International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 03 , March - 2026

The Effects of *Trichoderma* spp. and *Saccharomyces cerevisiae* on the Growth of Pepper *(Capsicum annuum L.)* Plant and Root Rot Disease Caused by *Phytophthora capsici* Leonian

Emre Demirer Durak
Yuzuncu Yil University, Agriculture Faculty, Plant Protection Department, 65080, Van, Turkey

Abstract - Pepper (*Capsicum annuum* L.) is an important vegetable crop in Turkey. Phytophthora root rot, caused by *Phytophthora capsici* Leonian, is an important soilborne plant disease that causes economic losses inTurkey and world-wide. Biological control of different plant diseases was focused primarily using fungi. In this study, the effects of *Trichoderma* spp. and yeast were investigated on the growth of pepper and *P. capsici* disease. *Trichoderma* spp., has potential as a biological control agent against several soilborne pathogens and shown to be capable of increasing plant growth and yields. Application of yeasts as biocontrol agents acts as a new trend against different pathogens. Especially *Saccharomyces cerevisiae* is considered a new promising plant growth promoting yeast for different crops. Under controlled conditions, two F1 pepper cultivars were inoculated (Bafra and Sirena) with three different *Trichoderma* strains (*Trichoderma harzianum*, *Trichoderma virens* and *Trichoderma asperellum*) and yeast (*Saccharomyces cerevisiae*) in order to determine the most appropriate combination of *P. capsici*. Inoculated pepper seedlings were grown in a greenhouse for about 10 weeks at 22-24 °C. The experiment was conducted two times in three replications. At the end of the study, it was found that *Trichoderma* spp. and yeast application significantly increased the growth components (plant height, shoot fresh and dry weights, root fresh and dry weights) compared to control pepper plants or inoculated with *P. capsici* alone. Similarly *Trichoderma* spp. and yeast significantly reduced the harmful effects of the disease. The best affinity was determined *T. harzianum* x *S. cerevisiae* combination. Also, the results indicate that *S. cerevisiae* have strong potential as plant growth promoters and as biocontrol agents of the soil-borne fungal plant pathogen *P. capsici* causing root rot in pepper.

Key words: Pepper, *Phytophthora capsici* Leonian, *Saccharomyces cerevisiae, Trichoderma* spp.

I. INTRODUCTION

Pepper (*Capsicum annuum* L.), a member of the Solanaceae family, is an economically important vegetable crop cultivated worldwide. However, its production is severely constrained by numerous diseases and pests that lead to significant yield and quality losses. Among these diseases, Phytophthora blight caused by *Phytophthora capsici* Leonian is considered one of the most destructive pathogens affecting pepper cultivation. This soil-borne pathogen is widely distributed in pepper-growing regions and can infect plants at all developmental stages. During the seedling stage, it causes root and collar rot, leading to plant wilting and death, whereas in later stages it infects roots, stems, leaves, and fruits, resulting in severe economic losses [1,2,3]. Due to the pathogen's biological characteristics and persistence in soil, the management of *P. capsici* remains difficult. Although chemical fungicides and cultural practices are commonly used, their effectiveness against soil-borne pathogens is often limited and may raise environmental and health concerns. Therefore, environmentally friendly and sustainable alternatives such as biological control have gained increasing importance in plant disease management [4].

Among microbial biocontrol agents, species of the genus Trichoderma have been widely studied because of their strong antagonistic activity against plant pathogens and their plant growth–promoting properties. Trichoderma species are commonly found in soils rich in organic matter and are characterized by rapid growth, high competitive ability, and the production of various antimicrobial metabolites [5,6]. These fungi suppress pathogens through several mechanisms, including mycoparasitism, antibiosis, competition for nutrients and space, and the activation of plant defense responses [7,8]. Numerous studies have demonstrated the effectiveness of *Trichoderma* spp. against *P. capsici*. For example, *Trichoderma harzianum* has been shown to significantly reduce disease severity and mitigate pathogen-induced reductions in plant biomass [9], while other species such as *T. viride* and *T. reesei* can inhibit the mycelial growth of *P. capsici* and improve plant growth parameters [10]. Additionally, *Trichoderma* spp. are capable of parasitizing *P. capsici* hyphae and degrading its reproductive structures, thereby limiting pathogen development [11].

In addition to filamentous fungi, yeasts have recently emerged as promising biological control agents in plant disease management. Yeasts can suppress plant pathogens through mechanisms such as competition for nutrients and space, production of

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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antifungal metabolites, and induction of plant defense responses. Among them, *Saccharomyces cerevisiae*, commonly known as baker's yeast, has received considerable attention due to its safety, natural occurrence, and ease of cultivation [12]. Previous studies have reported that *S. cerevisiae* can inhibit plant pathogens such as *Fusarium oxysporum* while simultaneously enhancing plant growth parameters and chlorophyll content [13]. Moreover, yeast applications have been shown to reduce disease severity and improve plant biomass in several crops [14]. Despite these promising findings, studies evaluating the combined or comparative effects of *Trichoderma* spp. and yeasts on pepper growth and *Phytophthora capsici* disease remain limited. Therefore, the aim of this study was to investigate the effects of *Trichoderma* spp. and *Saccharomyces cerevisiae* on the growth of pepper plants and the development of root rot disease caused by *Phytophthora capsici*, and to assess their potential as environmentally friendly biological control agents.

The results of this study are expected to contribute to the development of sustainable and environmentally friendly disease management strategies for pepper cultivation by highlighting the potential of microbial biocontrol agents as alternatives to chemical fungicides.

II. MATERIALS AND METHODS

Under controlled conditions, two F1 pepper cultivars were inoculated (Bafra and Sirena) with three different *Trichoderma* strains (*Trichoderma harzianum*, *Trichoderma virens* and *Trichoderma asperellum*) and yeast (*Saccharomyces cerevisiae*) in order to determine the most appropriate combination of *P. capsici* Leonian. These pepper cultivars are used often in Turkey. Isolates were provided by the Collection of Mycology, Plant Pathology Department, University of Yuzuncu Yil. Isolates were identified with molecular techniques previously. *Trichoderma* isolates were obtained from soil and *P. capsici* was obtained from pepper. The bio-compound used in this study is active dry yeast of *S. cerevisiae*. The seeds were sown to pot including sterile mixture of peat and sand. *Trichoderma* species were grown on PDA incubated for 7 days at 24 °C. The spore suspensions were prepared $1x10^6$ conidia/ml with the aid of a haemacytometer slide. These suspansions were added to soil 10 ml separately . Yeast application was conducted as soil inoculation using concentration of 5 g L^{-1}. Two weeks later, the plants were inoculated with 10 ml of a zoospore suspension of *P. cactorum (*10^5 ml^{-1} zoospores) to each plant with a pipette. Inoculated pepper seedlings were grown in a greenhouse for about 10 weeks at 22-24 °C. The experiment was conducted two times in three replications. Disease severity was determined with a (0–5) scale (0 = no symptom and 5 = plant death), plant height, shoot and root fresh and dry weights (oven-dried at 70ºC for 48 h) were recorded [15,16]. Data were subjected to analysis of variance (ANOVA), and mean comparisons were performed using the Waller–Duncan multiple range test at $P < 0.05$.

III. RESULTS AND DISCUSSION

The results of the present study demonstrate the effects of *Trichoderma* spp. and *Saccharomyces cerevisiae* on pepper plant growth and the suppression of *Phytophthora capsici*. Overall, microbial treatments improved plant growth parameters and reduced disease severity compared with the pathogen-inoculated control, highlighting the potential of these microorganisms as biological control agents in sustainable pepper production systems. The effects of different microbial treatments on growth parameters and disease incidence of pepper plants are presented in Table 1.

TABLE 1. Effects of *P. capsici, T. harzianum, T. virens, T. asperellum*, and *S. cerevisiae* treatments on growth parameters and disease incidence in pepper plants.

Treatments	**Shoot height (cm)**	**Root height (cm)**	**Shoot fresh weight (g)**	**Shoot dry weight (g)**	**Root fresh weight (g)**	**Root dry weight(g)**	**Disease incidence (%)**
Control	13.8 bc*	19.2 ab	17.8 bc	2.2 a	6.4	1.5	-
T. harzianum	15.5 b	22.4 a	21.4 a	2.0 ab	6.5 bc	1.3 b	-
T. virens	14.3 b	18.7 b	17.5 c	1.5 c	7.4 b	1.4 b	-
T.asperellum	13.2c	17.4 c	18.7 b	1.9 b	5.5 c	1 c	-
S. cerevisiae	15.6 b	17.0 c	18.0 b	1.8 b	6.2 c	1.2 b	-

T. harzianum+ S. cerevisiae	19.0 a	21.1 a	19.4 ab	1.9 b	9.0 a	1.8 a	-
T. virens+ S. cerevisiae	14.6 b	19.0 ab	17.0 c	1.6 c	7.7 b	1.3 b	-
T. asperellum+ S. cerevisiae	16.1 ab	17.3 c	15.4 d	1.8 b	6.5 bc	1.2 b	-
T.harzianum+T.virens +T.asperellum+ S.cerevisiae	13.0 c	15.9 c	16.8 c	1.2 d	5.2 c	1.4 b	-
P.capsici	13.2c	16.4 c	16.3 d	1.3 d	7.0 b	1.4 b	78.8
T. harzianum + P.capsici	18.4 a	17.8 bc	20.4 a	1.6 c	9.3 a	1.7 a	**42.6**
T. virens+ P.capsici	16.0 ab	21.5 a	18.6 b	1.9 b	4.4 cd	1.1 c	47.3
T. asperellum + P.capsici	12.5cd	18.7 b	16.3 d	1.5 c	4.0 d	0.8 c	59.6
S. cerevisiae + P.capsici	11.6 d	16.8 c	17.4 c	1.8 b	5.4 c	1 c	54.9
T.harzianum+T.virens +T.asperellum+ S.cerevisiae + P.capsici	16.5 ab	18.0 b	15.2 d	1.6 c	5.5 c	1.1 c	45.1

*values within columns followed by different letters were significantly different ($P < 0.05$) according to the Waller-Duncan procedure.

Microbial applications generally improved plant growth compared with the untreated control. Among the treatments without pathogen inoculation, the combination of *T. harzianum* + *S. cerevisiae* produced the highest shoot height (19.0 cm) and root fresh weight (9.0 g), indicating a strong plant growth–promoting effect. In contrast, the treatment including all tested microorganisms (*T. harzianum* + *T. virens* + *T. asperellum* + *S. cerevisiae*) resulted in comparatively lower growth parameters, which may indicate competition among microbial agents within the rhizosphere environment.

In plants inoculated with *P. capsici*, disease incidence reached 78.8% and was associated with significant reductions in plant growth parameters. However, the application of microbial agents substantially reduced disease incidence and mitigated the negative effects of the pathogen. Among the tested treatments, *T. harzianum* showed the highest level of disease suppression and significantly improved plant growth compared with the pathogen-only treatment. The combination of *T. harzianum* and *S. cerevisiae* further enhanced plant growth performance, suggesting a possible synergistic interaction between fungal and yeast-based biocontrol agents. No significant differences were observed between the two F1 pepper cultivars; therefore, the results were evaluated collectively.

This synergistic interaction between *Trichoderma* spp. and yeasts may be explained by their complementary modes of action in the rhizosphere environment. While *Trichoderma* species are known to suppress pathogens through mycoparasitism, production of antifungal metabolites, and induction of systemic resistance, yeasts can contribute to pathogen inhibition through nutrient competition, antibiosis, and secretion of lytic enzymes. The combined presence of these microorganisms may therefore create a more suppressive rhizosphere environment, enhancing both pathogen inhibition and plant growth promotion. Similar synergistic effects between fungal and yeast biocontrol agents have been reported in several studies, suggesting that multi-microbial approaches may provide more stable and effective biological control strategies than single-agent applications.

The effectiveness of Trichoderma species in suppressing *Phytophthora capsici* has been widely reported in previous studies. For example, [17] reported that *T. asperellum* (T34 strain) reduced disease severity by up to 71% in pepper under greenhouse conditions and significantly increased plant biomass. Similarly, [18] demonstrated that *T. longibrachiatum* and *T. aggressivum f. europaeum* reduced disease severity caused by *P. capsici* by 76% and 54%, respectively. The antagonistic activity of *Trichoderma* spp. is generally attributed to several mechanisms, including mycoparasitism, competition for nutrients and space, and the production of antifungal metabolites and cell wall–degrading enzymes.

In addition to filamentous fungi, yeasts have also been reported as promising biological control agents against several plant pathogens. Yeasts are known to suppress pathogens through mechanisms such as antibiosis, nutrient competition, production of lytic enzymes, and the induction of plant defense responses. In the present study, *S. cerevisiae* also contributed to plant growth promotion and disease suppression, supporting its potential role as a plant growth–promoting microorganism.

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Previous studies have also demonstrated that *Trichoderma* spp. can stimulate plant growth by enhancing nutrient uptake, producing phytohormone-like compounds, and improving root development. For instance, [9] reported that *T. harzianum* alleviated the reduction in plant biomass caused by *P. capsici* infection and helped maintain plant growth under pathogen pressure.

Furthermore, the combined application of different biological control agents may enhance disease suppression through complementary mechanisms. [19] demonstrated that the combination of *Trichoderma* spp. and yeast culture filtrates effectively suppressed damping-off and root rot pathogens while simultaneously stimulating plant defense enzymes and improving plant physiological traits. Such synergistic interactions between beneficial microorganisms may increase the effectiveness and reliability of biological control strategies.

Overall, the results of this study confirm that *Trichoderma* spp., particularly *T. harzianum*, and *Saccharomyces cerevisiae* can significantly improve pepper plant growth and reduce disease severity caused by *Phytophthora capsici*. These findings highlight the potential of combining beneficial fungi and yeasts as an environmentally friendly strategy for sustainable management of soil-borne diseases in pepper cultivation.

IV. CONCLUSION

The results of this study demonstrate that *Trichoderma* spp. and *Saccharomyces cerevisiae* significantly improved pepper plant growth and reduced disease severity caused by *Phytophthora capsici.* Among the tested treatments, *T. harzianum* alone and in combination with *S. cerevisiae* showed the most promising effects on plant growth promotion and disease suppression. The microbial applications enhanced plant growth parameters while mitigating the negative effects of pathogen infection. These findings highlight the potential of beneficial fungi and yeasts as environmentally friendly biological control agents for the management of soil-borne diseases in pepper production. Further studies under field conditions are recommended to confirm the effectiveness of these microorganisms in practical agricultural systems.

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