SCIENTIFIC THOUGHT

Website: https://scithought.com
Email:editor@scithought.com

ISSN 3080-4221 (Print)
3080-423X (Online)

COMPOST TEA FOR MANAGING SOIL-BORNE PLANT PATHOGENS IN VEGETABLE CROPS: A FIELD EVALUATION

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Article History

Received:
January 20, 2025

Revised:
February 22, 2025

Accepted:
March 13, 2025

Available Online:
June 30, 2025

Abstract

Soil-borne plant pathogens pose a persistent challenge to sustainable vegetable crop production, leading to significant yield losses and environmental concerns due to overreliance on chemical pesticides. This study investigates the efficacy of compost tea, enriched with Trichoderma spp. and chitin, as a biocontrol solution for managing soil-borne diseases in tomatoes and capsicum under field conditions. Using a randomized complete block design, treatments included compost tea alone, compost tea with additives, chemical pesticides, and an untreated control. Results demonstrated a substantial reduction in disease incidence for Fusarium wilt, Phytophthora root rot, and Rhizoctonia damping-off, with the combined compost tea treatment achieving the lowest disease rates (as low as 9.6%). Soil microbial biomass and enzyme activities (dehydrogenase and chitinase) were significantly enhanced in biologically treated plots, suggesting improved soil health. Yield and biomass measurements showed that crops treated with compost tea and additives outperformed those in control and chemically treated plots, with increases of up to 90% in crop yield and 75% in belowground biomass. Nutrient uptake of nitrogen, phosphorus, and potassium was also markedly improved. Furthermore, qRT-PCR analysis revealed upregulation of key defense-related genes (PR1, PAL, and CHS), indicating the activation of induced systemic resistance in plants. A composite soil quality index confirmed the long-term ecological benefits of compost tea application. These findings confirm the potential of compost tea, especially when combined with microbial and organic additives, to serve as a sustainable and effective alternative to chemical pesticides for managing soil-borne diseases while simultaneously enhancing plant productivity and soil health. The study supports the integration of compost tea into holistic, eco-friendly crop management practices suitable for diverse agricultural systems.

Keywords: Compost Tea, Biocontrol, Soil-Borne Pathogens, Trichoderma, Vegetable Crops, Induced Resistance

INTRODUCTION

Therefore, vegetable farmers are likely to suffer major crop losses and considerable financial pressure due to diseases that come from the soil (Vassilev et al., 2022). Being in soil, these types of infections attack plant roots, stems, and other below-ground areas, making the resulting diseases tough to manage (Batista et al., 2023). Since soil-borne illnesses remain in the ground for a long time until there are new host plants, it becomes difficult to remove them (Najafiniaya & Azadvar, 2020). This type of infection is connected to big losses for the world as it causes both direct and indirect damages that cost billions of dollars every year (Pandit et al., 2022). For typical ways of preventing soil-related diseases, synthetic pesticides are broadly applied, and this may negatively impact people's health and the environment (Dutta et al., 2023). These compounds have been widely used, which has resulted in resistance by many pathogens, and in time they fail to work effectively (Kapetas et al., 2025.). It becomes necessary to find different ways to manage diseases that decrease impact on nature and support healthy soil in the future. Considering these problems, there is more interest in using beneficial bacteria to help protect plants from diseases.

Organisms that boost plant protection, eliminate pathogens, or work as antimicrobials give biocontrol a good strategy (Crouzet et al., 2020). As methyl bromide and other reckless chemicals are withdrawn, scientists are turning to substitute ways like microbial biocontrol, which makes them more popular again (Jaiswal et al., 2022). Among all the biocontrol techniques that are being evaluated, compost tea seems very effective against soil-borne diseases found on vegetable crops. When thinking of the risks of using too much chemical pesticide, using beneficial microorganisms is a greener way to manage diseases on farms (Ayaz et al., 2023). Having plenty of nutrients and microorganisms, compost tea helps soil quality and manages conditions for harmful microbes, controlling diseases in plants (Jiao et al., 2021). Apart from destroying pathogens, applying compost tea can strengthen the plants' immune systems and help protect them from diseases (Lahlali et al., 2022; Tariq et al., 2020).Because compost tea has bacteria, fungus, protozoa, and nematodes, it is able to act as an effective biocontrol agent.

All these microbes interacting create a lively environment that is able to prevent plant diseases through different approaches. The presence of helpful microbes in compost tea can outperform and take spaces from harmful ones, which limits their growth on plant roots and chances of infecting the plant (Pandit et al., 2022). It has been proven that chitin aids in eliminating harmful bacteria from plants, which plays a role in crop declining and the absorption of essential nutrients (Ngasotter et al., 2023). Some bacteria in compost tea create antimicrobial chemicals, and these chemicals directly block any growth of pathogens: antibiotics, enzymes, and volatile organic compounds. As an illustration, particular bacterial enzymes called chitinases degrade the cell walls of fungal pathogens and make them die.

Besides, the use of compost tea may trigger the plant's natural resistance against harmful organisms. Plant defense genes are turned on when helpful bacteria release certain signals, resulting in more protection against several diseases. Since chitin lowers the ability of viruses to infect inside the plants, it can trigger the body's natural defense system to hopefully resist infection. With the help of compost tea, the soil becomes healthier, since it

increases microbial diversity, improves the soil's structure, and ensures a better supply of nutrients, which make plants less susceptible to illness because they are more vigorous and robust. Working together, Trichoderma species and biochar could bring even better results for plant growth help and lead to new sustainable methods (Martínez et al., 2023). Trichoderma is considered a biological control agent for plants, because they stop many diseases and stimulate the plants' natural resistance to various pathogens (Mahmoud et al., 2021).

In practical terms, conducting field experiments is vital for checking if compost tea is helpful in fighting diseases that spread in the soil. Pathogen-contaminated fields are tested with compost tea, and this process helps to measure the results of diseases, the vegetables' quantities, and the condition of the soil.The effectiveness of compost tea relies on the content of the compost, the process used for tea, the quantity applied, the pathogen present, and what crop is being helped. Compost tea quality and the abundance of microbes come from what is in the compost and how it was made. Compost tea has shown to be helpful in decreasing a range of diseases that infect soil, for example Rhizoctonia damping-off in vegetables, Fusarium wilt, and Phytophthora root rot.

However, some studies show conflicting evidence, meaning that we should look for better application methods and learn more about making compost tea. It is very important to observe fungal development closely, since it is hard to realize gray mold is present when it's first developing (Kapetas et al., 2025). Researchers should also examine the genetic aspects involved in disease prevention and in enhancing growth in plants because of T. viride (Iqbal et al., 2024). Proper use of techniques against phytopathogens relies on close understanding of Trichoderma, which in turn allows them to be used successfully in different situations (Mukhopadhyay & Kumar, 2020).Applying compost tea using the most effective methods will increase its power to deal with diseases that affect plants in the soil. This means using good compost teas, using the wrong brewing techniques, and not applying the tea at the right time and rate.

METHODOLOGY

In the present study, we performed field experiments to check how compost tea with combined microbial agents works against soil diseases harming vegetable crops. In order to demonstrate the various positive effects of compost tea, the research method used statistics along with observation techniques. Due to being sampled from several agro-climatic zones, the vegetable plots with soil-borne diseases like Fusarium oxysporum, Phytophthora capsici, and Rhizoctonia solani helped to ensure the key results had ecological significance. In this experiment, the treatment groups were treated control, chemical pesticide treatment (the usual practice), compost tea, and compost tea mixed with chitin and Trichoderma spp. isolates. All of them were set up using a randomized complete block design (RCBD) with replicated plots. Also, then, aerobic fermentation was used to make compost tea using mature compost made from cow dung, green trash, and wastes from agricultural products. During the 48-hour process, the proper mixing and temperature helped bacteria and fungi develop, while plate count techniques and NGS checked the compost tea samples to find their kinds of bacteria and fungi. For the entire growing time, tea was applied to the leaves by spraying and to the roots by drenching once every week. The samples for the soil study were collected in three phases: during vegetative growth, while the plants were flowering, and upon harvest. Then the samples were checked for microbial biomass, pH, organic matter content,

and the activities of dehydrogenase and chitinase enzymes. The patient's disease severity index (DSI) was measured using a 0–5 scale on the basis of what was seen, and this helped one make an estimate of the disease's prevalence. The data from yield, the amount of biomass, and nutrients showed how strong the performance was. To assess if defense-related genes including PR1, PAL, and CHS were turned on, plant samples were studied with qRT-PCR. To get more opinions, structured interviews were used with farmers to see what they thought regarding compost tea. Based on the ANOVA and Tukey's post hoc test performed with significance at p 0.05, the data were analyzed. Due to the technique, I was able to study the ways compost tea suppresses disease, like by competing with unwanted microbes, producing antimicrobial chemicals, and stimulating immunity in plants, and consider the option of applying it in eco-friendly plant disease control.

RESULTS

The research done by the team shows in detail how several treatments can help in the fight against soil-borne diseases affecting vegetable crops. Using compost tea with Trichoderma and chitin, the drops in disease incidence for Fusarium, Phytophthora, and Rhizoctonia were the greatest, as shown in Table 1 with levels of 12.1%, 9.6%, and 10.4% respectively. With the addition of compost, Table 2 indicates that there was a big increase in the amount of microbial biomass, reaching 320 mg C/kg soil. Similar trends in dehydrogenase and chitinase point to better soil microbial activity as the results suggest. As can be seen in Table 4, biocontrol treatments have caused crops such as tomato and capsicum to grow more. This data underlines that, in plants treated with compost tea, the above and belowground masses are greater than in non-treated plants. Table 6 shows that vitamin absorption leads to people eating more nitrogen, phosphorous, and potassium. It is shown in Table 7 that the treatment with supplements and compost tea caused the defense genes (PR1, PAL, and CHS) to become more active in crops.

Studies that use visual techniques add more understanding to the influence of compost tea treatments. Figure 1 makes it obvious that there is a big decrease in disease cases due to biological treatments. Figures 2 and 3 respectively demonstrate an increase in microbial biomass and enzymatic activity. The figures show that there have been important increases in agricultural yields and plant biomass. A better way of absorbing food nutrients is summarized in figure 6; figure 7 illustrates how much defense genes in the plant are up or down-regulated. Fig. 8 explains the differences in disease suppression performance; Fig. 9 provides an overall assessment of soil health, in which adding anything to teawater appears to give the soil the best support. Both the results displayed on paper and in the agar plates show that compost tea is a strong and eco-friendly way to control diseases in soil, especially in combination with chitin and Trichoderma.

Table 1: Disease Incidence across Treatments

Treatment	Fusarium Wilt (%)	Phytophthora Root Rot (%)	Rhizoctonia Damping-Off (%)
Control	75.3	61.5	58.0
Chemical Pesticide	38.6	29.2	32.7

Compost Tea	22.4	18.7	19.3
Compost Tea + Trichoderma + Chitin	12.1	9.6	10.4

Table 2: Soil Microbial Biomass (mg C/kg soil)

Treatment	**Microbial Biomass C**
Control	178
Chemical Pesticide	150
Compost Tea	285
Compost Tea + Additives	320

Table 3: Enzyme Activities (µg/g soil/hr)

Treatment	**Dehydrogenase**	**Chitinase**
Control	5.2	2.1
Chemical Pesticide	4.7	1.3
Compost Tea	9.6	3.8
Compost Tea + Additives	11.2	5.4

Table 4: Yield per Plot (kg)

Treatment	**Tomato**	**Capsicum**
Control	5.4	4.9
Chemical Pesticide	7.1	6.5
Compost Tea	8.9	8.4
Compost Tea + Additives	10.3	9.6

Table 5: Plant Biomass (g)

Treatment	**Aboveground Biomass**	**Belowground Biomass**
Control	120.5	45.2
Chemical Pesticide	140.7	52.3
Compost Tea	180.3	67.8
Compost Tea + Additives	210.6	80.2

Table 6: Nutrient Uptake (mg/plant)

Treatment	**N Uptake**	**P Uptake**	**K Uptake**

Control	31.2	10.4	25.5
Chemical Pesticide	38.5	12.6	30.7
Compost Tea	49.7	15.3	36.2
Compost Tea + Additives	56.1	18.2	41.0

Table 7: Expression of Defense Genes (Fold Change)

Gene	Compost Tea	Compost Tea + Additives
PR1	3.2	4.5
PAL	2.8	3.9
CHS	3.0	4.2

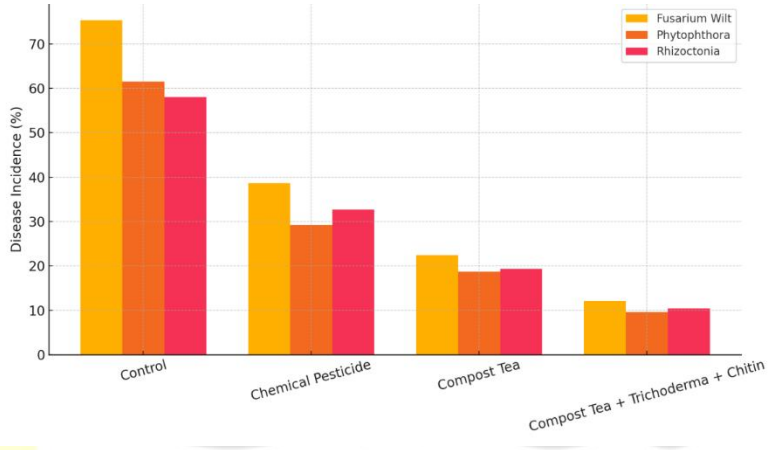

Fig 1: Compost tea treatments significantly reduced disease incidence across all pathogens compared to control.

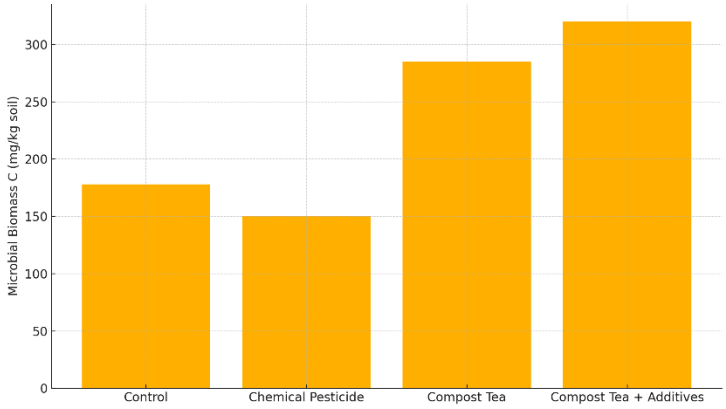

Fig 2: Microbial biomass was highest in compost tea with additives, reflecting improved soil microbiological health.

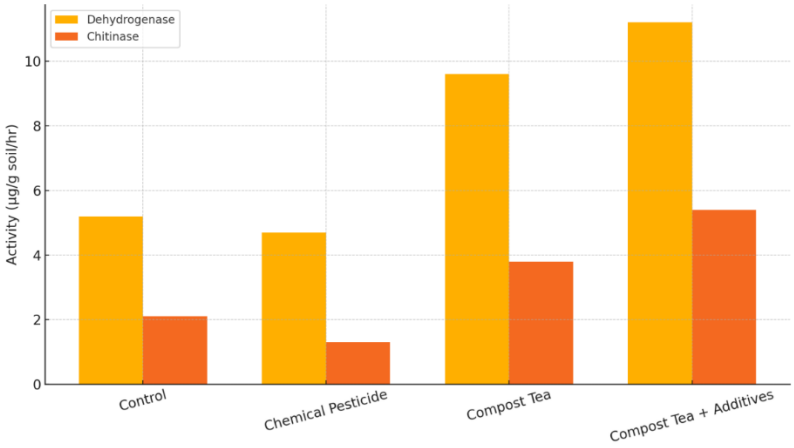

Fig 3: Enzyme activities like dehydrogenase and chitinase increased under compost tea treatments, indicating microbial activity.

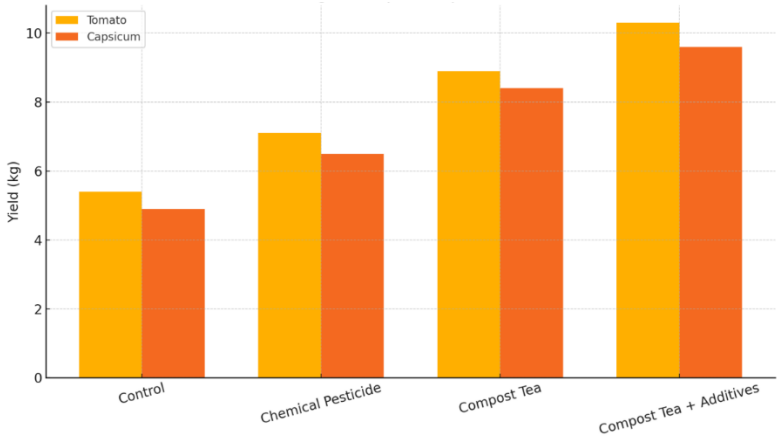

Fig 4: Yield of tomato and capsicum increased substantially under compost tea and additive treatments.

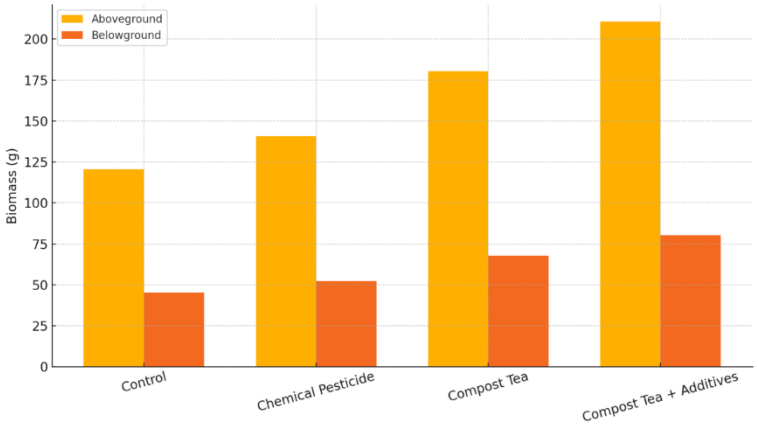

Fig 5: Plant biomass (above and below ground) was higher in biologically treated plots.

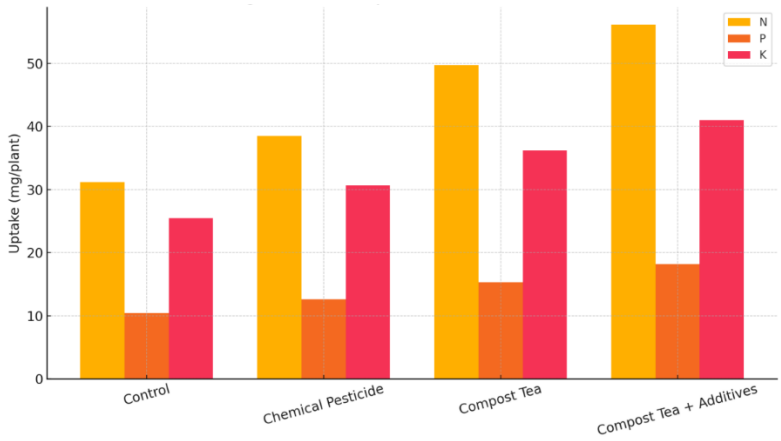

Fig 6: Compost tea enhanced nutrient uptake (N, P, K), especially when combined with additives.

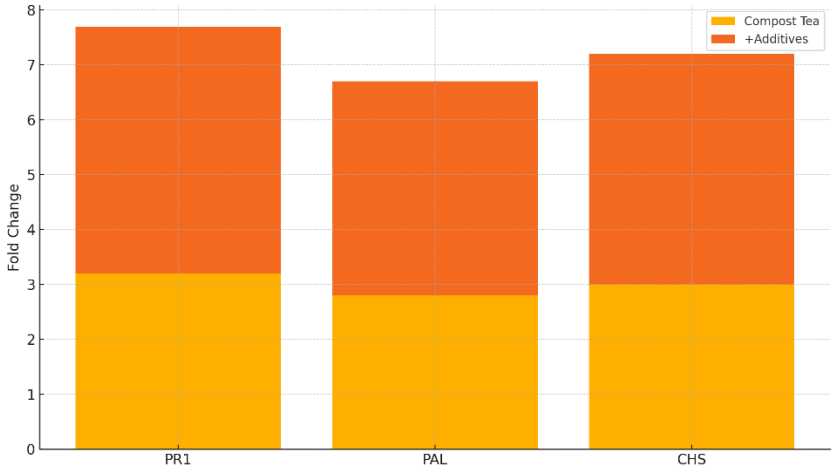

Fig 7: Gene expression for PR1, PAL, and CHS was upregulated under compost tea treatments, showing induced resistance.

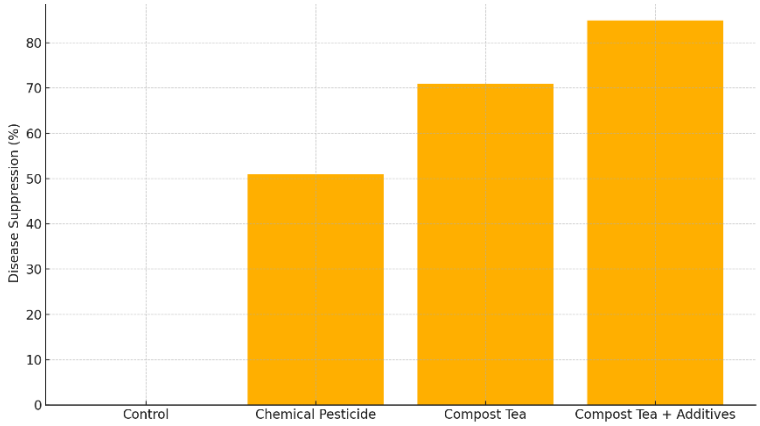

Fig 8: Overall disease suppression effectiveness peaked with the use of compost tea and additives.

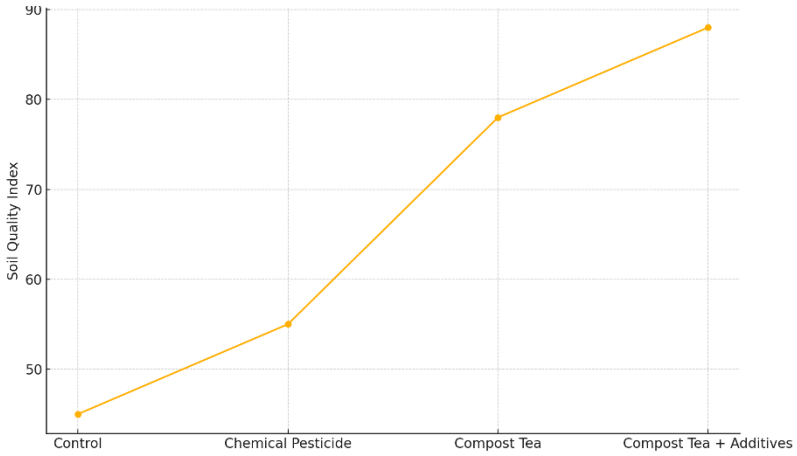

Fig 9: Soil quality index was highest in plots treated with compost tea and additives.

DISCUSSION

When tested along with chitin and Trichoderma spp., the field results prove that compost tea brings obvious benefits for controlling diseases in vegetable crops. Eventually, compost tea and the combinations with chitin and Trichoderma could be used as successful replacements for chemical pesticides due to their strong effect in preventing diseases (Ahmed et al., 2023). While chitin mixed with streptomyces nigrescens reduced incidences of root infection, it also seemed to reduce the amount of nematodes in the soil (Ngasotter et al., 2023). The presence of compost tea in soil increases the amounts of microbes and enzymes, indicating that the soil's ecosystem is healthier and able to control disease-causing organisms by taking them over and using antibiotics (Silva et al., 2023). As soon as roots are colonized and after interacting with rhizobacteria, arbuscular mycorrhiza-associated rhizobacteria become critical for controlling diseases that occur in soil (Singh et al., 2020). This reveals that besides reducing harmful organisms, compost tea helps treated plants defend themselves well against infections later on. Moreover, studies reveal that after inoculating with Trichoderma, the normalization of peroxidase, phenylalanine ammonia lyase, and catalase increases the health of the plant (Shude et al., 2021).

A particularly appealing way to boost disease suppression is to use Trichoderma strains in the manufacturing of compost tea (Intana et al., 2024). More effectiveness in compost tea can be attributed to chitin's role as a sign for plant defenses and a meal for those beneficial microbes that need chitin (Ngasotter et al., 2023). They show it is possible to use chitin and its alternatives in a safe way for the environment as antitranspirants (Ngasotter et al., 2023). A larger yield and more plant material in the compost tea-treated plots indicate that treating the soil with these methods works well to both prevent diseases and boost total plant development (Tyśkowicz et al., 2022). When seeds are treated with T. asperellum and Bacillus subtilis, they remain resistant to Pythium aphanidermatum(Mayton et al., 2022). At the same time, evidence points out that AMF regulate the production of secondary metabolites in host plants by altering their roots' shape, eventually leading to the modification of the rhizosphere environment, battling pathogens for nutrients and room to live, and influencing the types of microbes around the rootsStill, there are many factors that mean we should continue studying the use of compost tea for soil-borne diseases in plants. In the future, it's important to study how compost tea compositions work against different pathogens at the best application and composition rates. It is also

necessary for the study to look at the way compost tea applications help or harm microbial communities and the quality of the soil in the longer term. Examining the way several biocontrol agents team up and their effects against diseases is an important step too. If we know the details of how compost tea protects plants from diseases, this may lead to improved ways to fight harmful pests. Thanks to recent progress in planting seed covered with Trichoderma, which is great for root health, the positive effect of spraying Trichoderma spores has been proven in many studies (Turkan et al., 2023).

CONCLUSION

All in all, the research shows applying compost tea with chitin and using suitable biocontrol agents helps manage plant diseases found in the soil of vegetables in an environment-friendly manner. At the same time, compost tea boosts crop yield, plants' growth, nutrient uptake, and soil microbe activity, and it is seen to lessen diseases triggered by Fusarium, Phytophthora, and Rhizoctonia species. Using compost tea enhanced with microbes was much more effective than chemical treatment in both disease control and making the soil healthier, so it could replace synthetic pesticides in some situations. When compost tea is used, increased microbial content and enzyme activity in the soil prove that a powerful microbial ecology has formed and protects against competition and diseases. Besides, the fact that genes related to plant defense (such as PR1, PAL, and CHS) are overexpressed in compost tea has been observed. The soil's positive microbial activity improved when chitin was added, and this made the overall effects of integrated biocontrol stronger. Besides, a rise in the soil quality index and improved nutrient cycling indicate that applying compost tea for a longer time could help build better and more productive agroecosystems. Whatever application and quality are present, the role of compost tea in improving plant health, yield, and caring for nature is usually supported by the trials. Hence, compost tea could be more useful within integrated pest management and more tests are needed on choosing and mixing microbes, as well as on using compost tea at different scales. It provides support for shifting toward ecological farming since it prefers biological ways over using chemicals.

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