https://doi.org/10.61308/MMCO3405

Compatibility of integrated management (chemical x biological, and botanical x biological) strategies deployed against *Athelia rolfsii*, causing *Sclerotium* rots

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Citation: Ndifon, E. M. (2024). Compatibility of integrated management (chemical x biological, and botanical x biological) strategies deployed against *Athelia rolfsii, causing Sclerotium rots. Bulgarian Journal of Crop Science, 61*(3) 109-115

Abstract: *Athelia rolfsii* induces severe *Sclerotium* rots on 500 plant species, thus efficient field and post-harvest management strategies for this disease exist. A completely randomized design with three replications was used to set up two sub-trials. Sub-trial 1: Interaction of Mancozeb (all concentrations) x *Trichoderma* species caused 29.3-100% inhibition and all Ketoconazole x *Trichoderma* species caused 95.8-100% inhibition of A. *rolfsii*. Ketoconazole and Mancozeb (main effects) ranged between 23.3-100% inhibition of *A. rolfsii*. *T. virens*, *T. harzianum,* and *T. viride* (main effects) ranged from 60.3-96.7% inhibition of *A. rolfsii.* Unfortunately, Ketoconazole inhibited *Trichoderma* species more than Mancozeb. The chemical fungicides and *Trichoderma* species were highly positively correlated (0.522**, P≤0.05). Sub-trial 2: The Plant extracts (*Ricinus* and *Eucalyptus species:* 100% concentration) x *Trichoderma* species interactions caused 95-100% inhibition of *A. rolfsii*. Botanicals (50% concentration) x *Trichoderma* species caused above 80% inhibition of *A. rolfsii*. *Trichoderma* species (main effects) (in environs of 50% botanicals) caused 57-84% inhibition. The results revealed that at 100% concentration, plant extracts completely inhibited *A. rolfsii*.

Key words: brinjal; aubergine; pesticides; *Trichoderma* species; white mould

INTRODUCTION

Sneha et al. (2016) and Ünal et al. (2019) recounted that *Athelia rolfsii* (syn. *Sclerotium rolfsii*) induce *Sclerotium* rot (Ndifon, 2022) on more than 500 plant species causing heavy yield loss. *S. rolfsii* is pervasive in warm humid climates. Dilbo et al. (2015) testified that most of the conventional control methods are not effective against soil-borne diseases, thus the development of an eco-friendly and cost-effective integrated management method is critically required.

Sudeep et al. (2023) iterated that the era of chemical agriculture implied the application of hazardous chemicals against different soil and seed-borne diseases. Sneha et al. (2016) concurred that the use of synthetic fungicides is cost-effective but they are expensive, they have detrimental effects on our health and lead to increased disease resistance as well as environmental pollution.

Integrated management of *Sclerotium* rot can benefit from the application of biocontrol, botanical, and chemical agents (Ndifon, 2022). *Trichoderma* species feature much in the literature on the management of root and stem rot agents. Thus, this study was conducted to evaluate the compatibility of chemical or botanical fungicides (combined with biological agents) for the integrated management of recalcitrant disease agents like *A. rolfsii*.

MATERIALS AND METHODS

This research was carried out at the Faculty of Agriculture Laboratory complex in Alex Ekwueme Federal University, Ndufu-Alike in Ikwo Local Government Area (at 6.069°N by 8.199°E) in Nigeria. The fungi (*Trichoderma* spp. and *A. rolfsii*) were isolated using autoclaved (121°C, 15 minutes and 15 psi) potato dextrose agar and identified according to Ndifon (2022; 2023).

Procedure 1: Effects of synthetic pesticides x biocontrol agents on *A. rolfsii*

Nutrient agar (autoclaved at 121°C, 15 minutes and 15 psi) was utilized for these experimental procedures. These *in vitro* Petri dish experimental procedures were conducted by placing the experimental units on the laboratory bench at room temperature (28-32°C) and atmospheric pressure. The chemical or botanical agents were applied first in the Petri dishes followed by the placement of the biocontrol agent. The pathogen was placed diametrically opposite the biocontrol agent.

The treatment set consisted of two factors (i.e.; 3 isolates of *Trichoderma* species (*T. virens* isolate BGMZ2, *T. viride* isolate AIBK, and *T. harzianum* isolate AICV26), combined with fungicides (i.e.; Mancozeb and Ketoconazole (each at 50% and 100% concentrations))), and a control; laid out using a replicated completely randomized design.

Procedure 2: Effects of botanicals x biocontrol agents on *A. rolfsii*

The treatment set consisted of two factors (i.e.; the 3 isolates of *Trichoderma* species combined with two plant extracts (*Eucalyptus globulus* resin and *Ricinus communis* soap)) and a control; laid out using a replicated completely randomized design. The plant extracts were utilized at concentrations of 50% and 100%. The 100% plant extract consisted of 77.78 g of plant material per litre of distilled water.

Data collection and analysis

The data collected consisted of radial growth of the pathogen at 24-hour intervals. The percentage inhibition of the pathogen was calculated using Equation 1.

$$PI = ((C - T)/C) \times 100\% \quad \text{(Eqn. 1)}$$

Where

PI = % inhibition of the radial growth of the fungus

C = Perpendicular* radius of fungus colony in the control plate

T = Perpendicular radius of the fungus colony in the treated plate (Ndifon, 2022).

The data were subjected to the analysis of variance (ANOVA) using the General Linear Model procedure in the Genstat (Second edition Discovery version) statistical package and separation of the means was carried out using the Duncan Multiple range test (DMRT) at $P \leq 0.05$.

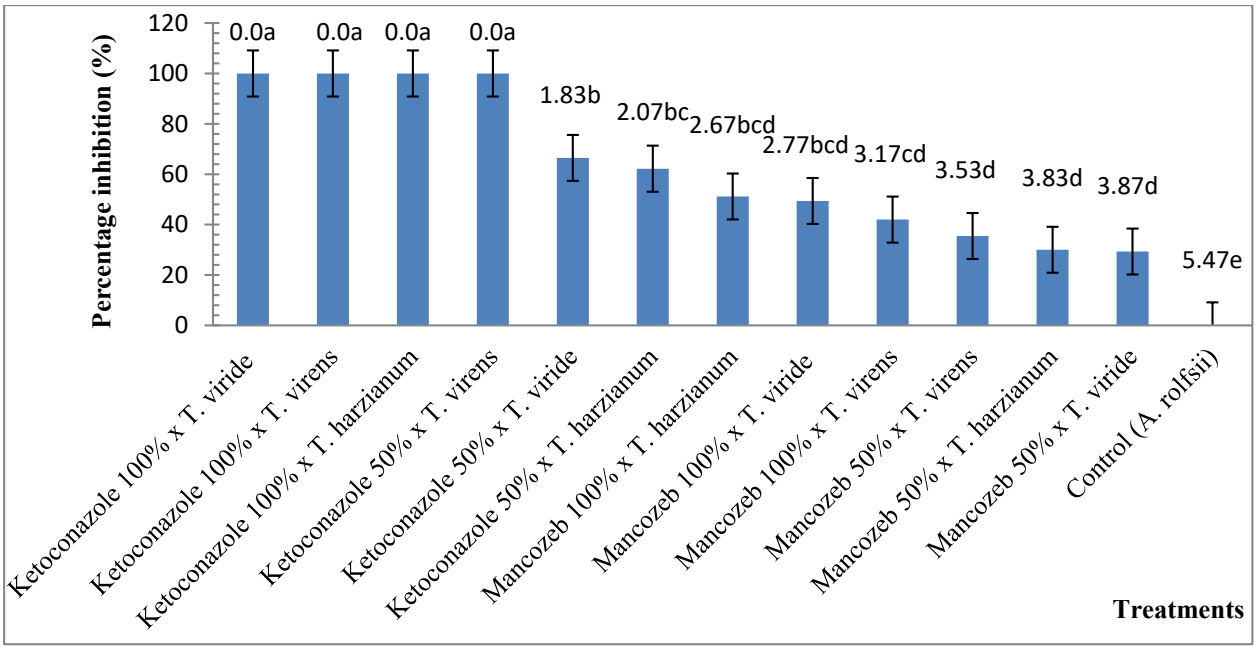
RESULTS AND DISCUSSION

The result of the effect of the interaction of Fungicides x *Trichoderma* species deployed against *A. rolfsii* is presented in Figure 1. The result reveals that combining Ketoconazole (50% and 100% concentrations) x *Trichoderma* species resulted in 95.8-100% inhibition of *A. rolfsii*. The control of the pathogen ranged from 39.3-100% inhibition for all concentrations of Mancozeb x *Trichoderma* species.

At the higher concentration of Mancozeb, *T. harzianum* interactions controlled the pathogen more, followed by *T. viride* combinations and lastly the *T. virens* combinations. All the chemical x *Trichoderma* species combinations were significantly different ($P \leq 0.05$) compared to the control.

The main effect of synthetic chemicals applied against *A. rolfsii* is presented in Figure 2. The result shows that the 100% rate of Ketoconazole completely inhibited the pathogen throughout. The effects of the two rates of Mancozeb (50% and 100% concentrations) reduced with time. The effects of both chemicals were consistently significantly different $P \leq 0.05$ compared to the control.

The main effect of the chemical fungicides in terms of decreasing level of efficiency could be ranged as Ketoconazole (100% concentration),



Means (radial growth (cm) in all the charts) followed by the same letter(s) in a series are statistically similar based on DMRT (P≤0.05).

Figure 1. The interaction effect of synthetic fungicides x *Trichoderma* species against the radial growth of *A. rolfsii*

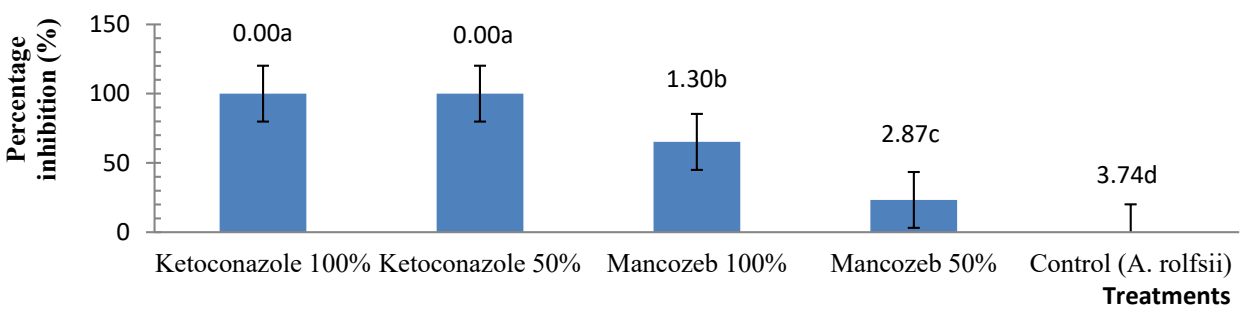


Figure 2. Main effect of synthetic chemicals against the radial growth of *A. rolfsii*

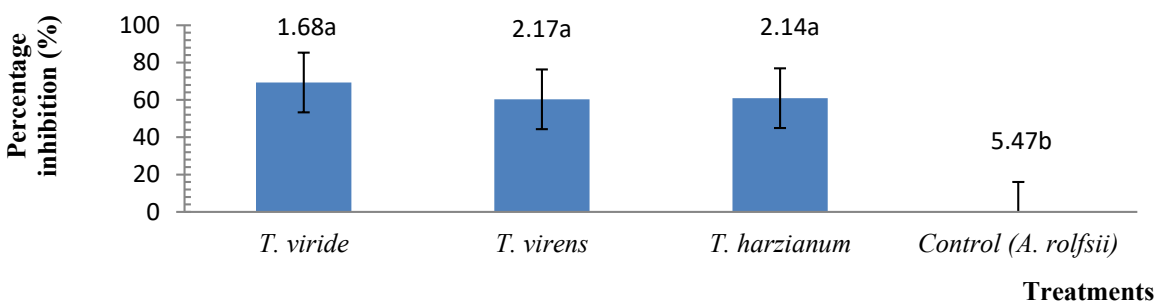


Figure 3. Main effect of *Trichoderma* species against the radial growth of *A. rolfsii*

Ketoconazole (50% concentration), Mancozeb (100% concentration), and lastly Mancozeb (50% concentration).

The main effect of *Trichoderma* species applied against *A. rolfsii* is presented in Figure 3. The result shows that the effect of *Trichoder-*

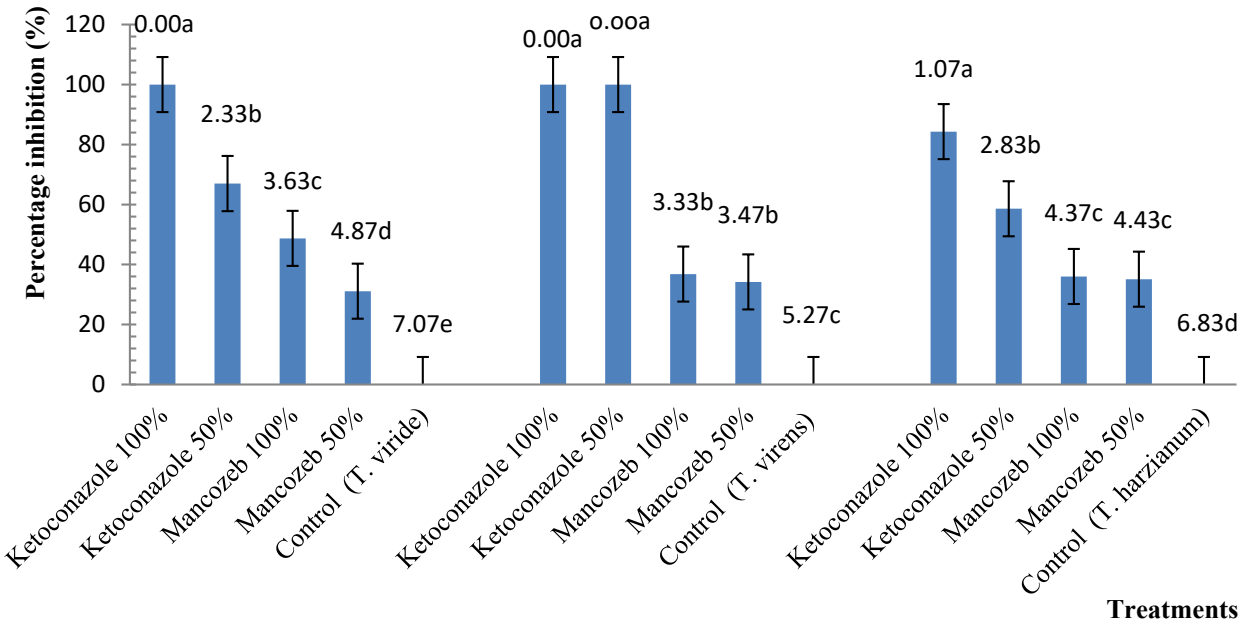


Figure 4. Influence of synthetic fungicides against *Trichoderma* species in the system

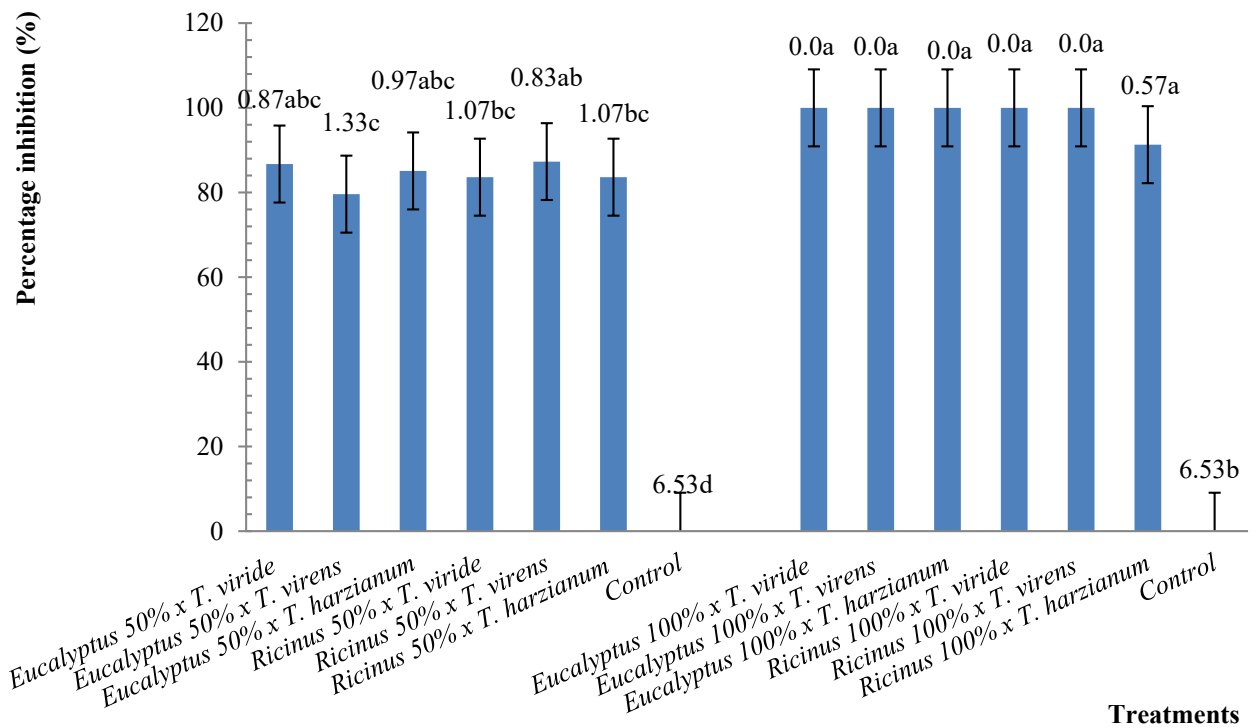


Figure 5. Interaction effect of plant extracts x *Trichoderma* species against the radial growth of *A. rolfsii*

ma species was fairly consistent against *A. rolfsii.* The percentage inhibition ranged from 60.3-96.7% for all *Trichoderma* species.

The influence of synthetic fungicides against *Trichoderma* species in the system is presented in Figure 4. It revealed that rates of Ketoconazole inhibited *Trichoderma* species more than the rates of Mancozeb. The effects of chemical fungicides correlated to *Trichoderma* species were highly positively correlated (0.522** at P≤0.05).

The result of the interaction effect of Plant extracts x *Trichoderma* species against the radial growth of *A. rolfsii* is presented in Figure 5. The interaction effects at 100% concentrations of the plant extracts were significantly different compared to the control. The interactions with *Ricinus* soap were better than those with *Eucalyptus* resin.

When using *Ricinus* sp., *T. virens* was the best agent but when using *Eucalyptus* sp., *T. viride* and *T. harzianum* were preferable. The percentage inhibitions were all above 80%. The interaction effects at 100% plant extracts were all able to provide 100% inhibition of *A. rolfsii* throughout.

The result of the main effect of *Trichoderma* species (as influenced by 50% botanical extracts) on the radial growth of *A. rolfsii* is presented in Figure 6. The result shows that *Trichoderma* species were capable of inhibiting the pathogen from onset till the termination of the trial. They provided excellent inhibition between 57-84%.

The result of the main effect of Plant extracts against the radial growth of *A. rolfsii* is presented in Figure 7. The results reveal that at 100% concentration, the *Ricinus* and *Eucalyptus* plant extracts completely inhibited this pathogen. This mid-range 50% concentration provided more than 80% inhibition of *A. rolfsii*.

The results of the influence of plant extracts on *Trichoderma* species in the system are presented in Figure 8. It reveals that *Eucalyptus* sp. inhibited all the *Trichoderma* species more than did *Ricinus* soap. *T. harzianum* was the least affected agent followed by *T. virens* then *T. viride.*

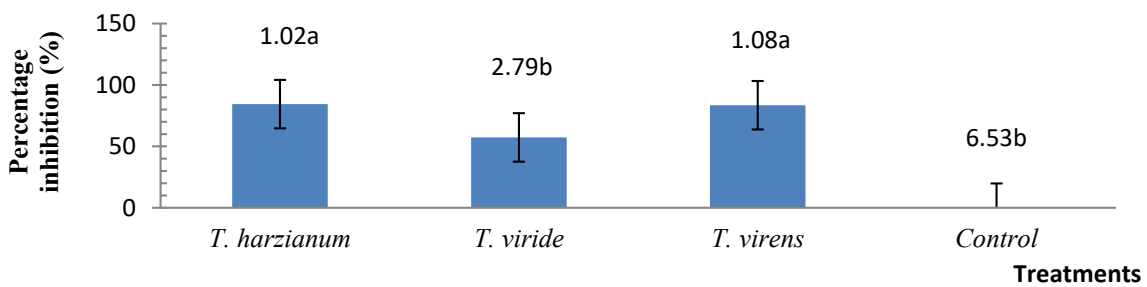


Figure 6. Main effect of *Trichoderma* species (at 50% botanical extracts) against the radial growth of *A. rolfsii*

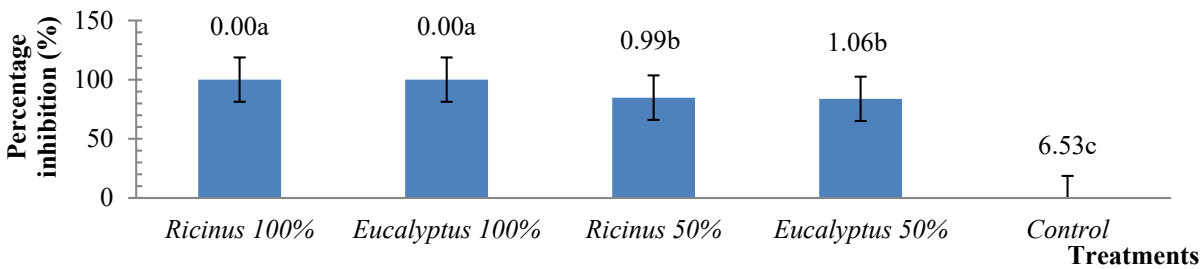


Figure 7. Main effect of plant extracts against the radial growth of *A. rolfsii*

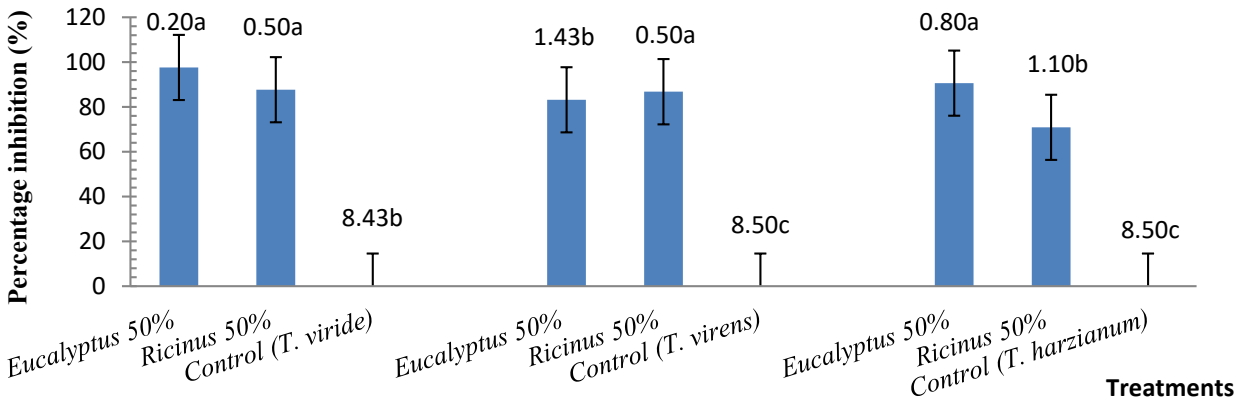


Figure 8. Influence of plant extracts on *Trichoderma* species in the system

Ndifon (2022) clarified that inhibition of *A. rolfsii* by Mancozeb (100% concentration) ranged between 10-90% with time. Maheshwary et al. (2022) fleshed out that *Trichoderma asperellum* was compatible with Mancozeb, Mancozeb+Metalaxyl-M, but not compatible with Tebuconazole, Propiconazole, Captan, and Carbendazim.

Ndifon (2023) amplified that Mancozeb+ Carbendazim Mancozeb+Cu(I)O+Metalaxyl, and Mancozeb significantly (P≤0.05) inhibited *Colletotrichum alatae* more compared to the other treatments. Arain et al. (2022) reported that *T. harzianum* was highly tolerant to Sulfur followed by Mancozeb (64% WP)+Metalaxyl (M4%), Metalexyl (M4%), Chlorothalonil (40%), Copper hydroxide, and Propiconazole. However, *T. harzianum* was highly susceptible to Difenoconazole and Carbendazim and higher rates of most fungicides. These findings corroborated the findings of this current study on the compatibility of fungicides and *Trichoderma* spp.

Parraguirre et al. (2023) reported that *Trichoderma asperellum* showed high compatibility with Captan and Mancozeb. The use of antagonistic strains of biocontrol agents together with Chlorothalonil, however, resulted in a reduction of the growth of *Trichoderma* species. These findings confirm the findings of this current study whereby higher levels of fungicides inhibited the biocontrol agents.

Additionally, Kumar et al. (2019) expounded that at higher rates Mancozeb, Thiram, and Chlorothalonil caused severe inhibition of the radial growth of *T. viride*. Finally, Carbendazim, Propiconazole, and Hexaconazole were not compatible with *T. viride*. Again, these concurs with findings that higher levels of the fungicides were antagonistic to biocontrol agents.

Sneha et al. (2016) elaborated that 4-5% garlic was 100% effective against *S. rolfsii* compared to 5% ginger (51.5% inhibition). Ndifon (2022) reported that *Eucalyptus* resin extracts inhibited the growth of *A. rolfsii* (8.0-100% inhibition) with time. This research concurs with the findings herein that botanicals especially *Eucalyptus* spp. can significantly inhibit radial growth of *A. rolfsii.*

Utilization of biocontrol agents has been touted as the best thing to happen to man. Ndifon (2023) reported that *T. harzianum* isolates AIM16 showed significantly (P≤0.05) better inhibition of *Colletotrichum alatae*. Sudeep et al. (2023) observed that aqueous extracts (neem and ginger) were compatible with *T. harzianum*, but other extracts were incompatible. This clearly shows the potential of combining Plant extracts x Biocontrol agents to combat diseases.

CONCLUSION

Sclerotium rots severely damage roots, stems, necks/collars/crowns, leaves, seeds, pods, and

fruits of more than 500 plant species globally. It was effectively managed *in vitro* using integrated biocontrol agents (*Trichoderma* species) concomitantly combined with either chemicals (Mancozeb or Ketoconazole) or botanicals (*Ricinus* or *Eucalyptus* species). However, in this integrated management approach, the biocontrol agents can be severely hindered by other agents when they are applied simultaneously. Thus, the expected additive results were not attained. Research on these hindrances is strongly recommended.

Conflict of interest: The author has declared that no conflict of interest exists concerning this research communication.

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Received: December 11 2023; *Approved:* April 16 2024; *Published:* June 2024