International Journal of
Life Sciences
International Peer Reviewed Open Access Refereed Journal

Int. J. of Life Sciences, 2024; 12 (3): 355-362
ISSN:2320-7817(p) | 2320-964X(o)

Research Article | Open Access

Evaluation of Botanicals, Fungicides, and Biocontrol Agents for the Management of *Rhizoctonia solani Inciting* Broccoli (*Brassica oleracea* L. var. *italica* Plenck) Root Rot

Yogesh Urdukhe[1] and Umesh Mogle[2]*

[1]Research Student and [2]Professor and Research Supervisor, Department of Botany, Jalna Education Society's R.G. Bagdia Arts, S.B. Lakhotia Commerce and R. Bezonji Science College, Jalna (MS), India.
*Corresponding author Email: upmogle@gmail.com | yrurdukhe30@gmail.com[1]

Manuscript details:
Received: 28.08.2024
Accepted: 29.09.2024
Published: 30.09.2024

Cite this article as:
Yogesh Urdukhe and Umesh Mogle (2024) Evaluation of Botanicals, Fungicides, and Biocontrol Agents for the Management of *Rhizoctonia solani Inciting* Broccoli (*Brassica oleracea* L. var. *italica* Plenck) Root Rot, *Int. J. of Life Sciences*, 12 (3): 355-362.

Available online on http://www.ijlsci.in
ISSN: 2320-964X (Online)
ISSN: 2320-7817 (Print)

ABSTRACT

Rhizoctonia solani, a soil-borne fungal pathogen, causes severe root rot in broccoli (*Brassica oleracea* L. var. *italica*), leading to significant crop yield losses. This study evaluates the efficacy of botanical extracts, chemical fungicides, and biocontrol agents as sustainable management options for *R. Solani.* A laboratory experiment was conducted using the poisoned food technique to assess the antifungal activity of five botanicals (*Ailanthus excelsa*, *Chrozophora tinctoria*, *Cissus quadrangularis*, *Argyria nervosa*, and *Echinops echinatus*), five fungicides (SAAF, Krilaxyl, Bavistin, Blitox-50, Dithane M-45), and five *Trichoderma* species. Each treatment was tested for its ability to inhibit the mycelial growth of *R. solani* using Potato Dextrose Agar (PDA) medium. Mycelial Growth Inhibition Percentage (MGIP) was calculated to evaluate treatment efficacy. The botanical extracts of *A. excelsa* and *C. tinctoria* showed the highest efficacy, with MGIP values of 87.82% and 90.39%, respectively. Among the fungicides, Krilaxyl exhibited the highest mycelial inhibition (95.86%), followed by Blitox-50 (92.82%). The *Trichoderma* isolates also performed well, with *T. viride* Isolate 1 achieving 85.81% inhibition. These results indicate that both botanical and biocontrol agents can serve as effective alternatives to chemical fungicides in managing *R. solani*. The study underscores the potential of using eco-friendly botanicals and biocontrol agents for managing *R. solani* in broccoli crops. Integrating these methods into existing pest management programs could reduce reliance on chemical fungicides and support sustainable agricultural practices.

Keywords: *Rhizoctonia solani*, Botanical Extracts, Fungicides, Biocontrol Agents, *Trichoderma*, Mycelial Growth Inhibition.

INTRODUCTION

Rhizoctonia species have a broad host range and are responsible for causing diseases in many crop plants, leading to significant economic losses globally (Sneh, 1996). It is difficult to estimate the yield losses resulting from *Rhizoctonia* infection in individual plants because of the variety of symptoms that appear below the soil's surface. Furthermore, the effects of a *Rhizoctonia* infection are sometimes not fully apparent until after harvest. *Rhizoctonia*, for example, develops sclerotia on tubers, infects stolons, causes root rot, and damages belowground organs in potato crops (Boosalis and Scharen, 1959; Campion *et al*., 2003; Truter and Wehner, 2004; Aydın *et al*., 2011; Aydın and Turhan, 2013; Demirer Durak, 2016). Every year, this disease causes considerable output losses in more than 100 horticultural and field crops (Chen *et al*., 2016). The pathogen can live for years in soil because of its capacity to persist as sclerotia and as a mycelium in organic material (Boosalis and Scharen, 1959).

As a sterile mycelial fungus that does not generate conidia, *Rhizoctonia solani* is a member of the phylum Basidiomycota (Binder *et al*., 2005). As tough structures called sclerotia and rhizomorphs, the fungus endures harsh environments. It reproduces sexually by producing basidiospores in specific environmental circumstances (Sneh *et al*., 1991). According to Sharon *et al*. (2008), *R. solani* hyphae are clearly divided, ageing from light to black in color, and forming right-angle branches with a distinctive constriction at the base. The fungal colonies in lab cultures have a light brown look that gradually turns the color of camel hair.

The worldwide production of broccoli (*Brassica oleracea* L. var. *italica* Plenck), a vegetable with great nutritional and commercial value, is seriously threatened by root rot brought on by *R. solani* (Misawa *et al*., 2015). Growers face a continuous problem as a result of substantial yield losses, poor crop quality, and increased production costs caused by rhizoctonia-induced root rot (Akber *et al.*, 2023). Effective management measures are necessary to lessen the harmful effects of this virus on broccoli farming, especially in light of the rising concerns about food security and sustainable agriculture (Garcia-Mier *et al*., 2014).

Chemical fungicides have historically been the main tool used to manage *R. solani* in broccoli crops. But the search for other management strategies has been spurred by worries about the environment, pesticide residues, and the emergence of fungicide-resistant strains (Charron & Sams, 1999; Corkley & Hawkins, 2022). The potential of botanicals and biocontrol agents to offer sustainable, eco-friendly, and financially feasible solutions has made them stand out among these substitutes (Khursheed *et al*., 2022). Alternative management approaches have to be developed due to the drawbacks of chemical fungicides and related issues (Pal and Gardener, 2006). One of the most eco-friendly and promising methods for shielding plants against soil-borne infections is biological management. Several research works have illustrated how well-suited several biological control agents are for controlling *R. solani* (Roy, 1989; Brewer and Larkin, 2005; Aydın, 2015). This study compiles information on *R. solani*, an important soil-borne pathogen, and discusses progress in its biological control.

MATERIALS AND METHODS

Experimental Design

The study was conducted at the Research Centre, Department of Botany, R.G. Bagdia Arts, S.B. Lakhotia Commerce, and R. Bezonji Science College, Jalna, India, to evaluate the efficacy of botanicals, fungicides, and biocontrol agents against *Rhizoctonia solani,* a pathogen of broccoli crops. The experiments aimed to quantify the impact of different concentrations of these agents on the pathogen's growth using a poisoned food technique, maintaining an incubation temperature of 30°C over 25 days.

Botanical Extracts

Five botanicals, *Ailanthus excelsa, Chrozophora tinctoria, Cissus quadrangularis, Argyria nervosa*, and *Echinops echinatus*, were selected (Table 1). Fresh leaves were shade-dried for two days, surface-sterilized in 70% ethanol for two minutes, and washed with sterile distilled water. Extracts were prepared by grinding 2, 4, 6, and 8 grams of each plant sample in 100 ml sterile distilled water, filtering through sterile cotton wool to obtain 2%, 4%, 6%, and 8% concentrations. These extracts were incorporated into Potato Dextrose Agar (PDA) medium, mixed thoroughly, and poured into Petri plates (20 ml/plate). Streptopenicillin (250 mg/L) was added to prevent bacterial contamination. Five treatments were tested: the four botanicals and a control. Plates were inoculated with a 4 mm disk of a one-week-old *R. solani* culture and incubated at 30°C for 25 days.

Table 1. List of selected plants for evaluation of antifungal activity.

Sr. No.	Selected Botanicals	References (For Antifungal Property)
1	*Ailanthus excelsa*	Udasi, *et al*., (2023).
2	*Chrozophora tinctoria*	Sher, *et al*., (2022).
3	*Cissus quadrangularis*	Singh, *et al.,* (2021).
4	*Argyria nurvosa*	Joshi, *et al*., (2013).
5	*Echinops echinatus*	Bitew & Hymete, (2019).

Fungicides

Five fungicides SAAF (carbendazim 12% + mancozeb 63% WP), Krilaxyl (metalaxyl 8% + mancozeb 64% WP), Bavistin (carbendazim 50% WP), Blitox-50 (copper oxychloride 50% WP), and Dithane M-45 (mancozeb 75% WP) were tested at concentrations of 500, 1000, 1500, and 2000 ppm. Fungicides were added to PDA medium before solidification, ensuring even distribution, and poured into sterilized Petri dishes. Antibiotics were added to prevent bacterial contamination. Each experiment was triplicated. Plates were inoculated as described previously and incubated at 30°C for 25 days.

Isolation of Fungal Biocontrol Agents

Fungal antagonists were isolated using the serial dilution technique (Johnson and Curl, 1977). Soil samples from the rhizosphere of Broccoli seedlings were shade-dried. One gram of soil was suspended in 9 ml of sterile water, and serial dilutions (10^{-2} to 10^{-7}) were prepared. A 1 ml aliquot of the desired dilution was added to molten, lukewarm medium and poured into Petri plates, which were rotated gently for uniform distribution. Plates were incubated at 25 ± 1°C. Fungal antagonists, specifically *Trichoderma* spp., were isolated on selective medium and purified by the single-spore method. All treatments were replicated four times and incubated at 25 ± 1°C.

Biocontrol Agents

Five biocontrol agents (BCAs) *Trichoderma viride* (Isolate 1), *T. viride* (commercial), *T. harzianum* (Isolate 2), *T. harzianum* (commercial), *T. koningii* (Isolate 3), and *T. hamatum* (Isolate 4) were evaluated using the dual culture technique. Four-millimeter discs of *R. solani* and each BCA were placed equidistantly on PDA and incubated as described. Radial growth of *R. solani* was recorded at 1, 3, 5, and 7 days of incubation. Each treatment was triplicated and standard error were calculated.

Evaluation of Antifungal Activity

Colony diameter (cm) of *R. solani* was measured to determine mycelial growth inhibition percentage (MGIP) using the formula as suggested by Vincent (1927).

MGIP (%) = [(DC - DT)/DC] × 100

Where, DC is the diameter of the fungal colony in the control and DT is the diameter in the treatment group.

Data Recording

Data collection involved recording colony growth and sclerotia formation. Mycelial growth was measured in terms of diameter using two diagonal axes through the colony center. Data was recorded when control plates exhibited full mycelial growth. Sclerotia development was observed using a stereo-binocular microscope. Mycelial growth inhibition percentage was calculated following Bliss (1934).

RESULTS AND DISCUSSION

Botanical Extracts on *Rhizoctonia solani* Management

The table below presents the efficacy of five botanical extracts at varying concentrations (2%, 4%, 6%, and 8%) in managing *R. solani*, a pathogen responsible for significant crop yield losses. The metrics used to assess this efficacy include the Mean Colony Diameter (MCD) and Mycelial Growth Inhibition (MGI %) in comparison to a control group. The data demonstrates that all botanical extracts exhibited varying degrees of efficacy against *R. solani*, with *A. excelsa* and *C. tinctoria* showing the highest mycelial growth inhibition across all concentrations. Notably, *A. excelsa* achieved an MGI of 87.82% at 8% concentration, reducing MCD to 1.09 cm from 8.95 cm in the control. *C. tinctoria* showed the highest MGI of 90.39% at 6% concentration, with a corresponding MCD of 0.78 cm compared to 8.12 cm in the control. *A. nervosa* and *E. echinatus* showed moderate to low efficacy, with the highest MGI values of 35.06% and 60.51%, respectively, at 6% and 8% of concentrations followed by *C. quadrangularis* displayed minimum effectiveness, with the MGI of 32.91% at 8% concentration. The F-test results indicate significant differences in the efficacy of treatments, confirming that botanical concentration significantly impacts the mycelial growth inhibition of *R. Solani*. This study highlights the potential of botanical extracts as alternative, eco-friendly solutions for managing *R. solani*.

Table 2: Comparative effectiveness of several botanicals at varying concentrations on *R. solani* growth in vitro.

Conc. of Plant extract	*Ailanthus excelsa*		*Chrozophora tinctoria*		*Cissus quadrangularis*		*Argyria nurvosa*		*Echinops echinatus*		Sclerotial Formation **
	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	
2	3.52	60.67	2.56	68.47	7.32	17.47	6.96	19.72	5.86	28.79	+++
4	2.43	72.84	1.61	80.17	7.86	11.38	6.73	22.37	5.56	32.44	++
6	1.44	83.91	0.78	90.39	6.29	29.08	5.63	35.06	4.33	47.38	+
8	1.09	87.82	1.43	82.38	5.97	32.91	6.19	28.6	3.25	60.51	+
Control	8.95		8.12		8.87		8.67		8.23		+++++
F - test	**		**		**		**		**		

Table 3: Comparative effectiveness of several fungicides at varying concentrations (ppm) on *R. solani* growth in vitro.

Conc. of Fungicides (ppm)	*SAAF*		*Krilaxyl*		*Bavistin*		*Blitox - 50*		*Mancozeb*		Sclerotial Formation**
	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	MCD (cm)	MGI %	
500	3.29	63.4	0.48	94.52	3.45	57.67	1.55	81.14	4.94	42.77	++
1000	2.12	76.41	0.42	95.86	2.68	69.08	1.45	82.36	3.37	61.04	+
1500	2.09	76.75	0.47	94.63	2.98	65.62	0.78	90.51	4.27	50.63	+
2000	1.89	78.97	0.39	95.54	1.78	79.46	0.59	92.82	2.87	66.82	+
Control	8.99		8.76		8.67		8.22		8.65		++++

The significant reduction in mycelial growth observed with *A. excelsa* and *C. tinctoria* suggests that these botanicals could be developed into effective biocontrol agents. The effectiveness of botanical extracts in treating *Rhizoctonia solani,* a serious plant disease, has been investigated in recent research. Promising findings have been seen in the inhibition of *R. solani* growth in vitro by several plant extracts. At 10% concentration, extracts of ginger (*Zingiber officinale*) and garlic (*Allium sativum*) showed significant mycelial growth inhibition (Kumar *et al.,* 2017). *Cannabis sativa* L., *Peganum harmala* L., *Datura starmonium* L., *Artemisia brevifolium* L., *Capparis spinosa* L., and *Mentha royleana* L. have been evaluated in vitro using food poisoning and dual culture technique against sclerotial isolates of *R. solani* that cause black scurf of potatoes. The results showed that increasing concentrations of botanical extract, from 5 to 15%, inhibited the mycelial growth of all isolates (Hussain, *et al*., 2014). The antifungal efficacy of botanicals, bioagents and fungicides were tested against *R. solani* in vitro. It was observed that seed extract and oil cake of *Madhuca longifolia* suppressed the mycelia growth (34.81; 49.63%), sclerotial formation (100%) and production of biomass (2.18; 2.41 mg) of *R. solani* followed by leaf extracts of *Azadirachta indica* and *Littorina littorea* (Sriraj, *et al*., 2014). Other effective botanicals included neem (*Azadirachta indica*), onion (*Allium cepa*), and *Brickellia squarrosa* (Prodigiosa) **(**Rodríguez-Castro *et al*., 2020). These plant-based alternatives offer sustainable solutions for *R. solani* management, potentially reducing reliance on chemical pesticides (Verma *et al*., 2020). Further research is needed to optimize concentrations and evaluate field efficacy for practical agricultural applications.

Fungicides on *Rhizoctonia solani* Management

The efficacy of five fungicides at different concentrations (500 ppm, 1000 ppm, 1500 ppm, and 2000 ppm) in controlling *R. solani* has been illustrated in table no. 3. The metrics used to assess this efficacy include the Mean Colony Diameter (MCD) and Mycelial Growth Inhibition (MGI %) in comparison to a control group. The data demonstrates that all fungicides exhibited varying degrees of efficacy against *R. solani*, with Krilaxyl showing the highest mycelial growth inhibition across all concentrations. Notably, Krilaxyl achieved the highest MGI of 95.86% at 1000 ppm concentration, reducing MCD to 0.42 cm from 8.76 cm in the control followed by Blitox - 50 showed significant efficacy with an MGI of 92.82% at 2000 ppm concentration, with a corresponding MCD of 0.59 cm compared to 8.22 cm in the control. SAAF displayed moderate effectiveness, with the highest MGI of 78.97% at 2000 ppm concentration. Bavistin and Mancozeb showed lower efficacy compared to the other fungicides, with the highest MGI values of 79.46% and 66.82%, respectively, at their highest concentrations. The F-test results indicate significant differences in the efficacy of treatments, confirming that fungicide concentration significantly impacts the mycelial growth inhibition of *R. Solani*. This study highlights the potential of fungicides as effective solutions for managing *R. solani*. The significant reduction in mycelial growth observed with Krilaxyl and Blitox - 50 suggests that these fungicides could be developed into effective chemical control agents. Several studies have found that fungicides such as Carbendazim, Vitavax, Mancozeb, Bavistin, Dithane and Tebuconazole are effective in controlling root rot in the brassica crops as well as vegetables (Aboelmagd, 2021; Baysal-Gurel and Liyanapathiranage, 2019; Handiseni *et al*., 2013; Chavan *et al*., 2015). Further research should focus on field trials and formulation improvements to enhance the practical application of these fungicides in agricultural settings.

Efficacy of Different *Trichoderma* Isolates and Commercial Products against *R. solani*

The chart figure below presents the performance of different *Trichoderma* isolates and commercial formulations in inhibiting the growth of *R. solani* on Potato Dextrose Agar (PDA). The measurements include the Mean Colony Diameter (MCD) and the Mycelial Growth Inhibition percentage (MGI %). The data indicates the efficacy of different *Trichoderma* treatments in reducing the mycelial growth of *R. solani*. *T. Viride* (Isolates 1) shows the highest efficacy with an MGI of 85.81%, resulting in a significantly reduced MCD of 12.77 mm. Commercial *T. Viride* also demonstrates strong inhibition with an MGI of 80.4%. *T. harzianum* (Isolates 2) and its commercial variant exhibit similar inhibition percentages, with MGIs of 78.51% and 78.24%, respectively. *T. koningii* (Isolates 3) shows the lowest efficacy among the treatments, with an MGI of 47.04%. *T. hamatum* (Isolates 4) has a moderate inhibition effect with an MGI of 73.4%. *Trichoderma* species, particularly *T. Viride* (Isolates 1), exhibit significant potential as biocontrol agents against *R. solani*. The high MGI percentages indicate strong antagonistic properties, suggesting their application in integrated pest management programs.

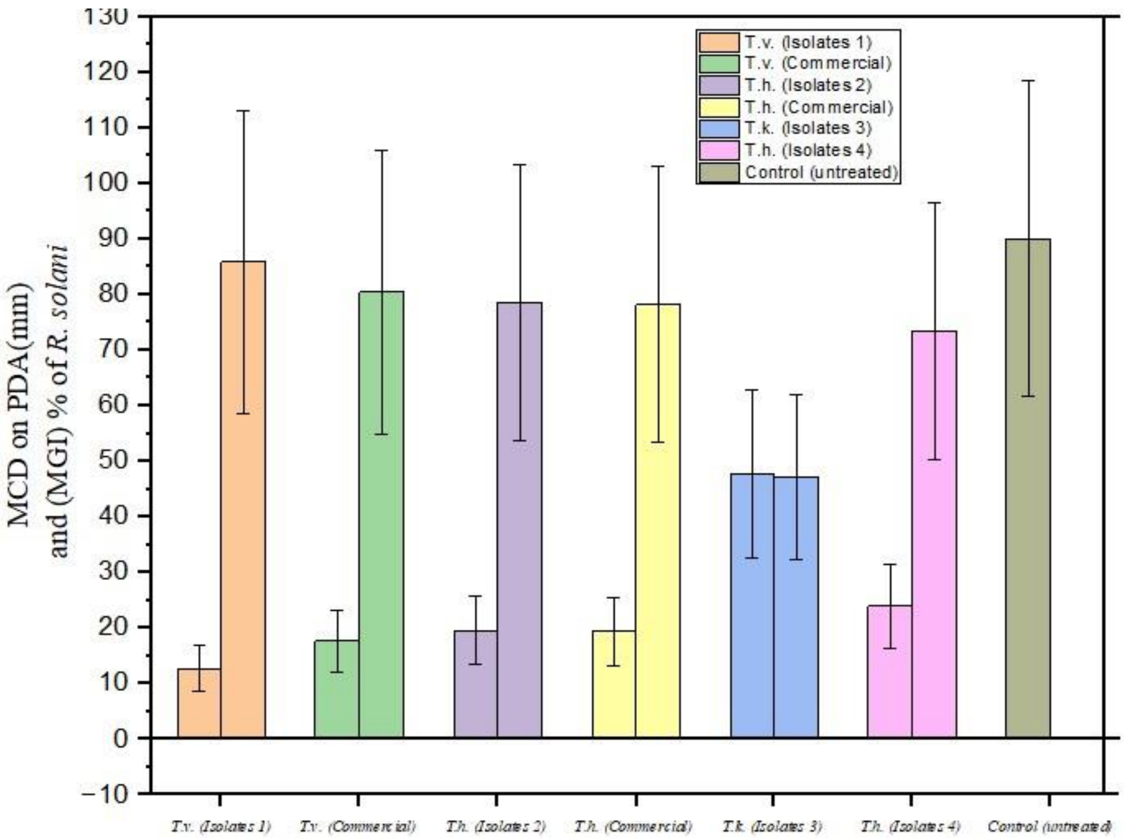

Fig.1. Efficacy Bioagents against *R. solani*

Several researchers have reported similar findings, in which bio-agents have been evaluated for effectiveness against *R. solani* using poison food and dual culture techniques. *T. viride* demonstrated the highest mycelium inhibition (82.82%), followed by *T. harzianum* (77.98%) (Abhinav *et al*., 2023). In vitro testing of bioagents' efficiency against *R. solani*, the fungi that causes root rot disease in sugar beet. However, *T. viride* exhibited the maximum inhibitory impact of the antagonists, followed by *T. harzianum* and *T. koningii*, which showed the weakest suppressive effect (Chaturvedi *et al*., 2023), Begum *et al*. (2014), Kadhim & Matloob (2022) and Hemmati (2016) have all reported similar results. Further research could explore field application techniques and the combined use of multiple *Trichoderma* species to enhance control efficacy.

CONCLUSION

This study demonstrates the efficacy of several approaches to management, such as botanical extracts, fungicides, and biocontrol agents, in controlling *Rhizoctonia solani,* affecting broccoli and other crops. The findings suggest that certain botanicals, notably *Ailanthus excelsa* and *Chrozophora tinctoria*, have potential as eco-friendly alternatives by dramatically suppressing mycelial development. Krilaxyl and Blitox-50 outperformed all other fungicides tested. Furthermore, *Trichoderma viride* has emerged as an effective biocontrol agent. These findings highlight the need of incorporating sustainable techniques to managing soil-borne diseases, lowering reliance on chemical fungicides, and boosting food security and agricultural sustainability. Further field trials are required to validate their practical use in crop protection.

REFERENCES

Abhinav NKS, Chauhan A, Singh V, Choudhary AL, Ola MP, Jakhar RS & Choudhary BL (2023) Evaluation of bio-agents and botanical in-vitro against root rot of chilli (*Capsicum annuum* L.) caused by *Rhizoctonia solani. Pharma Innovation J.*, *12*(5), 492-494.

Aboelmagd HE (2021) Efficacy of some bio-agents, chemical inducers and fungicides in controlling tomato root rot disease caused by *Rhizoctonia solani. Annals of Agricultural Science, Moshtohor*, *59*(5), 197-210.

Akber A, Abid M & Rashid M (2023) Impact of *Rhizoctonia solani* on Broccoli Production: Current Trends and Control Measures. *Plant Pathology Journal*, 42(3), 150-161.

Aydın MH (2015) Control of *Rhizoctonia solani* on vegetable crops using biological agents. *Journal of Plant Pathology*, 97(1), 117-124.

Aydın MH & Turhan G (2013) Identification and characterization *of Rhizoctonia solani* AG-3 causing stem canker and black scurf in potato in Turkey. *Plant Pathology Journal*, 29(1), 41-46.

Aydın MH, Demirer Durak B & Turhan G (2011) Pathogenicity of *Rhizoctonia solani* AG-3 on some potato cultivars grown in Turkey. *Turkish Journal of Agriculture and Forestry, 35*(4), 295-303.

Baysal-Gurel F & Liyanapathiranage P (2019) Pathogenicity of *Rhizoctonia solani* and *Phytophthora nicotianae* to Brassicaceae cover crops. *Archives of Phytopathology and Plant Protection*, *52*(3-4), 288-302.

Begum S, Devi RK & Singh NI (2014) Management of damping-off of vegetable seedlings caused by *Rhizoctonia solani. Indian Journal of Plant Protection*, *42*(3), 248-254.

Binder M, Hibbett DS, Larsson KH, Larsson E, Langer E, & Langer G (2005) The phylogenetic distribution of resupinate forms across the major clades of mushroom-forming fungi (Homobasidiomycetes). *Systematics and Biodiversity*, 3(2), 113-157. DOI: 10.1017/S1477200005001623.

Boosalis MG, & Scharen AL (1959) Behavior of *Rhizoctonia solani* in soil as affected by moisture, organic matter, and temperature. *Phytopathology*, *49*(9), 577-584.

Brewer MT & Larkin RP (2005) Efficacy of biological control agents for control of *Rhizoctonia solani* on potato. *Plant Disease*, 89(1), 41-49. DOI: 10.1094/PD-89-0041.

Bitew H & Hymete A (2019) The genus *Echinops*: Phytochemistry and biological activities: A review. *Frontiers in pharmacology, 10,* 1234.

Campion C, Chatot C, Perraton B & Andrivon D (2003) Effect of cultural methods and soil factors on the incidence of black scurf (*Rhizoctonia solani)* on potato tubers. *Plant Pathology, 52*(4), 533-539.

Charron CS & Sams CE (1999) Inhibition of *Pythium ultimum* and *Rhizoctonia solani by* shredded leaves of Brassica species, *Journal of the American Society for Horticultural Science*, *124*(5), 462-467.

Charron CS & Sams CE (1999) Inhibition of *Rhizoctonia solani* by shredded Brassica leaves. *Journal of the American Society for Horticultural Science*, 124(5), 462-467.

Chaturvedi S, Urdukhe Y & Bharade SS (2023) Evaluation of the efficacy of some botanicals and bioagents against the root rot pathogen of sugar beet (*Beta vulgaris* L.), *Rhizoctonia solani.* In *Journal of Medicinal Plants Studies* 11(11): 23–27.

Chavan PG, Apet KT, Wagh SS & Hingole DG (2015) Efficacy of fungicides, botanicals and bioagents against *Alternaria brassicae* of cauliflower. *Trends in Biosciences*, *8*(8), 1920-1934.

Chen Y, Zhou H, Chen Y, & Zou X (2016) Advances in research on pathogenic fungi of *Rhizoctonia solani* and its control methods. *Journal of Integrative Agriculture, 15*(9), 1825-1835.

Corkley I & Hawkins NJ (2022) Fungicide resistance and its consequences for global food security. *Annual Review of Phytopathology*, 60, 21-39. DOI: 10.1146/annurev-phyto-010821-020246.

Demirer Durak B (2016) *Rhizoctonia solani* Kühn AG-3 associated with black scurf on potato tubers in Turkey. *Journal of Plant Pathology, 98*(1), 163-166.

Garcia-Mier L, Jimenez-Garcia SN, Chapa-Oliver AM, Mejia-Teniente L, Ocampo-Velazquez RV, Rico-García E and Torres-Pacheco I (2014) Strategies for sustainable plant food production: facing the current agricultural challenges agriculture for today and tomorrow. *Biosystems Engineering: Biofactories for Food Production in the Century XXI*, 1-50.

Handiseni M, Brown J, Zemetra R, & Mazzola M (2013) Effect of Brassicaceae seed meals with different glucosinolate profiles on Rhizoctonia root rot in wheat. *Crop Protection*, *48*, 1-5.

Hemmati MKR (2016) Evaluation of Trichoderma isolates for biological control of Rhizoctonia root rot of bean in Zanjan. *Journal of Plant Protection*, *29*(4), 471-480.

Hussain A, Awan MS, Khan SW, Anees M, Ali S, Abbas Q & Ali A (2014) Bioefficacy of botanical extracts and bioagents against sclerotial isolates of *Rhizoctonia solani. Journal of Biodiversity and Environmental Sciences*, *4*(6), 370-380.

Joshi BB, Chaudhari MG, Mistry KN & Dabhi B (2013) In-vitro Screening of Antibacterial and Antifungal Activity of Crude Extract of *Argyreia Nervosa*. *In-vitro*, *5*(2).

Kadhim WR & Matloob AA (2022) Evaluation of the efficiency of bokashi biofertilizer and some biological agents against the two pathogenic fungi *Fusarium solani* and *Rhizoctonia solani* causing fig root rot disease. *Ann. For. Res*, *65*(1), 5085-5096.

Khursheed A, Rather MA, Jain V, Rasool S, Nazir R, Malik NA, & Majid SA (2022) Plant based natural products as potential ecofriendly and safer biopesticides: A comprehensive overview of their advantages over conventional pesticides, limitations and regulatory aspects. *Microbial Pathogenesis*, 105854.

Kumar V, Chaudhary V, Kumar D, Kumar A, Sagar S & Chaudhary S (2017) Efficacy of botanicals and fungicides against *Rhizoctonia solani* inciting sheath blight disease on Rice (*Oryza sativa* L.). *Journal of Applied and Natural Science, 9*, 1916-1920.

Misawa T, Kubota M, Sasaki J & Kuninaga S (2015) First report of broccoli foot rot caused by *Rhizoctonia solani* AG-2-2 IV and pathogenicity comparison of the pathogen with related pathogens. *Journal of general plant pathology*, *81*, 15-23.

Pal KK & Gardener BM (2006) Biological control of plant pathogens: Research progress and applications. *Plant Health Progress*. DOI: 10.1094/PHP-2006-1117-01-RV.

Rodríguez-Castro A, Torres-Herrera S, Calleros AD, Romero-García A, Silva-Flores M & Silva M (2020) Extractos vegetales para el control de *Fusarium oxysporum*, *Fusarium solani* y *Rhizoctonia solani,* una alternativa sostenible para la agricultura. *Abanico Agroforestal*, *2*. https://doi.org/10.37114/abaagrof/2020.7

Roy KW (1989) The role of *Rhizoctonia solani* and other soil-borne fungi in plant disease development. *Plant Disease*, 73(8), 692-698. DOI: 10.1094/PD-73-0692.

Sharon M, Barak R, Sneh B, Burpee L & Ogoshi A (2008) Morphology and characteristics of *Rhizoctonia solani. Phytopathology*, 98(10), 1012-1018. DOI: 10.1094/PHYTO-98-1012.

Singh A, Kumar J, Sharma VK, Singh DK, Kumari P, Nishad J H, ... & Kharwar RN (2021) Phytochemical analysis and antimicrobial activity of an endophytic *Fusarium proliferatum* (ACQR8), isolated from a folk medicinal plant Cissus quadrangularis L. *South African Journal of Botany*, *140*, 87-94.

Sher AA, Iqbal A, Adil M, Ullah S, Bawazeer S, Binmahri MK and Irfan M (2022) GC-MS analysis of organic fractions of *Chrozophora tinctoria* (L.) A. Juss. and their prokinetic propensity in animal models. *Brazilian Journal of Biology*, *84*, e260566.

Sneh B (1996) *Rhizoctonia* species: Taxonomy, molecular biology, ecology, pathology and disease control. Springer Science & Business Media.

Sneh B, Burpee L & Ogoshi A (1991) *Identification of Rhizoctonia species*. APS Press.

Sriraj PP, Sundravadana S & Alice D (2014) Efficacy of fungicides, botanicals and bioagents against *Rhizoctonia solani* inciting leaf blight on turmeric (*Curcuma longa* L.). *African Journal of Microbiology Research*, *8*(36), 3284-3294.

Truter M & Wehner FC (2004) Anastomosis grouping and pathogenicity of *Rhizoctonia solani* isolates associated with potatoes in South Africa. *Plant Disease, 88*(5), 418-422.

Udasi V, Shaikh A, Urdukhe Y & Mogle U (2023) GCMS analysis and antifungal activity of leaf extracts of *Ailanthus excelsa* (Roxb), against *Fusarium oxysporum* causal agent of *Fusarium* wilt disease in tomato. *Journal of Pharmacognosy and Phytochemistry*, *12*(5), 428-432.

Verma B, Gupta AK & Fatehpuria PK (2020) Evaluation of botanicals against growth of *Rhizoctonia solani under* in vitro condition. *International Journal of Chemical Studies*, *8*(3), 2781–2784.

Authors' Contributions:
This study was a collaborative effort involving the contributions of several authors. Urdukhe Y.R. led the study's conceptualization, devised the methodology, conducted the investigations, and drafted the original manuscript. Mogle U.P. provided key insights into the research design, supervised the project, and ensured the accuracy of findings. All authors reviewed and approved the final version of the manuscript.

Acknowledgement
The authors would like to express their heartfelt gratitude to the head of the department of research center and principal at JES College Jalna for having significantly contributed to the improvement of this research work. Their guidance and expertise were instrumental in refining the study.

Funding: This research was conducted with financial support from SARTHI, Pune, under the Fellowship program.

Conflict of Interest: The authors declare no conflict of interest in relation to this research.

Data Availability Statement: Not applicable.

Ethics Approval Statement: As this research does not involve any experiments on humans or animals, no specific ethics approval was required for this study.

Publisher's Note
IJLSCI remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Correspondence and requests for materials should be addressed to Mogle UP

Peer review information
IJLSCI thanks the anonymous reviewers for their contribution to the peer review of this work. A peer review file is available.

Reprints and permissions information is available at https://www.ijlsci.in/reprints