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Effect of *Trichoderma* Culture Filtrates of as Inducer on Growth Parameters of Tomato (*Solanum lycopersicum* L.) against Fusarium Wilt

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Authors' contributions

This work was carried out in collaboration among all authors. Author RK developed the research idea and formulated the research questions. Author SKB Supervisor of research and oversee the research project and provided guidance. Author SK gathered and organized the data. Author SK did data analysis and interpretation and collected the data. Author KL contributed to Wrote the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The present study was carried out to evaluate the effect of culture filtrates from diffe *Trichoderma* isolates at 10% concentration on the growth parameters of tomato plants over two grow seasons (2021-22 and 2022-23).

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Study Design: The experiment was performed both *in vitro and in vivo* condition, Comple Randomized Design (CRD) used for *in vitro* and Randomized Block Design (RBD) used for *in* experiment
Place and Duration of Study: The experiment was performed at Chandra Shekhar Azad Universit Agriculture and Technology, Kanpur (India) during 2021-22 and 2022-23.
Methodology: The soil sample collected from 12 different location of India and *Trichoderma* isola and these different isolates used to produce their individual culture filtrate and these culture filtra further use with 10% concentration as treatment for tomato plant. The effect of culture filtrates on p height, root length, number of branches, fresh and dry shoot and root weight were observed under experiment.
Results: Results show significant improvements in plant height, root length, fresh and dry weights number of branches in all culture filtrate treated plants involving T_9 (seedling treatment + one foliar sp with culture filtrate of *Trichoderma* Nagaur), which consistently outperformed other isolates. Plant he increased to 43.06 cm in 2021-22 and 44.56 cm in 2022-23 at 40 days after transplanting with isolate treatment followed by culture filtrate of *Trichoderma* Jabalpur (T_7) and *Trichoderma* Banda (T_6) sho 11.56, 22.96, 33.72, and 37.15 cm in 2021-22, and 11.38, 23.24, 34.46 and 36.08 cm for T_6 in the sa year. Among all the culture filtrates, the treatment T_9 significantly enhances root length, fresh shoot root weights and the number of branches. The plants treated with isolate T_9 also exhibited an incre of 98.94% in root fresh weight and 42.31% in shoot weight.
Conclusion: The findings confirm the growth-promoting potential of the T_9 *Trichoderma*, attribute mechanisms such as hormone production, enhanced nutrient uptake and improved root architect These results align with previous studies demonstrating the benefits of *Trichoderma* species in p growth enhancement.

Keywords: Culture filtrate; Trichoderma; plant height; root length and crude extract.

1. INTRODUCTION

Tomato is protective food due to high nutritional values like vitamins, minerals, lycopene, dietary fibre and a dietary source of antioxidants [1]. Mature tomato fruits contain vitamin A, B and C, essential amino acids, and minerals such as Magnesium (Mg), Calcium (Ca), Phosphorus (P), Ferrous (Fe), Sodium (Na), Potassium (K), Copper (Cu) and Sulphur (S). On average, a tomato fruit contains proteins 1.9 g, Fats 0.1 g, minerals 0.6 g, dietary fibre 0.7 g and carbohydrates 3.7 g per 100 g of edible portion, it is also excellent source of various micronutrients [2]. In India, the leading producer states of tomato are Madhya Pradesh, Karnataka, Andhra Pradesh, Gujarat, Odisha, Tamil Nadu, West Bengal, Bihar, Chhattisgarh, Maharashtra, Uttar Pradesh, Haryana, Himanchal Pradesh and Telangana. Together, these states produce 90% of total tomato yield of India. Madhya Pradesh is the top among the tomato producing state, which contributing about 16.80% of the total production, followed by Karnataka (11.30%), Andhra Pradesh (10.50%), Gujarat (6.93%), Odisha (6.8%), Tamil Nadu (76.3%) and West Bengal (6.2%), respectively [3]. Tomato crops cultivation faces numerous challenges from both abiotic and biotic factors, among them biotic factors tend to cause greater extent of damage, with over 200 known diseases that can impact tomato production, among them Fusarium wilt of tomato is a major devastating disease leading to yield losses of up to 70 to 95% [4]. *Trichoderma* species are well known fungi that enhance plant growth by nutrient solubilization in the soil, growth hormones production in plants and defense against pathogens. Due to these characteristics, *Trichoderma* protect the plants against various biotic as well as abiotic stresses. To combat pathogenic fungi, *Trichoderma* is known to produce a range of mycotoxins [5]. When *Fusarium* interacting with, *Trichoderma* employs a mechanism that involves a sequence of actions, from attracting the pathogen to ultimately breaking down its cells. This is achieved through the attachment and coiling of its hyphae, facilitated by various hydrolytic enzymes and secondary metabolites [6]. The culture filtrate of *Trichoderma* species has also been found to enhance plant growth and vigour, further contributing to the plant's ability to withstand Fusarium wilt. In addition to inducing resistance, these filtrates contain growth-promoting substances such as auxins, gibberellins and cytokinins, which can improve root development and nutrient uptake. Youssef et al. [7] reported that treating cucumber plants with *Trichoderma* culture filtrate not only reduced the severity of *Fusarium* wilt but also led to increased

plant height, root length and overall biomass. This dual action of disease suppression and growth promotion makes *Trichoderma* culture filtrates a valuable tool in integrated pest management programs, offering a sustainable way to enhance crop resilience and productivity.

2. MATERIALS AND METHODS

The current experiment was conducted at Student Instructional Farm and Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur during 2021-22 and 2022-23. The work has been formed during experiment describes as below:-

2.1 Isolation, Purification and Identification of *Trichoderma* Isolates

2.1.1 Collection of soil sample

Soil samples for the isolation of *Trichoderma*were collected from 12 different places of India, such as Ayodhya (Kumarganj, 26.5676° N latitude and 82.3205° E longitude), Jhansi (Punch, 25.4902° N latitude and 78.5685° E longitude), Hardoi (Kaurha, 27.4458° N latitude and 80.1312° E longitude), Lakhimpur (Barbata, 27.9528° N latitude and 80.7824° E longitude), Varanasi (Banaras Hindu Vishwa Vidyalaya Campus, 25.265184° N latitude and 82.994399° E longitude), Banda (Beldan, 25.5260° N latitude and 80.7864° E longitude) district of Uttar Pradesh, Jabalpur (Jawaharlal Nehru Krishi Vishwa Vidyalaya, 23.1450° N latitude and 79.9373° E longitude) district of Madhya Pradesh, Udham Singh Nagar (Govind Vallabh Pant University Campus, 29.0339° N latitude and 79.4776° E longitude) district of Uttrakhand, Nagaur (Khanpur Majhra,, 27.1564° N latitude and 74.1944° E longitude) district of Rajasthan, Anand (Anand Agriculture University campus, 22.5755° N latitude and 72.9322° E ongitude) district of Gujarat, Ludhiana (Ayalikhurd, 30.8430° N latitude and 75.8498° E longitude) district of Punjab and Motihari (Chattavni, 26.6465° N latitude and 84.9135° E longitude) district of Bihar. *Trichoderma* selective medium was prepared by using Rose Bengal -0.15 g, Chloramphenicol -250 mg, Potassium dihydrogen phosphate -1 g, Magnesium sulphate -0.20 g, Streptomycin sulphate -0.3 g, Agar agar -20 g mixed in 1000 ml of distilled water used to isolate *Trichoderma* from different collected samples by using serial dilution technique (Koch, 1883) and further purified on Potato Dextrose Agar medium [8,9]. The isolated *Trichoderma*spp. were identified under compound microscope on the basis of culture texture, colour, growth pattern of colony, conidiophores, phialides and conidia as per describedby Harman (2000). After isolation of *Trichoderma* from different soil samples collected from different locations of India and each was named with first 3 letters of location from where it was isolated as:-

Trichoderma species isolated from Ayodhya = *Trichoderma* Ayo

Trichoderma species isolated from Jhansi = *Trichoderma* Jha

Trichoderma species isolated from Hardoi = *Trichoderma* Har

Trichoderma species isolated from Lakhimpur = *Trichoderma* Lak

Trichoderma species isolated from Varanasi = *Trichoderma* Var

Trichoderma species isolated from Banda = *Trichoderma* Ban

Trichoderma species isolated from Jabalpur = *Trichoderma* Jab

Trichoderma species isolated from Udham Singh Nagar = *Trichoderma* Udh

Trichoderma species isolated from Nagaur = *Trichoderma* Nag

Trichoderma species isolated from Anand = *Trichoderma* Ana

Trichoderma species isolated from Ludhiana = *Trichoderma* Lud

Trichoderma species isolated from Motihari = *Trichoderma* Mot

2.1.2 Preparation of culture filtrate of *Trichoderma* isolates

Potato dextrose broth (PDB) was poured into sterile conical flasks, filling them about 1/4 of their capacity. Sterilized the flasks containing the broth by autoclaving at 121.6 °C (15 psi) for 15 minutes. With the help of a cork borer, small bits were cut from the pure culture of *Trichoderma* in

the Petri plate and then transferred to the potato Dextrose Broth (PDB) filled conical flask using an inoculation needle under Laminar air flow. Covered the conical flasks with cotton plug to allow air exchange while preventing contamination. Placed the inoculated flasks on a shaker set at 25±1 °C for 21 days but at every 5-6 days, flasks have to be manually shaken. After the incubation period, the flasks were removed from the shaker. The broth was filtered to separate the fungal biomass from the liquid culture filtrate using sterile Whatman filter paper no. 1. Alternatively, the broth was centrifuged at 2500- 3000 RPM for 10-15 minutes to pellet the fungal biomass and then the supernatant was decanted. The supernatant was passed again through sterile Whatman filter paper no. 1 to remove any remaining spores or mycelial fragments to ensured that the culture filtrate was free of *Trichoderma* cells. The filtered culture filtrate was collected in sterile conical flask and labelled with the first three letter of name of location from where soil samples were collected for isolation of *Trichoderma* and date of preparation. The culture filtrate was stored at 4 °C until ready for use. All the collected *Trichoderma* isolates were used to prepare individual culture filtrates. These filtrates were applied as inducer in various treatments on tomato plants.

2.2 Isolation of *Fusarium oxysporum* f.sp. *lycopersici*

The isolation of *Fusarium oxysporum* f.sp. *lycopersici* was performed in laboratory of Department of plant Pathology from infected plant sample collected from Student Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The identification of pathogen was performed under compound microscope as per description provided by Snyder and Hansen (1940).

Seeds of Tomato cultivar Aazad T-6 obtained from Department of Vegetable Science, C.S. Azad Univeristy of Agriculture and Technology, Kanpur used in this experiment and grown under wire house condition for raising nursery.Plant height (cm), root length (cm), fresh and dry weight of stem,fresh and dry weight of root (g) were tested by treating seeds with 10% concentration of culture filtrate of different isolates of *Trichoderma*. The pots seeded with tomato seed further inoculated with *F. o.* f. sp. *lycopersici*.

2.3 Treatment Details

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Ayo) with 10%, Treatment 2 = Seedling treatment +One foliar spray of culture filtrate of *Trichoderma* (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of *Trichoderma* (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Udh) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* (Mot) with 10%, Treatment T_{13}= Control (Untreated).

2.4 Statistical Analysis

The data were analyzed by following the procedure of Randomized Block Design (RBD) and Completely Randomized Design (CRD). Data recorded in percentage were first transformed at arcsin value (Fisher and Yates, 1963) $\sqrt{\sin^{-1}}$ before statistical analysis. Treatments were compared by means of critical difference (CD) at five per cent level of significant.

3. RESULTS AND DISCUSSION

3.1 Plant height

The present investigation was performed to evaluate the effect of culture filtrate of different isolates of *Trichoderma* with 10% on growth parameters of tomato. The findings from the study illustrate the significant impact of culture filtrates of *Trichoderma* as inducer on enhancing growth of tomato plants.The findings, as presented in Table 1, demonstrate the significant impact of culture filtrate of *Trichoderma* on the

growth of tomato plants, particularly in terms of plant height. The results over the two-year period (2021-22 and 2022-23) indicate that treatments involving seedling treatment and one foliar spray of culture filtrates, especially from the *Trichoderma* Nag (T_9), consistently produced the highest plant heights. This treatment resulted in plant heights of 12.45, 27.74, 37.90 and 43.06 cm in 2021-22, and 13.15, 28.67, 39.00 and 44.56 cm in 2022-23, at 10, 20, 30 and 40 days age of plants, respectively. These findings align with the existing body of research that highlights the growth-promoting effects of culture filtrate of *Trichoderma* on various crops [10]. The increase in plant height observed in T_9 treatment (Culture filtrate of *Trichoderma* Nagaur) is consistent with previous studies, where *Trichoderma* have been shown to enhance plant growth through various mechanisms, including improved nutrient uptake, hormonal stimulation and the production of growth-promoting substances [10]. Shoresh et al. [11] and Harman et al. [12] demonstrated that Trichoderma spp. can produce auxins and other phytohormones that stimulate root and shoot growth, leading to increased plant height and biomass. The treatments involving culture filtrate of *Trichoderma* Jab (T_7) and *Trichoderma* Ban (T_6) also showed significant improvements in plant height, ranking second and third, respectively, in both years. The plant heights recorded for T_7 were 11.56, 22.96, 33.72, and 37.15 cm in 2021-22, and 11.38, 23.24, 34.46, and 36.08 cm for T_6 in the same year, which aligns with studies by Mastouri et al. [13] Verma et al. [10] and Singh et al. (2021), where different Trichoderma isolates were shown to vary in their effectiveness but still significantly contribute to plant growth. These observations are also supported by studies of Harman et al. [12] and Poveda (2020), which discuss the long-term benefits of culture filtrate of Trichoderma applications, including soil health improvement and enhanced plant resilience. Current study is also align with Idris et al. [14] used culture filtrates of plant growth-promoting rhizobacteria (PGPR) Bacillus amyloliquefaciens (FZB24, FZB42 and FZB45) and Bacillus subtilis FZB37, reported that it have a strong growth-promoting activity.

3.2 Root Length

The culture filtrate of *Trichoderma* has been shown to significantly enhance root length in various plants by promoting root elongation and improving nutrient uptake. This effect is linked to the production of growth-promoting compounds such as auxins and secondary metabolites by *Trichoderma* species [13]. The substantial impact of seedling treatment and foliar spray with *Trichoderma* culture filtrates on the root length of tomato plants over the two growing seasons (2021-22 and 2022-23) was tested. The findings reveal (Table 2) that culture filtrates of *Trichoderma* not only enhance shoot growth but also significantly promote root development, a critical factor for overall plant health and productivity. During 2021-22 season, the T_9 treatment [14] (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag) led to the maximum root lengths at all observed intervals (10, 20, 30 and 40 days after transplanting). This trend continued in the 2022-23 season, with T_9 again outperforming other treatments, highlighting its consistent ability to enhance root growth. Similar findings have been reported by other researchers who have demonstrated that specific isolates of *Trichoderma* can significantly improve root architecture by increasing root length, volume and surface area [15,16]. The remarkable root growth observed in the T_9 treatment could be due to several factors. *Trichoderma* is known to produce various secondary metabolites, such as indole-3-acetic acid (IAA) and other auxins, which directly promote root elongation (Carvajal-Muñoz and Carmona-Garcia, [17] Gao et al., [18] Singh et al., [1] Additionally, these fungi enhance nutrient uptake by solubilizing phosphates and other minerals in the soil, making them more available to plants, thereby supporting better root development [12] Shoresh et al., [19,20]. This dual role of promoting root growth and improving nutrient uptake underscores the potential of *Trichoderma* as effective biostimulants in agricultural practices. The T_6 treatment (Seedling treatment + one foliar spray of culture filtrate of *Trichoderma* Ban) was the second most effective, indicating that while *Trichoderma* Nag (T_9) was the most potent isolate. This supports the idea that different *Trichoderma* isolates may vary in their effectiveness, likely due to differences in their production of growth-promoting substances or their ability to colonize roots [21-25]. This variability in effectiveness among different isolates is consistent with the literature, where certain strains of *Trichoderma* are known to be more aggressive and effective in colonizing plant roots and producing bioactive compounds [26,27]. These findings underscore the importance of selecting the appropriate *Trichoderma* strain for specific agricultural applications, as the effectiveness of different strains can vary widely depending on the crop

and environmental conditions. The control treatment (T_{13}), which exhibited the lowest root lengths in both years, highlights the significant impact of culture filtrate of *Trichoderma* treatments. In the absence of inducer tomato plants showed significantly reduced root development, emphasizing the critical role of beneficial microbes in promoting root growth and overall plant vigour (Poveda, 2020) [28].

3.3 Fresh Weight

The observations recorded at 40 day after transplanting on fresh weight of shoot and root presented in Table 3, found that among the treatments, the highest fresh weigh of shoot and root was found in plants treated with T_9 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag) with the value 94.66 and 18.20 g against 68.65 and 9.17 g noted in case of control (Un-treated), respectively. The per cent increased over control as 37.88 and 98.47%, respectively, during 2021-22. Similarly, plants treated with T_9 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag) recorded maximum fresh weigh of shoot and root with the value as 95.96 and 18.70 g with 42.31 and 98.94 per cent increased over control, respectively during 2022-23. Rahmanet al. (2007) used culture filtrates of five *Trichoderma* strains *viz*., *Trichodermavirens* IMI-392430, *T. pseudokoningii* IMI-392431, *T. harzianum* IMI-392432, *T. harzianum* IMI-392433 and *T. harzianum* IMI-392434 as seed treatments alone and in combination to assay their efficacy in suppressing Anthracnose fruit rot disease caused by *Colletotrichum capsici*. Culture filtrate treated plants showed enhance shoot and root weight, number of branches, plant height, root length total number of fruits and dry fruit weight. The culture filtrate of *Streptomyces olivaceoviridis* appeared to be the most effective in respect to enhance growth vigour and crop yield of wheat plants by producing high amount of auxins, gibberellins and cytokinin-like substances [29-31].

3.4 Dry Weight

On the other hand, the dry weight of shoot and root was presented in the Table 4, showed that the plant treated with treatment T_9 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag), had highest value of 17.00 and 6.93g dry shoot and root weight, respectively. The second highest was found in T_6 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Ban) treatment as 14.00 and 5.96 g, respectively. Similarly, 2022-23, the dry weight of shoot and root was found highest in T_9 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag) treated plants with the value of 17.90 and 7.12 g, respectively. The dry weight of shoot and root of all rest treated plants were also increased than control.The results of the current study are in accordance with the observation taken by Biswas [32] reported that the cultural filtrate of *Chaetomium globosum* antagonised the conidia of *Drechslerasorokiniana* causal agent of spot blotch of wheat and also stimulated the plants growth. It was emphasized that the culture filtrate of bio-agents probably contains some kind of antifungal metabolities and growth promoting substances.

3.5 Number of Branches

In the phenomenon, on number of branches, the highest number of branches found in plants treated with T_9 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Nag) as 7.73, followed by T_6 (Seedling treatment + One foliar spray of culture filtrate of *Trichoderma* Ban) treatment, indicated as 6.83 against control during 2021-22(Table 5). Similarly, during 2022-23, the highest number of branches produced in plant treated with culture filtrate of *Trichoderma* Nag (T_9) as 8.03 numbers against over control with the number 4.87 branches. Several studies have highlighted the beneficial effects of *Trichoderma* species on plant biomass. For instance, *T. harzianum* and *T. asperellum* significantly enhanced the biomass of *Diplotaxis tenuifolia* [33,34] and *Mentha spicata* [35] respectively. Additionally, the combined use of *Trichoderma simmonsii* and *Aspergillus westerdijkiae* was found to promote growth in apple trees [36-38]. These findings strongly support the potential of *Trichoderma* species as plant growth promoters, aligning with the results of the present study. Mudawi and Idris [39,40] used crude extract of *Bacillus* and *Trichoderma* against wilt disease of chick pea and found that it reduced wilt incidence and reduce flowering days, increase plant vigour like height, weight and number of branches.

Table 1. Effect of seedling treatment with culture filtrate of different isolates of *Trichoderma* with 10% as inducer on plant height of tomato

Treatments	2021-22					2022-23				
	Plant height (cm) at different days				% increased over control after 40 days	Plant height (cm) at different days				% increased over control after 40 days
	10 days	20 days	30 days	40 days		10 days	20 days	30 days	40 days	
T_1	10.82	21.39	29.64	35.32	26.61	11.53	22.31	30.74	36.82	23.16
T_2	11.25	22.47	31.89	34.75	24.56	11.96	23.39	32.98	36.25	21.24
T_3	10.89	21.41	28.17	31.86	14.21	11.59	22.33	29.27	33.36	11.59
T_4	11.40	22.72	32.98	34.78	24.65	12.11	23.64	34.08	36.28	21.33
T_5	10.95	22.26	29.84	29.50	5.75	11.67	23.18	30.94	31.00	3.70
T_6	11.38	23.24	34.46	36.08	29.34	12.09	24.16	35.56	37.58	25.70
T_7	11.56	22.96	33.72	37.15	33.16	12.27	23.88	34.82	38.65	29.27
T_8	10.56	22.17	30.64	33.14	18.80	11.27	23.09	31.74	34.64	15.87
T_9	12.45	27.74	37.90	43.06	54.36	13.15	28.67	39.00	44.56	49.05
T_{10}	11.11	21.62	25.50	31.20	11.85	11.82	22.54	26.6	32.70	9.38
T_{11}	11.02	21.68	26.27	31.32	12.25	11.73	22.60	27.37	32.82	9.76
T_{12}	10.62	21.99	27.52	35.37	26.78	11.33	22.91	28.62	36.87	23.32
T_{13}	8.53	18.80	22.74	29.40		9.24	19.72	23.84	30.9	
CD at 5%				1.912					1.756	
SEm±				0.655					0.602	
SEd				0.926					0.851	
CV				3.340					2.935	

Treatments-

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ayo) with 10%, Treatment 2 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of Trichoderma (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Usn) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Mot) with 10%, Treatment T_{13}= Control (Untreated)

Table 2. Effect of seedling treatment with culture filtrate of different isolates of *Trichoderma* with 10% as inducer on root length of tomato

Treatments	2021-22					2022-23				
	Root length (cm) at different days				% increased over control after 40 days	Root length (cm) at different days				% increased over control after 40 days
	10 days	20 days	30 days	40 days		10 days	20 days	30 days	40 days	
T_1	8	12	17.14	27.1	49.15	8.56	12.90	18.24	28.40	39.01
T_2	7.96	12.03	17.37	24.66	35.75	8.52	12.93	18.47	25.96	27.10
T_3	7.63	10.10	14.63	25.16	38.51	8.19	11.00	15.73	26.46	29.55
T_4	8.10	12.63	17.80	25.30	39.24	8.66	13.53	18.90	26.60	30.20
T_5	7.56	11.56	16.06	27.60	51.90	8.12	12.46	17.16	28.90	41.46
T_6	9.30	13.36	18.46	27.86	53.37	9.86	14.26	19.56	29.16	42.76
T_7	9.03	12.96	17.93	29.00	59.60	9.59	13.86	19.03	30.30	48.31
T_8	8.13	11.13	16.50	26.30	44.74	8.69	12.03	17.60	27.60	35.10
T_9	9.93	14.63	20.16	29.90	64.56	10.49	15.53	21.26	31.20	52.72
T_{10}	7.23	10.23	15.10	24.40	34.29	7.79	11.13	16.20	25.70	25.80
T_{11}	7.36	10.36	15.13	24.23	33.37	7.92	11.26	16.23	25.53	24.98
T_{12}	7.23	10.23	15.40	25.40	39.79	7.79	11.13	16.50	26.70	30.69
T_{13}	5.13	8.13	13.30	18.17		5.69	9.03	14.40	20.43	
CD at 5%				1.462					1.566	
SEm±				0.501					0.536	
SEd				0.708					0.759	
CV				3.364					3.422	

Treatments-

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ayo) with 10%, Treatment 2 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of Trichoderma (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Usn) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Mot) with 10%, Treatment T_{13}= Control (Untreated)

Table 3. Effect of seedling treatment with culture filtrate of different isolates of *Trichoderma* with 10% as inducer on fresh weight of shoot and root of tomato

Treatments	2021-22				2022-23			
	Fresh weight (g) at 40 days after transplanting				Freshweight (g) at 40 days after transplanting			
	Fresh shoot weight	% increased over control after 40 days	Fresh root weight	% increased over control after 40 days	Fresh shoot weight	% increased over control after 40 days	Fresh root weight	% increased over control after 40 days
T_1	78.97	15.03	11.86	29.33	80.27	19.04	12.36	31.49
T_2	85.62	24.72	14.27	55.62	86.92	28.90	14.77	57.13
T_3	77.14	12.37	12.11	32.06	78.44	16.33	12.61	34.15
T_4	81.26	18.37	13.54	47.66	82.56	22.44	14.04	49.36
T_5	82.67	20.42	12.81	39.69	83.97	24.53	13.31	41.60
T_6	88.04	28.24	16.73	82.44	89.34	32.49	16.86	79.40
T_7	89.70	30.66	15.30	66.85	91.00	34.95	15.80	68.09
T_8	79.03	15.12	13.35	45.58	80.33	19.13	13.85	47.34
T_9	94.66	37.88	18.20	98.47	95.96	42.31	18.70	98.94
T_{10}	80.60	17.41	13.53	47.55	81.90	21.46	14.03	49.22
T_{11}	78.13	13.80	13.10	42.86	79.43	17.80	13.60	44.68
T_{12}	85.70	24.84	13.27	44.71	87.00	29.02	13.77	46.45
T_{13}	68.65		9.17		67.43		9.40	
CD at 5%	2.423		1.051		2.584		1.120	
SEm±	0.830		0.360		0.885		0.384	
SEd	1.174		0.509		1.252		0.543	
CV	1.747		4.584		1.838		4.718	

Treatments-

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ayo) with 10%, Treatment 2 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of Trichoderma (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Usn) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Mot) with 10%, Treatment T_{13}= Control (Untreated)

Table 4. Effect of seedling treatment with culture filtrate of different isolates of *Trichoderma* with 10% as inducer on dry weight of shoot and root of tomato

Treatments	2021-22				2022-23			
	Dry weight (g) at 40 days after transplanting				Dry weight (g) at 40 days after transplanting			
	Dry shoot weight	% increased over control after 40 days	Dry root weight	% increased over control after 40 days	Dry shoot weight	% increased over control after 40 days	Dry root weight	% increased over control after 40 days
T_1	13.03	35.73	3.34	21.43	3.48	21.26	3.48	21.26
T_2	13.17	37.19	4.90	78.25	5.07	76.78	5.07	76.78
T_3	12.77	33.02	3.53	28.25	3.67	27.96	3.67	27.96
T_4	13.30	38.54	4.81	74.87	4.99	73.74	4.99	73.74
T_5	12.83	33.65	4.43	61.16	4.60	60.45	4.60	60.45
T_6	14.00	45.83	5.96	116.58	6.27	118.33	6.27	118.33
T_7	13.83	44.06	5.50	100.05	5.68	97.95	5.68	97.95
T_8	12.27	27.81	4.32	57.03	4.48	56.10	4.48	56.10
T_9	17.00	77.08	6.93	152.12	7.12	148.22	7.12	148.22
T_{10}	12.27	27.81	4.42	60.78	4.58	59.75	4.58	59.75
T_{11}	12.40	29.17	3.74	36.04	3.88	35.32	3.88	35.32
T_{12}	11.90	23.96	3.86	40.30	4.00	39.50	4.00	39.50
T_{13}	9.60		2.75		2.87		2.87	
CD at 5%	1.002		0.311		0.389		0.389	
SEm±	0.343		0.106		0.133		0.133	
SEd	0.486		0.151		0.188		0.188	
CV	4.592		4.099		4.939		4.939	

Treatments-

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ayo) with 10%, Treatment 2 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of Trichoderma (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Usn) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Mot) with 10%, Treatment T_{13}= Control (Untreated)

Table 5. Effect of culture filtrate of different isolates of *Trichoderma* with 10% as inducer on number of branches of tomato

Treatments	2021-22					2022-23				
	Number of branches at different days				% increased over control after 40 days	Number of branches at different days				% increased over control after 40 days
	10 days	20 days	30 days	40 days		10 days	20 days	30 days	40 days	
T_1	2.67	3.23	4.97	5.77	26.28	2.87	3.43	5.27	6.07	24.66
T_2	3.13	3.70	4.90	5.37	17.52	3.33	3.90	5.20	5.67	16.44
T_3	2.87	3.43	4.77	5.83	27.74	3.07	3.63	5.07	6.13	26.03
T_4	3.33	3.83	5.23	5.50	20.44	3.53	4.03	5.53	5.80	19.18
T_5	2.87	3.57	4.57	6.30	37.96	3.07	3.77	4.87	6.60	35.62
T_6	3.40	4.10	5.27	6.83	49.64	3.60	4.30	5.57	7.13	46.58
T_7	3.33	3.97	5.37	6.17	35.04	3.53	4.17	5.67	6.47	32.88
T_8	2.60	3.30	4.83	5.90	29.20	2.80	3.50	5.13	6.20	27.40
T_9	3.67	4.63	6.03	7.73	69.34	3.87	4.83	6.33	8.03	65.07
T_{10}	2.47	3.23	4.90	5.83	27.74	2.67	3.43	5.20	6.13	26.03
T_{11}	2.47	3.23	5.03	5.57	21.90	2.67	3.43	5.33	5.87	20.55
T_{12}	3.07	3.37	5.03	5.70	24.82	3.27	3.57	5.33	6.00	23.29
T_{13}	2.70	3.00	3.57	4.57		2.90	3.20	3.87	4.87	
CD at 5%				0.474					0.470	
SEm±				0.162					0.161	
SEd				0.230					0.228	
CV				4.748					4.480	

Treatments-

Treatment 1 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ayo) with 10%, Treatment 2 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jha) with 10%, Treatment 3 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Har) with 10%, Treatment 4 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lak) with 10%, Treatment 5 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Var) with 10%, Treatment 6 = Seedling treatment + One foliar spray of culture filtrate with 10% of Trichoderma (Ban), Treatment 7 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Jab) with 10%, Treatment 8 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Usn) with 10%, Treatment 9 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Nag) with 10%, Treatment 10 = Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Ana) with 10%, Treatment 11 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Lud) with 10%, Treatment 12 =Seedling treatment + One foliar spray of culture filtrate of Trichoderma (Mot) with 10%, Treatment T_{13}= Control (Untreated)

5. CONCLUSION

The present investigation demonstrates the significant positive effects of culture filtrates of various *Trichoderma* isolates on the growth parameters of tomato plants, with notable improvements in plant height, root length, fresh and dry weight, and the number of branches. The culture filtrate of isolate *Trichoderma* Nag (T_9), particularly with seedling treatment and one foliar spray, was consistently the most effective, yielding the highest plant height, root length, and shoot/root fresh and dry weights across both growing seasons (2021-22 and 2022-23). Culture filtrate of other isolates, such as *Trichoderma* Ban (T_6) and *Trichoderma* Jab (T_7), also showed considerable growth-promoting effects, albeit to a lesser degree compared to treatment T_9. The enhanced plant growth is attributed to ability of *Trichoderma* to produce growth-promoting substances like auxins and other phytohormones, improve nutrient uptake and promote root architecture. These results align with previous studies, reinforcing the role of culture filtrate of *Trichoderma* as an effective inducer for improving plant health and productivity. The findings underscore the potential application of *Trichoderma* culture filtrates as a sustainable solution for enhancing crop growth in agricultural practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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