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Research Article

Investigating the effectiveness of ginger and turmeric extracts on common soil-borne pathogens affecting plants

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ABSTRACT

The global agricultural industry faces significant concerns related to soil-borne pathogens, resulting in crop yield reduction, compromised crop performance, and elevated production costs. In order to address soil-borne diseases, there is a prevalent reliance on chemical fungicides to manage soil-borne pathogens, leading to adverse environmental effects. Therefore, it is desire need to adopt environmental friendly management practices. Keeping in view, in this study, two botanical extracts (Ginger and Turmeric) were investigated against some common soil-borne pathogen (*Fusarium sp* and *Rhizoctonia sp*) under vitro and vivo conditions. As a result of the experiments, turmeric plant extract at different concentrations significantly inhibited the growth of both *Fusarium* (74.59 %) and *Rhizoctonia sp* (73.49%) as compared to Ginger extract showed slightly less inhibitory effect against both soil borne pathogens. Furthermore, previously highly performed turmeric extract was subjected for vivo evaluation against *Rhizoctonia solani* and *Fusarium* sp. and result revealed that the application of turmeric extract led to a significant reduction in disease severity and incidence in both soil borne pathogens.

Keywords: Soil-borne; ginger; turmeric; *Fusarium oxysporum*; *Rhizoctonia solani*.

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INTRODUCTION

Plants are constantly threatened by pests and diseases. Plant diseases cause 14.1% of the global food crop losses today, accounting for $220 billion in agricultural trade losses annually. It is estimated that 20% to 40% of food crops are lost each year to pests and diseases (Khakimov et al., 2022). Approximately half of the world's population relies on agriculture for their income. The income of growers is significantly reduced by the damage caused by plant pathogens and pests (Mamarabadi et al., 2018). Worldwide, almost all types of crops are attacked by pests and diseases, most of which are caused by fungi. A fungal and bacterial infection causes around 50% of crop postharvest losses (Choudhury et al., 2018). Crop production is adversely affected by soil-borne diseases. Numerous soil-borne plant pathogens are causing 50-75% yield losses in wheat, cotton, maize, vegetables, fruits, and ornamentals, such as *Rhizoctonia, Fusarium, Verticillium, Sclerotinia, Pythium, and Phytophthora* (Panth et al., 2020). In many cases, a plant pathogen can persist for an extended period in plant debris, soil organic matter, free-living organisms, or resistant structures, such as *microsclerotia, sclerotia, chlamydospores,* and *oospores*. There is often a difficulty in diagnosing a certain disease accurately due to the similarities among symptoms such as damping-off of seedlings, root blackening, root rot, stunting, wilting, yellowing, bark cracking, and twig or branch death (Mokhtar et al., 2014).

A large number of different diseases in plants are caused by fungi, which are an essential group of microorganisms that can reduce a plant's yield by a significant amount (Kharde et al., 2010). There are many chemicals that are available on the market for the treatment of fungus that causes crop damage. Several of them are highly effective in terms of cost-benefit ratio and efficacy. Although these substances are toxic, their indiscriminate use has caused air, soil, and water pollution, resistance development in target organisms, and health problems due to their residues. Plant diseases are usually managed with synthetic chemicals in a way that has led to an increase in crop protection. However, there has been a significant decline in both environmental quality as well as human health as a result of the use of synthetic chemicals in the management of plant diseases (Cutler & Cutler, 1999). According to various studies, several plants possess fungi-toxic properties against plant pathogens, which could be exploited to control a wide range of insects and weeds biologically, while having minimal or no untoward effects on the ecosystem, which would also provide a valuable source of biocontrol (Kumar et al., 2008).

Plants contain compounds that make them useful as sources of pests and disease treatment (Tabassum & Vidyasagar, 2013). These substances prevent bacteria and fungi from colonization, spreading, and reproducing, which leads to disease in a number of different plants, such as field crops and vegetables (Kekuda et al., 2016). Ginger has been demonstrated to have significant antioxidant antigenotoxic, antimutagenic, and anticarcinogenic effects in both *In vitro* and *In vivo* investigations. 3.6 percent of the ginger rhizome powder contains fatty oils. 9% protein, 60-80% carbohydrates, 3.8% crude fiber, 8% ash, 9-12% water, various substances, and terpenoids. The average moisture content of fresh ginger is 80.9%, along with 23.0% protein, 0.90% fat, and 1.20% sugar. (Kotaet et al., 2008). Turmeric is an herb that has been ideally used for medicinal purposes for approximately 4,000 years. Turmeric is used not just as a primary spice in Southeast Asia but also as a feature in religious festivals (Thimmayamma et al., 1983). This study aims to develop and implement a non-chemical, cost-effective, and sustainable plan to prevent soil-borne.

MATERIALS AND METHODS

Preparation of Fungal Pathogens

The two isolated fungi, *Fusarium oxysporum, and Rhizoctonia solani* were obtained from the Mycology Laboratory of the Plant Pathology department at Arid Agriculture University Rawalpindi. These fungi were then cultured on potato dextrose agar (PDA) media, and incubated for 7 days at 25°C. The single spore culturing method was used for obtaining the pure cultures. In order to identify both fungi, their cultures were observed under a microscope at a magnification of 400 X on a slide prepared from a 7-day-old culture of both pathogens. Then kept at 80°C in a stock solution of 30% glycerol, and then placed on a PDA medium for further study.

Preparation of Plant Extracts

Plant samples were purchased from a local market. The extract was made using the rhizomes of Ginger (*Zingiber officinale*) and Turmeric (Curcuma longa). Samples were extracted from plant extracts using a modified (Al-Samarrai at., el 2013). The plant samples were rinsed in distilled water after being washed with tap water. Materials for the samples were dried in an oven at 40°C for the entire night before being ground up in a mixer. The 20 g of powder was weighed and placed in a conical flask. The materials were combined with 200ml of 95% methanol and continuously stirred for 30 minutes. After that, the mixture was passed through Whatman No. 2 filter paper and two layers of cheesecloth. The filter was air-evaporated at room temperature. The concentrated stock solution was placed in a screw-capped bottle and stored at 4°C.

In vitro Evaluation of Plant Extracts

Plant extracts were further diluted for *In vitro* evaluation against fungal pathogens. Three concentrations of 30%, 40%, and 50% were prepared from stock solution by adding distilled water. Plant extracts were prepared in the laboratory. Three concentrations were prepared and three replicates of each concentration were evaluated by poison food technique against both fungal pathogens. PDA medium was made and chilled to 45°C. After adding the plant extracts, the mixture will then be poured into Petri dishes. 5m agar discs from the 7-day-old fungal pathogen were placed in the plate’s center as an inoculum. The media on the control plates won't have any plant extracts added. One has positive control over which mancozeb is used. Antifungal activity was assessed by measuring the fungal colony radial development at 7 days after plating by using the following formula (Al-Samarrai et al., 2013).

% of Inhibition

X= Growth of the control plate Y= Growth of Plant extract treated plate.

***In vivo* Evaluation of Plant Extract**

In-vivo management was done with best-performed turmeric extracts. Plants were grown in pots under controlled conditions. Inoculum *Fusarium oxysporum* and *Rhizoctonia solani* were prepared from 7-day-old cultures. Fungal mycelium was blended with PDA media to make a paste. 2.5g of paste was mixed in the mid-depth of the pot to infect the soil. The tomato plants were uprooted from previous pots and transferred to inoculated parts. After 48h of inoculation turmeric extract was applied by irrigating the pots with 10ml in each pot for each treatment. The results were compared with the Mancozeb 0.20mg/ml. Each treatment was replicated three times. The pots were arranged in a plant growth chamber at 27c and 16h light periods. The disease severity and height of the plants were recorded 7, 14, and 21 days after inoculation. On a scale of 0-5, severity was measured as follows: 0 = healthy plant, 1 = 1-10% of leaves have initial wilts, 2 = 11-25 percent have initial wilts, 3 = 26-49% of leaves have wilting and chlorosis, 4 = 50-74% of leaves show pronounced wilting and necrotic areas, and 5 = whole leaves have wilting Disease severity was recorded by the following formula (Mekam et al., 2019).

Disease severity = Disease severity (%) = $[\sum (d \times n) / (D \times N)] \times 100$

D = severity score; n = number of disease plants with the same severity score; N = number of plants examined.

RESULTS AND DISCUSSIONS

***In vitro* Evaluation of Plant Extracts**

Ginger and turmeric extract were evaluated *In vitro* experiments against *Fusarium oxysporum* and *Rhizoctonia solani* at three different concentrations.

Effect of Plant Extracts on *Fusarium* sp.

The study evaluated the antifungal potential of ginger and Turmeric extracts against *Fusarium oxysporum* (Table 1). After 3 days, the results indicated that among the different extract treatments, the highest fungal mycelial growth inhibition of about 74.1% was observed in the treatment T3 with a 50% concentration of ginger extract. Following T3, treatments T2 with 40% and T1 with 30% ginger extract showed approximately 68.7% and 61.6% growth inhibition, respectively, indicating a dose-dependent effect. However, the treatment T4, which contained only the fungicide Mancozeb (at 0.2 mg/mL concentration), exhibited the highest fungal growth inhibition among all the treatments. Similar trends in fungal growth inhibition were also observed after 7 days.

After 7 days, the results indicated that the highest fungal mycelial growth inhibition of about 73.6% was observed in the treatment T3 with a 50% concentration of ginger extract and showed 63.3% at T1 with 30% ginger extract. The observed trend of fungal growth inhibition from highest to lowest was T4> T3> T2> T1> T0, which implies that the fungicide Mancozeb was the most effective in inhibiting fungal growth.

The antifungal potential of turmeric extract against *Fusarium oxysporum* revealed significant inhibitory effects on fungal mycelial growth for various extract treatments. After 7 days, Treatment T3 50% exhibited the maximum fungal mycelial growth inhibition, to about 74.5%. Following this, T2 with 40% and T1 with 30% showed approximately 73.4% and 67.9% growth inhibition, respectively. Similar trends were observed after 3 days of the experiment. Notably, T4 treatment containing the fungicide Mancozeb at a concentration of 0.2 mg/mL demonstrated the highest inhibition of 100% among all treatments. The trend of fungal growth inhibition observed was as follows: T4 > T3 > T2 > T1 > T0. These trends were consistently observed in both the day-3 and day-7 observations.

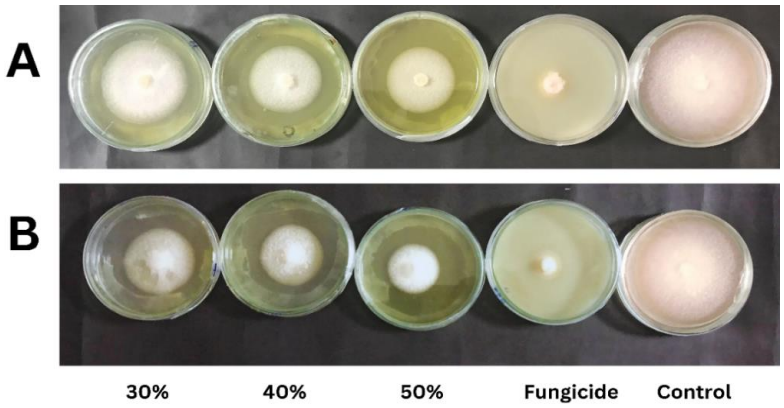

Figure 1. (A) *In vitro* efficacy of ginger against *Fusarium oxysporum* (B) *In vitro* efficacy of turmeric extract against *Fusarium oxysporum*.

Table 1. *In vitro* effect of plant extracts on *Fusarium* sp.

Treatments	Notation of Treatments	Concentrations	Inhibition (%) after 3 days	Inhibition (%) after 7 days
Healthy Control	T_0	0%	0.0 e	0.0 e
Ginger	T_1	30%	61.667 d	63.370 d
	T_2	40%	68.750 c	70.367 c
	T_3	50%	74.167 b	73.657 b
Mancozeb	T_4	0.2mg/mL	100.0 a	100.0 a
Healthy Control	T_0	0%	0.0 e	0.0 e
Turmeric	T_1	30%	65.037 e	67.947 d
	T_2	40%	69.933 c	73.487 b
	T_3	50%	71.133 c	74.593 b
Mancozeb	T_4	0.2mg/mL	100.0 a	100.0 a

***In vitro* Effect of Plant Extracts on *Rhizoctonia* sp.**

In this study, the in-vitro antifungal activity of the ginger and turmeric extract against the fungal pathogen *Rhizoctonia sp*. was investigated. Different concentrations of ginger extracts were tested, specifically 30%, 40%, and 50% in treatments labeled T1, T2, and T3, respectively. After 3 days, the results showed that among the ginger extract-containing treatments, the maximum mycelial growth inhibition of 70.6% was observed in T3, at a 50% concentration of ginger extract. Following this, T2 with 40% ginger extract showed a 63.4% growth reduction, and T1 with 30% ginger extract displayed a 42.2% growth reduction. Comparatively, the control treatment T4, which contained the fungicide Mancozeb at a concentration of 0.2 mg/mL, exhibited the highest inhibitory effect of 99.9%. After 7 days of treatment, the maximum mycelial growth inhibition of 72.1% was observed in T3, at a 50% concentration of ginger extract, and 50.5% growth inhibition at T1 with 30%.

The findings of this study are intriguing and align with previous research that has highlighted the potential antifungal activity of ginger and its bioactive components. Ginger, belonging to the *Zingiberaceae* family, is known for its diverse pharmacological properties, including antimicrobial and antifungal activities (Beristain-Bauza et al. 2019). Several studies have reported the effectiveness of ginger and its extracts against various fungal pathogens. For example, Wang et al. (2020) demonstrated the antifungal activity of ginger extract against Candida albicans (78% MGI), a common pathogen associated with fungal infections. Similarly, Rajasekaran et al. (2019) found that ginger extract displayed inhibitory effects on the growth of *Aspergillus flavus,* a fungus known to cause aflatoxin contamination in food and feed.

In this study, an *In vitro* evaluation of the antifungal efficacy of turmeric extract was also conducted. The results demonstrated that after 3 days of treatment, the highest antifungal activity of 71.5% at T3 with a 50% concentration of turmeric extract and 52.4% at T1 with a 30% concentration of turmeric extract. After 7 days of treatment, the highest antifungal activity of 73.4% at T3 with a 50% concentration of turmeric extract and 53.4% at T1 with a 30% concentration of turmeric extract. These results suggest that the antifungal activity of turmeric extract is concentration-dependent.

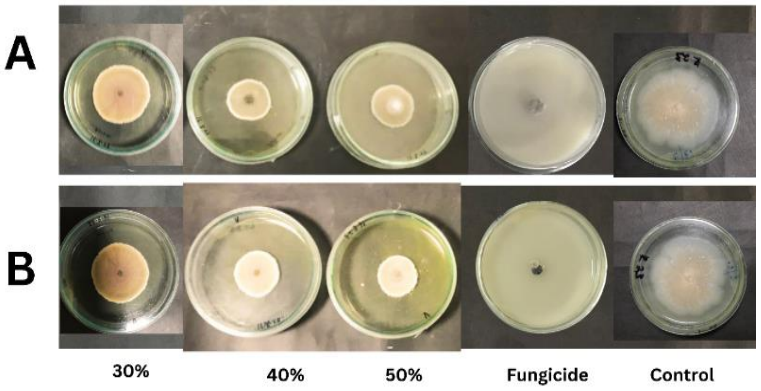

Figure 2. (A) *In vitro* efficacy of ginger against *Rhizoctonia solani* (B) *In vitro* efficacy of turmeric extract against *Rhizoctonia solani.*

Table 2. *In vitro* effect of Plant extracts on *Rhizoctonia solani*.

Treatments	Notation of Treatments	Concentrations	Inhibition (%) after 3 days	Inhibition (%) after 7 days
Healthy Control	T_0	0%	0.0 e	0.0 e
Ginger	T_1	30%	42.20 d	50.58 d
	T_2	40%	63.49 c	62.35 c
	T_3	50%	70.63 b	72.15 b
Mancozeb	T_4	0.2mg/mL	99.9 a	100.0 a
Healthy Control	T_0	0%	0.0 f	0.0 f
Turmeric	T_1	30%	52.42 e	53.43 e
	T_2	40%	67.66 d	69.33 cd
	T_3	50%	71.54 bc	73.49 b
Mancozeb	T_4	0.2mg/mL	100.0 a	100.0 a

***In vivo* effect of Turmeric Extract on Plant Height**

To investigate the effect of turmeric extract and *Rhizoctonia solani* pathogen on plant height was observed after 7, 14, and 21 days of application. All treatments show an increase in plant height as the day's progress from Day 7 to Day 21. The results indicate the effect of different treatments, *Rhizoctonia* and Turmeric extract, on the height of plants over a 21-day period. The height of the plants is measured in centimeters (cm) at three time points: Day 7, Day 14, and Day 21. The treatments include a control group treated with *Rhizoctonia*, Treatment 1 (T1) with Turmeric Extract, and Treatment 2 (T2) with Fungicide. Throughout the experimental period, the height of plants increased for all treatments. This is consistent with the natural growth of plants, as they tend to grow taller over time. However, there were noticeable differences in the growth patterns among the treatments. On Day 7, the control group treated with *Rhizoctonia* had the lowest average height of 3.10 cm. Treatment 1 (Turmeric Extract) and Treatment 2 (Fungicide) had slightly higher average heights of 3.57 cm and 3.87 cm, respectively. By Day 14, the differences in plant height became more evident. The control group treated with *Rhizoctonia* increased to an average height of 3.80 cm. Treatment 1 (Turmeric Extract) showed a greater increase in height, reaching an average of 4.67 cm. Treatment 2 (Fungicide) had the highest average height of 5.00 cm. Finally, at Day 21, the plants treated with the different treatments showed substantial growth. The control group treated with *Rhizoctonia* reached an average height of 5.20 cm. Treatment 1 (Turmeric Extract) displayed the most significant growth, with an average height of 6.67 cm. Treatment 2 (Fungicide) also demonstrated notable growth, reaching an average height of 6.97 cm.

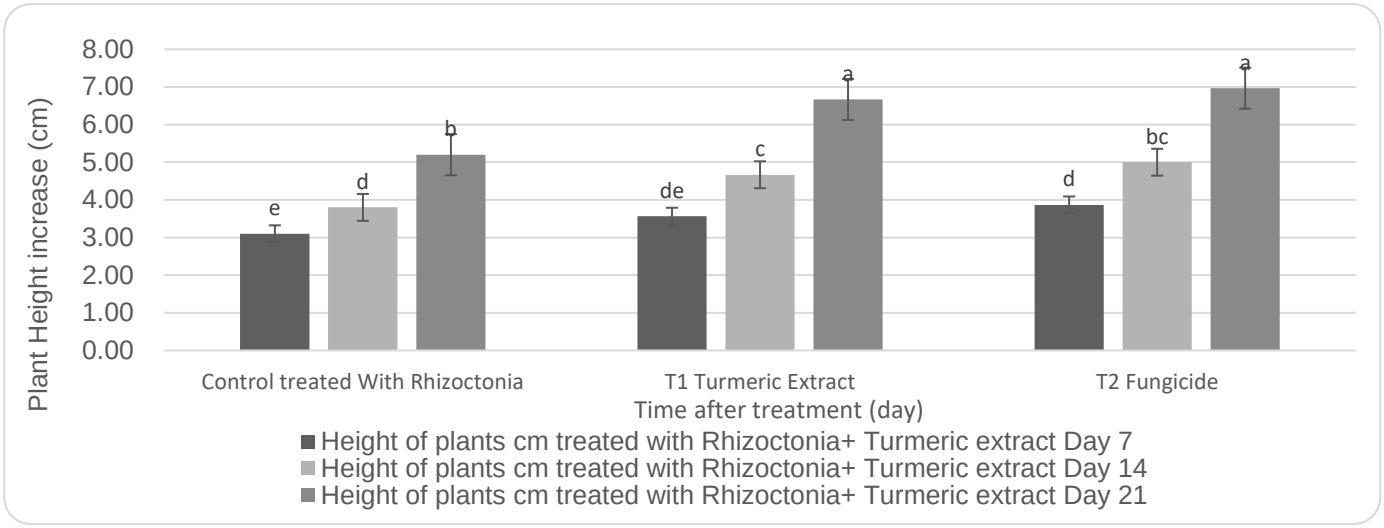

Figure 3. Height of plants (cm) treated with *Rhizoctonia sp* + turmeric extract.

The positive impact of Turmeric extract on plant growth aligns with previous studies on the potential benefits of Turmeric compounds in plant growth promotion and stress mitigation (Golpour et al., 2018). Turmeric has been reported to

contain bioactive compounds with antioxidant and anti-inflammatory properties, which may contribute to improved plant health and growth (Sarker et al., 2020). Moreover, the antimicrobial properties of Turmeric

The presented results display the heights of plants treated with *Fusarium* and Turmeric extract at different time points (Day 7, Day 14, and Day 21). The treatments include a Control treated with *Fusarium oxysporum*, Treatment 1 (T1) with Turmeric extract, and Treatment 2 (T2) with Fungicide. The heights of the plants are measured in centimeters (cm).

The data illustrates the progressive growth of the plants over time, as expected. Across all treatments, the heights increased from Day 7 to Day 21, indicating successful plant growth. Notably, Treatment 1 with Turmeric extract consistently exhibits higher plant heights compared to both the Control with *Fusarium* and Treatment 2 with Fungicide. This suggests that the application of Turmeric extract positively influences the growth of the plants, promoting taller heights at all three time points.

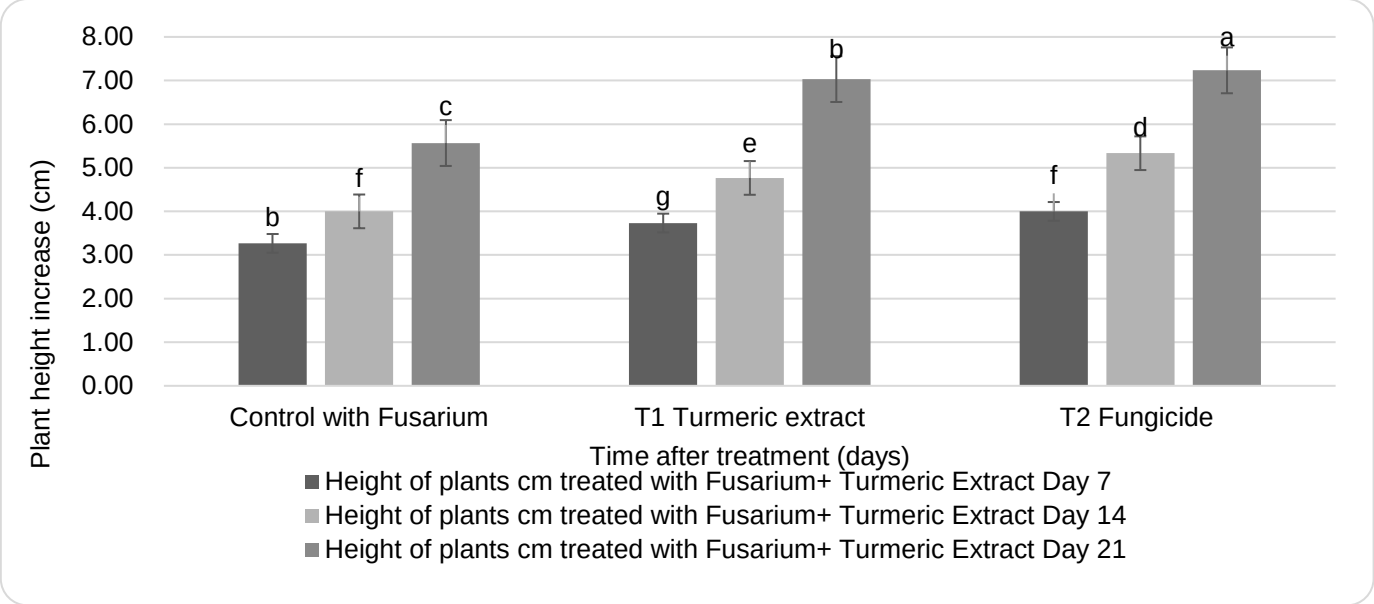

Figure 4. Height of plants (cm) treated with *Fusarium sp*+ turmeric extract.

***In vivo* effect of Turmeric Extract on Disease severity of both Fungi**

The *In vivo* efficacy of the prepared turmeric extract was assessed against the target fungus *Rhizoctonia solani.* The study recorded values after 7, 14, and 21 days, with T0 treatment serving as the control, containing only *Fusarium* without any treatment. T1 treatment included the application of turmeric extract, while T2 treatment consisted of the application of the fungicide mancozeb. The results of the study showed that the fungicide treatment (T2) exhibited the lowest mycelial growth percentage compared to the T1 turmeric extract and T0 control treatment. A lower mycelial growth percentage indicates a lower severity of the disease and higher fungal growth inhibition. Specifically, after 7 days of pathogen inoculation, T2 treatment demonstrated only 10% of mycelial growth, whereas the control treatment (T0) had approximately 30% fungal mycelial growth. The observations suggest that the fungicide treatment (T2) was highly effective in inhibiting the growth of *Rhizoctonia solani*, resulting in the least disease severity. On the other hand, the turmeric extract treatment (T1) exhibited intermediate efficacy, with a higher mycelial growth percentage compared to the fungicide treatment but still showing reduced disease severity as compared to the control treatment. The results presented in the table show the disease severity of plants treated with *Fusarium* and Turmeric Extract at different time points (Day 7, Day 14, and Day 21). The treatments include a control treated with *Rhizoctonia*, Treatment 1 (T1) with Turmeric extract, and Treatment 2 (T2) with Fungicide. Disease severity is measured as a percentage, with higher values indicating more severe disease symptoms. From the data, it is evident that disease severity decreases over time in all treatments. This reduction in disease severity is because of plant responses to applied treatments over time. Among the treatments, the most significant reduction in disease severity is observed in the group treated with "T2.

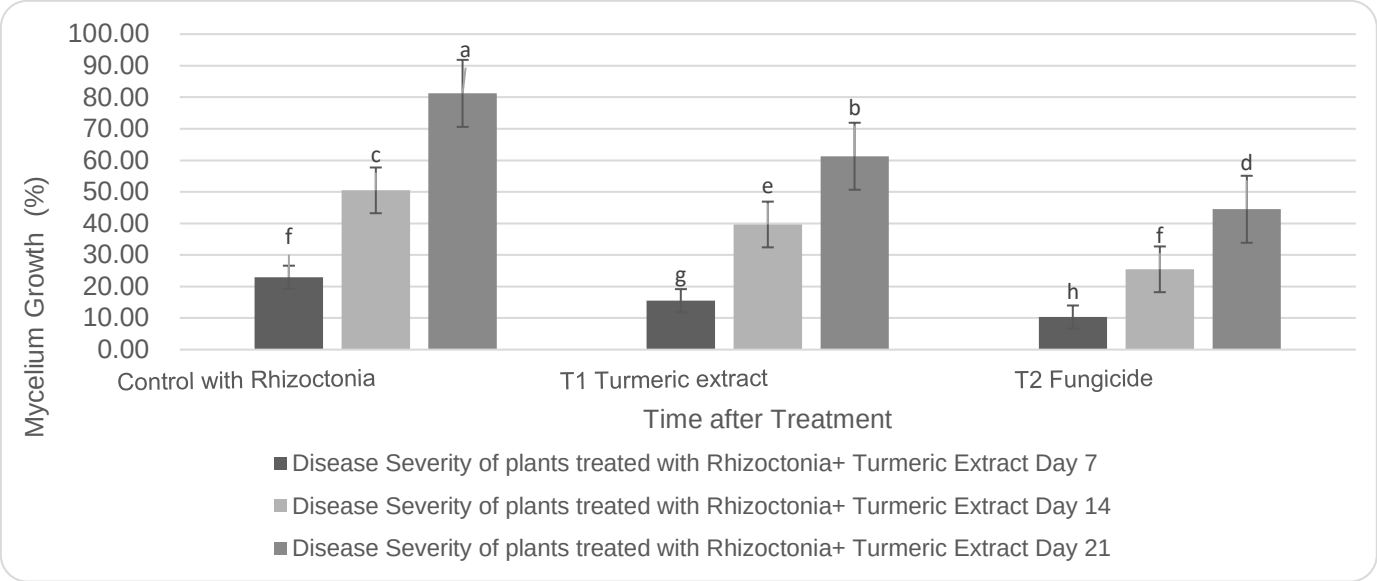

Figure 4. Disease severity of plants treated with Rhizoctonia+ turmeric extract.

Fungicide," showing the lowest disease severity values at each time point compared to the control and "T1 Turmeric extract." This indicates the efficacy of the fungicide treatment in managing the disease caused by *Fusarium*. Additionally, the "T1 Turmeric extract" treatment also shows a considerable reduction in disease severity compared to the control group. This suggests that the Turmeric extract has potential antifungal properties that could be beneficial in mitigating *Fusarium*-related diseases in plants. The "Control with *Rhizoctonia*" group exhibits the highest disease severity values throughout all time points, signifying that the pathogen *Rhizoctonia* significantly impacts disease development and progression in the absence of treatments.

***In vivo* Effect of Turmeric Extract on Disease Incidence of Both Fungi**

Here in the table, the mean values of each treatment are shown with standard deviations. Small alphabets show homogeneous groups according to LSD pair-wise comparison. On the other hand, the application of "T2 Fungicide" also resulted in substantial disease severity reduction, consistent with previous research indicating the efficacy of various fungicides in controlling *Fusarium* infections (Akhtar et al., 2019; Hamzah et al., 2021). These fungicides often act on specific biochemical pathways of the pathogens to suppress their growth and spread.

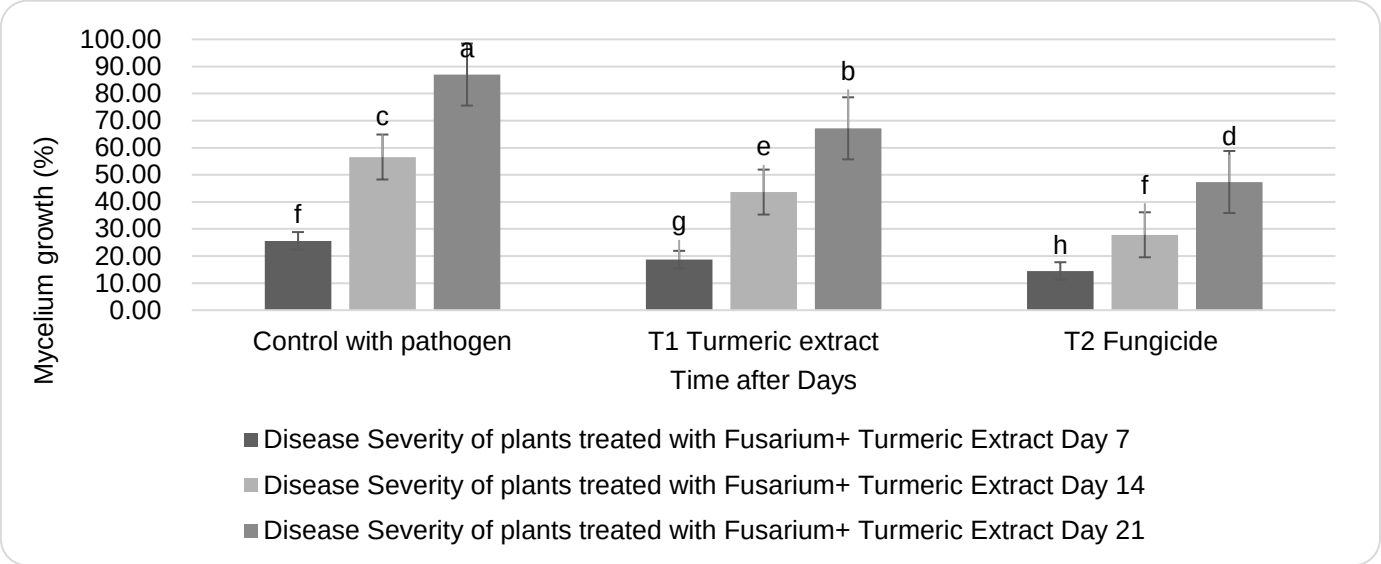

Figure 4. Disease severity of plants treated with *Fusarium sp*+ turmeric extract.

Table 3. *In vivo* effect of turmeric extract on disease incidence of both fungi.

Treatments	Disease incidence (%)		
	Day 7	Day 14	Day 21
Rhizoctonia	22.95 ± 1.368633^{f}	50.48 ± 0.730342^{c}	81.22 ± 1.160115^{a}
Rhizoctonia+ Turmeric extract	15.51 ± 0.923147^{g}	39.66 ± 0.632789^{e}	61.30 ± 1.975522^{b}
Rhizoctonia+ Fungicide	10.32 ± 0.509662^{h}	25.45 ± 0.869687^{f}	44.48 ± 0.653622^{d}
Fusarium	25.60 ± 0.568878^{f}	56.57 ± 0.866038c	87.03 ± 1.171238661^{a}
Fusairum+ Turmeric extract	18.67 ± 0.744774^{g}	43.62 ± 0.739204^{e}	67.16 ± 0.936459052^{b}
Fusarium +Fungicide	14.47 ± 0.942208^{h}	27.85 ± 1.049264^{f}	47.34 ± 0.863571396^{d}

The efficacy of ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) extracts as biocontrol agents against common soil-borne diseases was thoroughly studied in this work. Our research focused on the natural extracts' antifungal and antibacterial activities, as well as their effect on the development and vitality of plants infected with diseases such as *Fusarium oxysporum* and *Rhizoctonia solani*.

The phytochemical study of ginger and turmeric extracts indicated high amounts of strong bioactive components such as curcumin in turmeric and gingerol in ginger. Prior research has demonstrated the antibacterial activity of these chemicals, giving a theoretical basis for their usage as natural insecticides. In our experiments, both extracts had a clear inhibitory impact on the development of *F. oxysporum* and *R. solani In vitro*, with turmeric extract marginally more effective than ginger. Furthermore, in greenhouse circumstances, applying these extracts to the soil around the root zone significantly reduced the occurrence of disease symptoms in treated plants when compared to the control group. This shows that these extracts not only inhibit pathogen development but may also improve plant defense systems.

Future study should focus on improving the concentration and application technique of these extracts in various soil types and environmental situations in order to enhance their usefulness as sustainable agriculture tools. Furthermore, the long-term impacts of these extracts on soil health and microbial diversity deserve additional exploration.

Statical Analysis

All the treatments were observed at Day 3 and Day 7 after inoculation of the pathogen. Control Treatment has no plant extract, but only *Rhizoctonia*. T1 30%, T240%, T350% has different concentrations of Ginger plant extracts while T4 contain only fungicide. All the values are significantly different based on ANOVA and LSD test ($p<0.001$).

CONCLUSION

In conclusion, as a result of the botanical extracts, a decrease in the number of fungal species, *Fusarium* and *Rhizoctonia*, has been reported during both *In vitro* and *In vivo* trials. However, the efficacy of each extract varies depending on its formulation and concentration. Effectiveness may also be arranged in ascending order as Turmeric > Ginger >. There was also improved control over *R. solani* and *Fusarium oxysporum* disease progression by turmeric extract under greenhouse conditions, in addition to improved growth of tomato plants as a result of turmeric extract.

The *In vivo* evaluations further demonstrated the potential of turmeric extract in significantly reducing disease severity and enhancing plant height. Embracing such plant-based solutions can contribute to a more sustainable and eco-friendly approach to disease management in agriculture.

REFERENCES

Agrios, G. N. (2005). Plant pathology. *Elsevier*.

Al-Samarrai, G. F., Singh, H., & Syarhabil, M. (2013). Extracts some plants on controlling green mold of orange and on postharvest quality parameters. *World Applied Sciences Journal*, 22(4), 564-570.

Beristain-Bauza, S. D. C., Hernández-Carranza, P., Cid-Pérez, T. S., Ávila-Sosa, R., Ruiz-López, I. I., & Ochoa-Velasco, C. E. (2019). Antimicrobial activity of ginger (*Zingiber officinale*) and its application in food products. *Food Reviews International,* 35(5), 407-426

Choudhury, D., Dobhal, P., Srivastava, S., Saha, S., & Kundu, S. (2018). Role of botanical plant extracts to control plant pathogens-A review. *Indian Journal of Agricultural Research,* 52(4), 341-346.

Cutler H G and Cutler S J. 1999.Biological active natural product: Agrochemical CRS Press, Boca Raton: USA.Pp:299.

Gul, P., & Bakht, J. (2015). Antimicrobial activity of turmeric extract and its potential use in food industry. *Journal of Food science and Technology,* 52, 2272-2279.

Kekuda, P. T. R., Akarsh, S., Nawaz, N. A. S., Ranjitha, M. C., Darshini, S. M., & Vidya, P. (2016). *In vitro* antifungal activity of some plants against *Bipolaris sorokiniana (Sacc.) Shoem*. *Int J Curr Microbiol Appl Sci*, 5(6), 331-337

Khakimov, A., Salakhutdinov, I., Omolikov, A., & Utaganov, S. (2022). Traditional and current-prospective methods of agricultural plant diseases detection: A review*. In IOP Conference series: Earth and Environmental science* (Vol. 951, No. 1, p. 012002). IOP Publishing.

Kharde M N, Wabale A S, Adhav R M, Jadhav B D, Wabale A M and Pandey M. 2010. Effects of plant extracts on fungal pathogens causing leaf blight of tomato *In vitro*. *Asian J. Exp. Biol. Sci. Spl*. Pp: 121-123.

Kota, N., Krishna, P., & Polasa, K. (2008). Alterations in antioxidant status of rats following intake of ginger through diet. *Food chemistry*, 106(3), 991-996.

Kumar, A., R. Shukla, P. Singh and N. K. Dubey. 2010. Chemical composition, antifungal and antiaflatoxigenic activities of *Ocimum sanctum L.* essential oil and its safety assessment as plant based antimicrobial. *Food Chem Toxicol.,* 48(2): 539-543

Leslie, J. F., & Summerell, B. A. (2006). *Fusarium* Laboratory Manual. *Blackwell Publishing.*

Mamarabadi, M., Tanhaeian, A., & Ramezany, Y. (2018). Antifungal activity of recombinant *thaumatin* in comparison with two plant extracts and a chemical mixture to control fungal plant pathogens. *AMB Express*, 8, 1-12.

Mekam, P. N., Martini, S., Nguefack, J., Tagliazucchi, D., Mangoumou, G. N., & Stefani, E. (2019). Activity of extracts from three tropical plants towards fungi pathogenic to tomato (*Solanum lycopersicum*)*. Phytopathologia Mediterranea*, 58(3), 573-586.

Mokhtar, M. M., & El-Mougy, N. S. (2014). Bio-compost application for controlling soil-borne plant pathogens-A review. *Int. J. Eng. Innov. Technol*, 4(1), 61-68.

Nelson, P. E., Toussoun, T. A., & Marasas, W. F. O. (1983). *Fusarium* species: An Illustrated Manual for Identification. The Pennsylvania State University Press*.*

Panth, M., Hassler, S. C., & Baysal-Gurel, F. (2020). Methods for management of soil borne diseases in crop production. *Agriculture*, 10(1), 16.

Rajasekaran et al., Afr., *J. Complement Altern Med*. (2019) 16 (2): 24-25

Tabassum, N., & Vidyasagar, G. M. (2013). Antifungal investigations on plant essential oils. A review. International *Journal of Pharmacy and Pharmaceutical Sciences*, 5(2), 19-28.

Thimmayamma, B. S., RAU, P., & Radhaiah, G. (1983). Use of spices and condiments in the dietaries of urban and rural families*. Indian Journal of Nutrition and Dietetics*, 20(5), 153-162.

Wang, H. (2020). Introductory Chapter: Studies on Ginger. In Ginger Cultivation and Its Antimicrobial and Pharmacological Potentials. *Intech Open.*