pesticide residues in fresh leafy vegetables provides an additional motivation to search for non-chemical means to control pests and diseases (Reuveni et al., 2002). These issues are motivating increased interest in reduced chemical use and in the disease suppression benefits of organic products including composts.

As a result, sustainable alternatives are being sought to replace or complement these strategies. In recent years the use of microbial systems for nutrient mobilization, or as biofertilizers are getting popular and new systems are being introduced to cater to different cropping systems. Biological control agents are now being used in developed countries to control disease. The dual role of antagonistic activity against plant pathogens and promotion of soil fertility makes the biological control agents including antagonist fungi and bacteria appealing alternatives to hazardous fumigants and fungicides.

Trichoderma is a cosmopolitan soil and compost-borne saprophytic fungus used widely as a biological control agent in the field against plant diseases caused by economically important plant pathogens. Considerable efforts, both in the academic and commercial sectors, have been made to promote this group of fungi as a credible alternative to synthetic chemicals for combating against plant disease (Rubayet and Bhuiyan, 2023).

Composts or compost extracts used as an organic fertilizer have beneficial effects on plant growth and considered as a valuable soil amendment (Gharib et al., 2008). A water-based compost extract containing high population of beneficial microbes, is attracting the attention of growers and researchers for its apparent disease-suppressive activity and improvement of soil fertility. Composting is the biological decomposition of organic waste under controlled conditions. The use of *Trichoderma* spp., a cellulose decomposer fungus, to hasten the decomposition of agricultural wastes that is ready for application is referred to as compost fungus activator (CFA) reduces decomposition time of agricultural wastes from the normal 5–6 months to 3–5 weeks. Research on the application of compost has demonstrated a variety of disease-suppressive effects. The results indicate that suppressive effects can result from a combination of physiochemical and biological characteristics (Boulter et al., 2002). The activities of beneficial microorganisms within the total microbial community and their response to energy reserves available from the composts are the basis of disease control (Hoitink and Boehm, 1999).

The mechanism of biological control involves the production of antibiotic compounds by beneficial microorganisms that are effective in controlling various plant pathogens such as sclerotia of pathogenic fungus *Rhizoctonia solani* and *Sclerotium rolfsii* (Hoitink and Boehm, 1999). Composts can provide natural biological control of diseases of roots as well as of plant foliage. Beneficial fungi *Trichoderma* spp. are considered the predominant and aggressive parasites of *Rhizoctonia* and *Sclerotium* (Kuter et al., 1983). Not only have composts prepared from different raw materials/feedstock varied in disease suppressiveness, but those prepared from different batches of the same raw materials have varied in their effect (Nelson and Craft, 1992). Common beneficial microbes compete pathogens for food and space around plant roots. This mechanism (direct competition) is very effective against *Fusarium*, *Pythium*, *Phytophthora*, *Rhizoctonia* and *Sclerotium* causing damping off and seedling mortality of tomato crop. Among antagonistic microbes, *Trichoderma* is easy to culture and mass multiplication and mainly used for the prevention and control of soil-borne fungal diseases in plants such as *Fusarium*, *Verticillium* wilt, damping-off disease, Blight, *Gaeumannomyces* diseases, sheath blight, all kinds of vegetables and other seedling diseases. *Trichoderma* is also popular because it is good at combating a range of diseases on vitally important crops.

Trichoderma inhabits naturally in nearly all soils, so it is easy to find. It is also easy to cultivate. Producers can mix it with compost and sell it in bags or it may be produced in liquid form to be sprayed on leaves for the treatment of foliar fungal diseases. The beauty of *Trichoderma* is that it can be used to combat almost every pathogenic fungus that people want to control. There are constraints in using *Trichoderma* as biocontrol agents. *Trichoderma* colonizes in the spermosphere effectively but they do not survive well in the rhizosphere (Deacon, 1994). The same author observed that *Trichoderma* spp. are active only in some types of soil and season thus achieving only transitory localized dominance of the rhizosphere. For this reason, another constraint is the quiescent and inactive nature of *Trichoderma* spores in the soil and because of this, *Trichoderma* cannot be added as spores (Vidhyasekaran, 2004).

Furthermore, the application of compost fortified with *Trichoderma* is most effective not only control the pathogenic diseases or enhancing plant growth but also removal of atmospheric carbon through soil carbon sequestration, achieved directly through storage of compost carbon, and indirectly through enhanced plant growth, which in turn contributes also to increased soil carbon levels.

Research on the application of biocontrol agents began in the mid- 1990s but results from documented field trials on the application of Trichoderma-fortified compost in controlling vegetable diseases are scarce. Considering the above-mentioned facts, the study was undertaken to optimize the dose of *Trichoderma* in the Trichoderma-fortified compost in controlling the major field diseases of tomato and increase the growth promotion and yield of tomato.

II. MATERIALS AND METHODS

The experiment was conducted in the laboratory and research field of the department of Plant Pathology Department at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur 1706, Bangladesh. The experimental site is located at the centre of Madhupur tract (24°09' N latitude and 90°26' E longitude) having an elevation of 8.2 m from sea level. The soil type of the experimental field belongs to the Shallow red brown terrace type under Salna series of Madhupur tract (Saheed, 1984) of Agro ecological zone (AEZ) 28 which is characterized by silty clay with pH value of 6.5, less rainfall, almost clear sunshine and moderate temperature.

Preparation of compost

Before setting the experiment in the field, Trichoderma-fortified compost at different concentration was prepared by mixing saw dust, kitchen garbage, rice straw and cow-dung on equal proportion in a 1.0 m x 1.0 m x 1.5 m composting pit and covered with polythene sheet allowed for 90 days for decomposition and degradation following the procedure of the preparation of standard quality compost as described by James (2008). To determine the suitability of the compost to be used for the suppression of diseases and production of tomato, percent seed germination, root growth and germination index (GI, a factor determined by both germination & root growth) were carried out based on the following formula as stated by Zucconi et al. (1981):

Selection of *Trichoderma* isolate for compost

The highly antagonist isolate of *Trichoderma harzianum* TH 7 was collected from the stock culture of Plant Pathology Laboratory of BSMRAU, Gazipur and checked the antagonism against the highly virulent isolates of *Alternaria solani, Fusarium oxysporum, Sclerotium rolfsii, Rhizoctonia solani* and *Colletotrichum coccodes* in dual culture plate technique to reconfirm the antagonism of *T. harzianum* isolate TH 7. After reconfirmation of the antagonism wheat grain colonized inoculums of *T. harzianum* isolate TH 7 was prepared following the procedure as described by Raihan et al. (2003) and the requisite amount of inoculum was mixed with the compost at five different doses.

Preparation of *Trichoderma* inoculum

Inoculum of the selected isolate of *T. harzianum* isolate TH 7 was prepared on wheat grains in 1000 ml Erlenmeyer flask. Wheat grains were soaked in water for 12 hours. The water was drained off and 500 g of water-soaked grains were poured into 1000 ml Erlenmeyer flask. Five-millimeter diameter discs of the fungal mycelium were cut from the edge of three days old PDA cultures of *T. harzianum* isolate TH 7 in petridishes. Twelve to fifteen mycelial discs of PDA grown *T. harzianum* isolate TH 7 were added to the flasks containing autoclaved wheat grain and incubated at 25 C for 21 days (Rubayet and Bhuiyan, 2016). They were shaken by hand at 2-3 days intervals for even colonization. The colonized wheat grain with *T. harzianum* was air-dried for 1 week and stored at 10 C for using as inocula.

Mixture of wheat grain colonized *Trichoderma*

A total of six compost pits was prepared where each compost pit contains 40 kg well mixed saw dust, kitchen garbage, rice straw and cowdung in equal proportions. After 45 days of decomposition wheat grain colonized *Trichoderma* inoculum at 1.6, 2.4, 3.2, 4.0 and 4.8 kg were mixed in five different compost pits. A compost pit without wheat grain colonized *Trichoderma* inoculum was maintained as control treatment. Compost pits were allowed a total of 90 days for complete decomposition before application in the field.

Treatments maintained in the experiment

From prepared compost pits, a total of 2.5 kg Trichoderma-fortified compost was applied per plot at five different doses and maintained one control treatment of only compost without wheat grain colonized *Trichoderma*. The amount of wheat grain colonized *Trichoderma* for each treatment per plot is given below:

Treatments

T_1= only compost without wheat grain colonized *Trichoderma*, T_2= compost with 100 g wheat grain colonized *Trichoderma*, T_3= compost with 150 g wheat grain colonized *Trichoderma*, T_4= compost with 200 g wheat grain colonized *Trichoderma*, T_5= compost with 250 g wheat grain colonized *Trichoderma*, T_6= compost with 300 g wheat grain colonized *Trichoderma*, T_7 = without compost only 200 g wheat grain colonized *Trichoderma*, T_8 (Control) = no compost and no wheat grain colonized *Trichoderma.*

Land preparation and design of experiment

Land was prepared with well tilth using a tractor driven disc plough, rotavator and harrow. The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. After land preparation the whole experimental area was divided into three blocks, representing three replications. The unit plot size was 2.5 m x 1.5 m, distance between block to block was 1.0 m and that of plot to plot in a block was 0.50 m. Drains were made surrounding each unit plots and the excavated soil from the drains were used for raising plots 15 cm high from the general soil surface. Eight different treatments were allotted randomly to eight-unit plots in each block.

Plantation of Seedlings

Twenty-five days aged healthy tomato seedlings variety 'Ratan" was collected from the Horticulture Research Centre of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur for plantation where row to row and plant to plant distance was 50 cm. A total of 24 seedlings were planted in each plot. Weeding, irrigation and other intercultural operations were done as and when necessary, until the maturity of plants.

Observation of disease development

Tomato plants were observed regularly immediately after transplantation to record the incidence of post transplanting seedling mortality and different diseases at different stages of plant growth both on plant parts & fruits. Infected tomato plants were identified based on characteristic symptoms of the diseases. The causal agents of the recorded diseases were identified by isolation of the pathogen from the infected leaves, plants and fruits. The disease incidence was recorded continuously at 3 days intervals from transplanting to final harvest. Observations were made by selecting six plants randomly from each plot. Diseases of the crop were expressed as percentage.

Observation of growth promoting factors at maturity

Growth promoting factors including root length, root diameter, fresh root weight, dry root weight, dry shoot weight, plant height, no. of leaves, no. of branches, fresh shoot weight and dry shoot weight were recorded randomly taken three plants from each replication of all the treatments attained after fruit ripening stage. Fruits were harvested through four different stages depending on growth, maturity and ripening of the fruits. Because of bulk production, fruit were weighed by truss rather than individually. A cluster was harvested whenever the fruit had reached the breaker stage. Cluster weight and fruit number were recorded.

Collection of data and analysis

The experiment had eight treatments with three replications following a Randomized Complete Block Design (RCBD). Data were analyzed for ANOVA using MSTAT-C program. Duncan's Multiple Range Test (DMRT) was used to compare the means. Whenever necessary, data were transformed before statistical analysis following the appropriate method.

III. RESULTS AND DISCUSSION

Potential *Trichoderma* isolate TH 7

The highly antagonist isolate of *Trichoderma harzianum* TH 7 was collected from the stock culture of Plant Pathology Laboratory of Bangabandhu Sheikh Mujibur Rahman Agricultural University and checked the antagonism against the highly virulent isolates of test pathogens. In the present study, more than 90% growth inhibition of all the tested pathogens was observed. Based on the confirmation of the present study the highly antagonist isolate of *T. harzianum* TH 7 was selected to prepare the Trichoderma-fortified compost. The antagonism of *T. harzianum* TH 7 against *F. oxysporum*, *S. rolfsii*, *R. solani* and *C. coccodes* of the present study are in highly agreement with previous work (Sen, 2010; Bhuiyan and Rubayet, 2023). Many researchers reported the antagonistic behavior of the *Trichoderma* spp. against several types of seed and soil-borne as well as air-borne fungal pathogens (Ahmed et al., Arefin et al., Das et al., Liton et al., Simi et al., 2019; Rahman et al., 2020ab; Rubayet et al., 2020; Rahman et al., 2021, Roy et al., 2022).

Control of disease development in the field

A total of five diseases were recorded during the production of the crop in the field. Immediately after the plantation of tomato seedlings, post-transplanting seedling mortality caused by *R. solani*, *S. rolfsii* and *F. oxysporum* was recorded until two weeks of the field growth (Fig. 1). Post-transplanting seedling mortality was completely free where Trichoderma-fortified compost at the rate of 300 g colonized *Trichoderma* was used in the treatment T_6. All other doses of Trichoderma-fortified compost reduced the seedling mortality 60 to 80% and 20% reduction of seedling mortality was observed in the treatment T_1 where compost was used without *Trichoderma*. In treatment T_7 where only wheat grain colonized *Trichoderma* without compost was applied also reduced 60% seedling mortality.

The major diseases observed in the field were early blight and Fusarium wilt in the tomato plants and anthracnose in the fruits at the ripening stage. The highest incidence of early blight caused by *A. solani* was recorded at 44.44% in the untreated plot in treatment T_8. The highest 75% reduction of early blight was recorded in the treatment T_5 and T_6 where Trichoderma-fortified compost at 250 and 300 g colonized *Trichoderma* were applied. At the lower three doses 100, 150 and 200 g Trichoderma-fortified compost in the treatments T_2, T_3 and T_4 reduced early blight disease at 25% while only wheat grain colonized *Trichoderma* without compost in the treatment T_7 reduced 50% incidence of early blight disease. The lowest 12.12% early blight reduction was recorded with the application of only compost (Table 1).

Collar rot and Southern blight caused by *Sclerotium rolfsii*, Root rot caused by *Rhizoctonia solani* and Fusarium wilt caused by *F. oxysporum* are also recorded in the field from growing stage to the last harvesting stage. Among the three diseases, Fusarium wilt, fatal disease even at the mature stage of the crop was the most predominant and recorded 22.22% while collar rot and southern blight and root rot were observed at 22.22 and 12.12%, respectively in the untreated treatment T_8. All these three diseases were completely controlled with the treatment T_6. A similar trend of reduction of diseases was observed in the case of the other treatments. Although anthracnose was not observed in the tomato plants, 2.5% tomato fruits were infected with anthracnose disease at the ripening stage of the crop.

Tomato fruits in the field were completely free from anthracnose fruit rot in the treatment T_6. In the treatments T_4 and T_5 reduced 75% and 80% anthracnose fruit rot in the field condition (Table 1). Application of only compost and wheat grain colonized *Trichoderma* without compost also considerably reduced the appearance of anthracnose fruit rot in the field. The Recycled Organics Unit of The University of New South Wales (NSW, 1966) demonstrated the application of compost in controlling soil-borne diseases of tomato which are in partial agreement with the findings of the present study. Controlling of Fusarium wilt of tomato was successfully achieved with application of *Trichoderma* induced suppressive soil in Malaysia in accordance to Ingham (2005). Hoitink and Boehm (1999) stated that the natural disease-suppressive effects of composts are due to an increase in microbial biomass of *Trichoderma* is an ideal food base for biocontrol agents, it aids in their introduction and establishment into the soil for sustained biocontrol activities of soil microbiota supports the present findings of the study of controlling diseases of tomato by Trichoderma-fortified compost.

Table 1. Effect of Trichoderma-fortified compost in controlling field diseases of tomato

Treatments	% disease reduction					
	Transplanting seedling mortality	Early blight disease	Collar rot and southern blight	Root rot	Fusarium wilt	Anthracnose fruit rot
T_1	20.01 e	12.12 e	25.00 d	25.00 e	25.00 d	31.25 e
T_2	60.00 c	25.00 d	50.00 c	50.00 d	75.00 b	43.75 d
T_3	80.0 b	25.00 d	50.00 c	50.00 d	75.00 b	43.75 d
T_4	80.0 b	25.00 d	75.00 b	62.50 c	75.00 b	75.00 c
T_5	80.0 b	75.00 a	75.00 b	62.50 c	100.00 a	80.00 b
T_6	100.00 a	75.00 a	100.00 a	100.00 a	100.00 a	100.00 a
T_7	60.00 c	50.00 b	75.00 b	75.00 b	50.00 c	43.75 d
T_8	27.78$^{\#}$ d	34.44$^{\#}$ c	22.22$^{\#}$ e	12.12$^{\#}$ f	22.22$^{\#}$ e	2.50$^{\#}$ f

$^{\#}$ % Disease incidence. T_1= only compost without wheat grain colonized *Trichoderma*, T_2= compost with 100 g wheat grain colonized *Trichoderma*, T_3= compost with 150 g wheat grain colonized *Trichoderma*, T_4= compost with 200 g wheat grain colonized *Trichoderma*, T_5= compost with 250 g wheat grain colonized *Trichoderma*, T_6= compost with 300 g wheat grain colonized *Trichoderma*, T_7 = without compost only 200 g wheat grain colonized *Trichoderma*, T_8 (Control) = no compost and no wheat grain colonized *Trichoderma*.

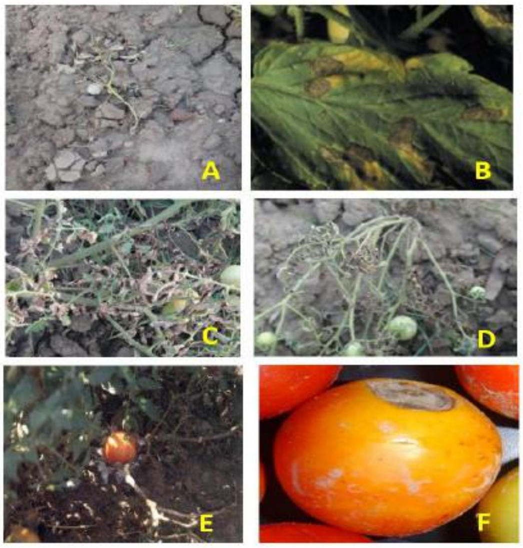

Fig 1. Different disease symptoms in the field

A. Post-emergence seedling mortality by *R. solani* B. Early blight disease Symptom caused by *Alternaria solani* C. Severe early blight disease symptom D. Fusarium wilt at mature stage E. Southern blight at mature stage by *S. rolfsii* F. Anthracnose fruit rot in the field by *C. coccodes*.

Effect of Trichoderma-fortified compost on growth promotion components of tomato

Growth promoting factors including root length, root diameter, fresh root weight, dry root weight, dry shoot weight, plant height, no. of leaves, no. of branches, fresh shoot weight and dry shoot weight were recorded randomly taken three plants from each replication of all the treatments attain after certain maturity (Table 2 and 3).

All the treatments significantly increased the growth-promoting components in comparison to the untreated control in the treatment T_8 where no supplements were added. Significantly increased growth parameter including root length, root diameter, fresh root weight, dry root weight, dry shoot weight, plant height, no. of leaves, no. of branches, fresh shoot weight and dry shoot weight were recorded in the treatment T_6 where the highest amount of wheat grain substrate colonized *Trichoderma* was mixed in the compost and identical in increasing growth promoting components with the treatment T_5, T_4 and T_3 except dry root weight. Growth promoting characters of the treatment T_1, T_2 and T_7 are identical but significantly inferior to the treatments T_5, T_4 and T_3. The treatments T_1 and T_2 are identical in increasing root dry weight but significantly inferior to T_7.

The result of the current study suggests the superiority of Trichoderma-fortified compost in comparison to the single application of compost or wheat grain colonized Trichoderma in the treatments T_1 and T_7 but significantly increased all the growth parameters. The results of the present study support the observation of De Brito et al. (1995), who observed the enhancement of the growth of carrot by *T. harzianum*. Increased growth promotion of different vegetable crops through the application of compost and *Trichoderma* was also reported by Gharib et al. (2008); Chowdhury et al. (2024) supports the findings of the current study.

Table 2. Effect of Trichoderma-fortified compost on growth parameters of tomato

Treatments	Root length (cm)	Root diameter (cm)	Fresh Root weight (g)	Dry Root weight (g)	Fresh Shoot weight (g)	Dry Shoot Weight (g)
T_1	46.67 c	3.48 c	41.67 c	10.00 e	319.3 c	100.0 c
T_2	48.33 bc	3.93 bc	44.00 bc	10.60 de	333.3 bc	105.0 bc
T_3	52.00 ab	4.23 ab	47.33 ab	11.67 c	360.3 ab	113.7 ab
T_4	54.00 a	4.87 a	49.00 a	12.67 b	374.3 a	118.0 a
T_5	55.00 a	4.97 a	50.33 a	13.33 ab	380.7 a	120.7 a
T_6	56.00 a	5.67 a	51.33 a	13.67 a	388.0 a	122.7 a
T_7	49.00 bc	3.19 bc	44.00 bc	11.00 cd	333.3 bc	105.7 bc
T_8	37.6 d	2.98 d	34.00 d	9.00 f	254.0 d	80.7 d

T_1= only compost without wheat grain colonized *Trichoderma*, T_2= compost with 100 g wheat grain colonized *Trichoderma*, T_3= compost with 150 g wheat grain colonized *Trichoderma*, T_4= compost with 200 g wheat grain colonized *Trichoderma*, T_5= compost with 250 g wheat grain colonized *Trichoderma*, T_6= compost with 300 g wheat grain colonized *Trichoderma*, T_7 = without compost only 200 g wheat grain colonized *Trichoderma*, T_8 (Control) = no compost and no wheat grain colonized *Trichoderma*.

Table 3. Effect of Trichoderma-fortified compost on plant height, number of leaves and number of branches of tomato

Treatments	Plant height (cm)	No. of branches	No. of leaves
T_1	80.67 c	16.33 d	5.333 a
T_2	87.00 c	17.67 c	5.667 a
T_3	94.67 b	19.33 b	6.000 a
T_4	98.00 ab	20.33 ab	5.667 a
T_5	100.3 ab	20.67 a	6.000 a
T_6	102.0 a	21.00 a	5.667 a
T_7	87.33 c	18.00 c	5.667 a
T_8	67.00 d	14.00 e	4.333 b

T_1= only compost without wheat grain colonized *Trichoderma*, T_2= compost with 100 g wheat grain colonized *Trichoderma*, T_3= compost with 150 g wheat grain colonized *Trichoderma*, T_4= compost with 200 g wheat grain colonized *Trichoderma*, T_5= compost with 250 g wheat grain colonized *Trichoderma*, T_6= compost with 300 g wheat grain colonized *Trichoderma*, T_7 = without compost only 200 g wheat grain colonized *Trichoderma*, T_8 (Control) = no compost and no wheat grain colonized *Trichoderma*.

Effect of Trichoderma-fortified compost on the yield of tomato

The highest 28.08% yield was increased in treatment T_6 followed by 21.67% in treatment T_5 (Table 4). The yield in the treatments T_4, T_3 and T_2 were identical and significantly inferior to the treatment T_5. The application of only compost in T_1 appeared to be superior in comparison to the application of only wheat grain colonized *Trichoderma* in the treatment T_7. On the other hand, the yield of tomato was increased with increasing the amount of *Trichoderma* in the compost (Fig. 2 & 3).

However, in all the supplement added treatments increased yields were significantly higher in comparison the untreated control treatment T_8. Harvesting was done at for different times as tomato fruits were not mature and ripen at the same time. The highest quantity of tomato was harvested at the 3rd harvest in the case of all the treatments. The size, uniformity and colour of tomatoes were also varied depending on the treatment. Tomatoes produced under the treatments T_6 and T_5 were larger size, uniform and mostly desirable reddish colour while tomatoes under the untreated control treatment were smaller and variable in size with variable colour yellowish to reddish.

The results of the present study of the application of Trichoderma-fortified compost in increasing as total yield supports the increased yield of vegetable crops reported by other investigators who applied *Trichoderma* mixed with compost (Hoitink and Keener, 1993). Beneficial effects of composts include increased plant yield and vigor, improved food quality, and improved soil fertility including suppression of diseases caused by plant pathogens was also reported by Hoitink and Keener (1993) which are in partial agreement with findings of the present study. Similar observations are also reported in the case of rice in the Philippines where composting with the fungus *Trichoderma* as an activator is mainly utilized as organic fertilizer (Cuevas, 1997). Composts produced from biosolids are used widely as peat substitutes to reduce production costs in horticulture which might also be applicable for crop production in Bangladesh.

Table 4. Effect of Trichoderma-fortified compost on the yield of tomato

Treatments	Fruit wt. (g) per plot				Total yield (Kg/plot)	Yield (ton/h)	% increased yield
	1st harvest	2nd harvest	3rd harvest	4th harvest			
T_1	1950	2150	7100	2600	13.80	36.80 d	13.30
T_2	2100	2200	7160	2100	13.96	37.23 cd	14.61
T_3	1900	2450	7650	2050	14.05	37.47 c	15.35
T_4	1900	2300	7750	2150	14.10	37.60 c	15.76
T_5	2000	2600	7600	2620	14.82	39.52 b	21.67
T_6	2100	3050	8550	2200	15.60	41.60 a	28.08
T_7	1750	2350	6650	2150	12.90	34.40 e	5.91
T_8	1700	2035	6450	1995	12.18	32.48 f	-

T_1= only compost without wheat grain colonized *Trichoderma*, T_2= compost with 100 g wheat grain colonized *Trichoderma*, T_3= compost with 150 g wheat grain colonized *Trichoderma*, T_4= compost with 200 g wheat grain colonized *Trichoderma*, T_5= compost with 250 g wheat grain colonized *Trichoderma*, T_6= compost with 300 g wheat grain colonized *Trichoderma*, T_7 = without compost only 200 g wheat grain colonized *Trichoderma*, T_8 (Control) = no compost and no wheat grain colonized *Trichoderma*.

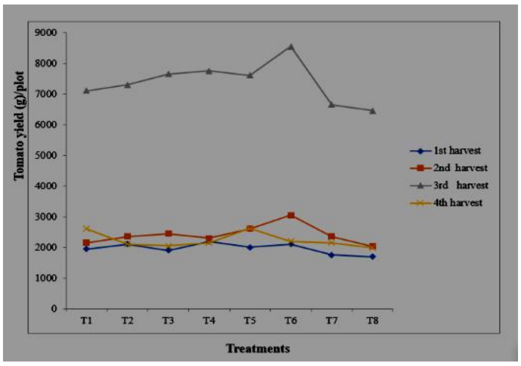

Fig. 2. Yield of tomato at different stages of harvesting

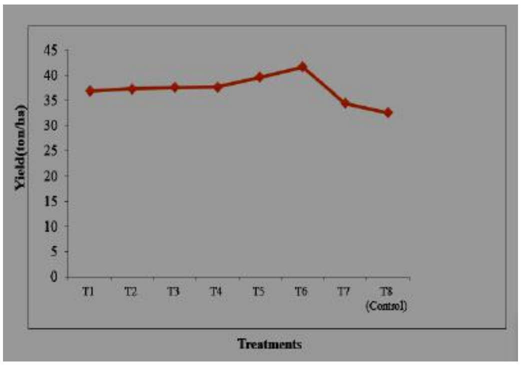

Fig. 3. Yield of tomato under different treatments

IV. CONCLUSION

Based on the current study, it could be concluded that Trichoderma-fortified compost appeared to be excellent in controlling different diseases of tomato with the significant increase of growth and yield. Farmers can adopt Trichoderma-fortified compost, an eco-friendly control measure for different diseases of vegetables with the lower cost in comparison to chemical pesticides.

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