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Comparative analysis of *Azadirachta indica* and *Trichoderma viride* in the management of fungal-induced rot in *Ipomoea batatas*

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Abstract

Ipomoea batatas are susceptible to many plant pathogens. The main causes of pre- and post-harvest rots and other quality problems are farming practices, unusual weather, and post-harvest operations including sorting and shipping. This study was carried out to analyze the antifungal activities of Azadirachta indica and Trichoderma viride in controlling the rot associated with sweet potato tuber. The presence of Fusarium spp, Phytophthora infestans, Rhizoctonia solani, Pythium spp and Alternaria solani were identified as the fungi causing rot in Ipomoea batatas. The study's findings demonstrated that leaf extracts from Azadirachta indica and Trichoderma viride inhibited the growth of pathogen but varied at different concentrations for each treatment. Azadirachta indica leaf extracts showed a higher inhibitory activity (2.067) than Trichoderma viride (0.512) for the mean difference. Result from this study showed Azadirachta indica to have a more inhibitory effects on the fungi causing rot in Ipomoea batatas than Trichoderma viride. Data obtained revealed that Azadirachta indica has a significant potential as an antifungal treatment for managing rot fungi in Ipomoea batatas than Trichoderma viride. This study recommends the use of Azadirachta indica as an effective and sustainable option for controlling fungal pathogens causing rot in sweet potato.

Keywords: *Ipomoea batatas, Azadirachta indica, Trichoderma viride*

INTRODUCTION

Cultivated in many countries, including sub-Saharan Africa, sweet potatoes (*Ipomoea batatas*, L.), a root crop of the Convolvulaceae family, are an important secondary crop that contributes to household food security in many countries (15, 19, 21). The yellow-orange cultivars contain variable, but occasionally large, quantities of carotenoids, which act as precursors of vitamin A (20). Microorganisms, primarily fungi, can infect sweet potato roots at various stages, including field, harvest, and storage stages. Infection is primarily facilitated by mechanical injuries of the roots and environmental conditions (25). These cultivars combine a number of advantageous characteristics that give them great potential as food (26). Azadirachtin is the primary constituent of seeds that has both antifeedant and poisonous effects on insects. It is a complex tetranortriterpenoid limonoid. (14). Both *Staphylococcus aureus* and MRSA were susceptible to the *in vitro* antibacterial activity of the neem leaf ethanol extract, with the largest zones of inhibition seen at 100% concentration (21). According to Nawrocka *et al*. (16), secondary metabolites have the ability to stimulate plant growth, function as antibacterial agents, and supply abundant resources for the production of agricultural antibiotics. Neem has the ability to scavenge free radicals because of its abundance of antioxidants (7). One of the most prevalent culturable fungi, *Trichoderma* is found in a wide range of ecological diversity. The genus is widely distributed in root and soil ecosystems as well as plant waste, and it is free-living, cosmopolitan, facultatively anaerobic, filamentous, and asexually reproducing. *Trichoderma* has long been recognized as a microbial biocontrol agent that can replace chemical fungicides in the fight against the diverse range of fungus responsible for root rot, soilborne, and foliar infections (6). The term "antibiosis" primarily describes *Trichoderma's* capacity to produce antagonistic compounds that prevent the growth of plant pathogenic fungi (10, 9, 13, 23, 3). *Trichoderma* employs this phenomenon of antibiosis to manufacture low-molecular-weight, diffusible, specialized chemicals or an antibiotic with antifungal and antibacterial effects. Antibiotics can enter host cells, function as metabolic inhibitors, or hinder protein synthesis (translational routes), and prevent the target pathogen from producing metabolites, growing, sporulating, absorbing nutrients, or forming cell walls, depending on their biochemical makeup. Trichoderma can create hundreds of antimicrobial secondary metabolites, including as trichomycin, gelatinomycin, chlorotrichomycin, and antibacterial peptides. (12). The purpose of this study is to investigate the influence of *Azadirachta indica* leaf extracts and *Trichoderma viride* in the control of fungi causing rot in *Ipomoea batatas*.

MATERIALS AND METHODS

AREA OF STUDY

The Maeve Academic Research Laboratory in Awka served as the study's location.

COLLECTION OF MATERIALS

Samples of *Ipomoea batatas* were procured from the Eke Nibo market and kept in sterile paper bags. The *Azadirachta indica* leaves were collected from a farmland in Okpuno Awka while *Trichoderma viride* was collected from Maeve Academic research laboratory Awka.

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PREPARATION OF PLANT SAMPLE FOR PHYTOCHEMICAL EXTRACTION

After being left to dry at room temperature for five days, the plant samples were blended into a powder using an electric blender. One hundred milliliters of ethanol were used to extract fifteen grams (15g) of the sample for thirty minutes after it had been weighed using a Soxhlet extractor. The extract was stored for phytochemical and antibacterial testing after being moved into a 250 ml conical flask.

PHYTOCHEMICAL ANALYSIS

Qualitative Analysis (5)

Phenol Test: Add a few drops of a diluted ferric chloride solution to test for phenol to a test tube containing five milliliters (5ml) of the extract. The presence of phenols is indicated by the production of a red, blue, green, or purple colouring.

Alkaloids Test: The extract was pipetted into a test tube to check for alkaloids in five milliliters (5ml). Using Mayer's reagent (potassium mercuric iodide), the filtrate was thoroughly examined. Alkaloids are present when the precipitate is yellow in color.

Keller-Killani Test for Cardiac Glycoside: Five milliliters (5 ml) of extract were mixed with a few drops of glacial acetic acid, 10% ferric chloride, and concentrated sulfuric acid. The presence of cardiac glycosides is indicated by the reddish-brown appearance at the intersection of the two liquid layers.

Anthraquinone glycosides: Bontrager's test for anthraquinone glycosides involved adding diluted sulfuric acid to five milliliters (5 ml) of extract, boiling it, and filtering it. Then, adding an equivalent volume of benzene or chloroform to the cold filtrate, the organic layer was separated, and ammonia was added, causing the ammonia layer to turn pink or red.

Test for Flavonoids: A few drops of ammonia solution were combined with five milliliters of extract. Flavonoids are indicated by their yellow or orange appearance.

Test for Tannins: In a test tube, two milliliters (5 ml) of a 10% ferric chloride solution were added to five milliliters (5 ml) of water extract of every plant part. The presence of tannins is indicated by a blue-black precipitate.

Test for Saponin: To a test tube containing five milliliters (5 ml) of the plant sample two milliliters of distilled water were added to the plant sample, and it was vigorously shaken. The presence of saponin is indicated by the volume of persistent froth or bubbles that form.

Test for Steroids and Terpenes: A test tube containing five milliliters (5 ml) of sample extract was mixed with two milliliters of acetic anhydride and a few drops of strong sulfuric acid. Steroids are indicated by blue-green rings between layers, while terpenes are indicated by pink-purple rings.

Quantitative Analysis

Tannin: As stated by Ejikeme *et al.* (2) and Amadi *et al.* (1). The tannin content was quantitatively ascertained using an analytical method. The Folin-Denis reagent was made by dissolving 50 g of sodium tungstate (Na_2WO_4) in 37 cm^3 of distilled water. After adding 25 cm^3 of orthophosphoric acid (H_3PO_4) and 10 g of phosphomolybdic acid, the reagent was refluxed for two hours, cooled, and diluted with 500 cm^3 of distilled water. In a conical flask, 2g of the material was mixed with 50ml of distilled water. This was cooked gradually on an electric hot plate for an hour before being filtered using number 42 (125 mm) Whatman filter paper in a 100 cm^3 volumetric flask. Using a Spectrum Lab 23A spectrophotometer, optical density was measured at 700 nm and compared on a standard tannic acid curve. To develop color, 10 milliliters of saturated Na_2CO_3 solution and 5 milliliters of Folin-Denis reagent were added to the aliquot volume. The solution was then left to stand for 30 minutes in a water bath at 25°C following thorough agitation. Tannin was computed using the following formula:

$$\text{Tannin (\%)} = \frac{C \times \text{Extract Volume} \times 100}{\text{Aliquot volume} \times \text{weight of sample}}$$

C = absorbance of tannic acid

Estimation of Total Terpenoid Content*:* Ferguson's technique (4) was used to estimate the total terpenoid content in the aqueous extracts. Samples weighing 1g were placed in a conical flask and let to soak in ethyl alcohol for a day. It was filtered after that, and petroleum ether was used to extract the filtrate. The amount of total terpenoid was measured using the ether extract.

$$\text{Total terpenoid content} = \frac{(\text{Final weight of the sample} - \text{Initial weight of the extract}) \times 100}{\text{Weight of the Sample}}$$

Identifying Alkaloids: Harborne's (5) method was used to quantitatively identify alkaloids. Twenty milliliters of 10% acetic acid in ethanol were combined with three grams of the sample in a 150 ml conical flask. For four hours, the mixture was let to stand**.** After concentrating the extract to 25% of its initial volume in a water bath, 15 drops of concentrated ammonium hydroxide were added drop by drop to the extract until the precipitation was finished just after filtering. Following three hours of mixture sedimentation, the precipitates were cleaned with 20 milliliters of 0.1M ammonium hydroxide, and the supernatant was disposed away. Gem filter paper (12.5 cm) was then used to filter the mixture. After the residue was weighed and baked in an oven, the proportion of alkaloid was calculated quantitatively as follows:

$$\text{Alkaloid (\%)} = \frac{\text{Weight of alkaloid} \times 100}{\text{Weight of sample}}$$

Determination of Flavonoid. Ejikeme *et al.* (2) used their approach to determine flavonoids. Three grams of the sample and fifty milliliters of 80% aqueous methanol were combined in a 250 cm^3 beaker, covered, and allowed to stand at room temperature for twenty-four hours. Following three extractions of the residue using the same amount of ethanol, Whatman filter paper number 42 (125 mm) was used to filter the entire sample solution.

Following the entire evaporation of the sample filtrate over a water bath, the contents of the crucible were chilled in a desiccator and weighed until a consistent weight was reached.

The flavonoid proportion was determined as:

$$\text{Flavonoid (\%)} = \frac{\text{Weight of flavonoid} \times 100}{\text{Weight of sample}}$$

Determination of Saponin:

Saponin was quantitatively determined using the procedure outlined by Obadoni and Ochuko (17) and Ejikeme *et al*. (2).

100 milliliters (100 ml) of 20% aqueous ethanol were heated over a hot water bath for four hours at 55°C while being continuously agitated after five grams of the sample were added to a 250 ml conical flask. After filtration, the mixture's residue was re-extracted using 100 milliliters of 20% aqueous ethanol, and it was heated for four more hours at a steady 55°C while being constantly stirred. 20 ml of diethyl ether was added to the concentrate in a 250 cm3 separator funnel after the combined extract had been evaporated to 40 ml over a water bath at 90°C. The concentrate was then violently stirred, and the ether layer was disposed of while the aqueous layer was recovered. This purification procedure was carried out twice, adding 60 milliliters of n-butanol and extracting it twice using 10 milliliters of 5% sodium chloride. After discarding the sodium chloride layer, the leftover solution was heated for half an hour in a water bath, transferred to a crucible, and baked until it reached a consistent weight.

The percentage of saponin content was determined:

$$\text{Saponin (\%)} = \frac{\text{Weight of Saponin x 100}}{\text{Weight of sample}}$$

Cardiac Glycoside. In this study, two (2) grams of the sample were weighed into a 250 ml round-bottom flask, 60 ml of distilled water was added, and the mixture was left to stand for two hours to allow autolysis to occur. Next, an antifoaming agent (tannic acid) was added to the sample, followed by 20 ml of 3% NaOH (sodium hydroxide), and full distillation was carried out in a 250 cm^3 conical flask. Using a micro burette against a black backdrop, 8 milliliters of 6M NH4OH (ammonium hydroxide) and 2 milliliters of 5% KI (potassium iodide) were added to the distillate or distillates, combined, and titrated with 0.02M AgNO3 (silver nitrate). The final point is shown by the continual turbidity. The sample's cardiac glycoside content was determined to be

$$\text{Cardiac glycoside (\%)} = \frac{\text{Titer value x 1.08 x extract volume}}{\text{Aliquot volume x sample weight}}$$

Determination of Phenols. In order to extract the phenolic components, two grams (2g) of the sample were defatted in 100 milliliters of petroleum using a Soxhlet extractor, or two grams of wood powder were defatted in 100 centiliters of ether using a Soxhlet apparatus. The defatted sample was then boiled for 15 minutes with 50 milliliters of ether, and five milliliters of concentrated amyl alcohol, 10 milliliters of distilled water, and two milliliters of 0.1N ammonium hydroxide solution were added to five milliliters of the extract. The mixture was then let react for 30 minutes to develop color, and the optical density was measured at 505 nm. The phenol standard curve was prepared by dissolving 0.20 g of phenolic acid in distilled water and diluting it to the 200 mL mark (1 mg/cm^3). Five independent test tubes were pipetted with varied concentrations (0.2–1.0 mg/cm^3) of the standard phenol acid solution. Next, five milliliters of amyl alcohol, ten milliliters of water, and two centimeters of NH3OH were added. After mixing the solution to a volume of 100 ml, it was left to react for 30 minutes in order to develop the color. The optical density at 505 nm was measured.

Determination of Anthraquinones glycoside: To determine the amount of anthraquinones glycoside, 50 grams of the sample were soaked for 16 hours in 50 milliliters of distilled water. This suspension was cooked for one hour at 70ºC in a water bath. Following cooling, 50 milliliters of 50% methanol (MeOH) were added to the suspension and filtered. The spectrophotometer assessed the clear solution at 450 nm and compared it to a standard solution that included 1 mg/100 mL purpurin and 1 mg/100 mL alizarin with an absorption-maximum of 450 nm (11).

Determination of Steroids: Determination of Steroids: This was determined by the method reported by Okeke and Elekwa, (18). Five 5g of the material was distributed in 100 ml of freshly distilled water and homogenized in a laboratory blender. After the homogenates were filtered, a standard ammonium hydroxide solution (pH 9) was used to elute the filtrate. Two milliliters of the eluents were combined with two milliliters of chloroform in test tubes. Two drops of conc and three milliliters of ice-cold acetic anhydride were added to the liquid in the flask. After preparing and processing a standard sterol solution, H_2SO_4 was cautiously added. The absorbance of the standard and produced samples was measured at 420 nm in a spectrophotometer and duly noted.

PREPARATION OF CULTURE MEDIA

Twenty-five (25) milliliters of distilled water were poured to a 250ml conical flask containing two grams (2 grams) of Sabouraud Dextrose Agar (SDA). The media was autoclaved for fifteen minutes at 121°C and 15 psi of pressure. After that, nine milliliters of the medium were put into a petri dish and left to cool. In order to promote the growth of fungal organisms, 2g of the sick plant sample was injected onto a petri dish and incubated for 72 hours. Pure cultures were gotten by further subculture into freshly prepared media.

ANTI-MICROBIAL ASSAY

The plant sample extracts were used to apply Shiriki's methodology (22). The plant extract at concentrations of 4 mg/l and 8 mg/l was pipetted into sterile, labelled petri dishes that held the organism's pure culture. The radial growth of the fungus on the medium containing and excluding extracts was used to assess and record the organism's inhibition zones. The results were then analyzed based on the percentage growth inhibitions of microorganisms. The toxicity of the extracts was measured by the suppression of microbiological growth on SDA medium. After three replications of the experiment, the percentage growth inhibition over four days was computed.

$$\text{\% growth inhibition} = \frac{R_a - R_b X\ 100}{R_b}$$

Where Ra = the pathogens' maximum radial distance in control plates.

Rb = the pathogens' maximum radial distance in extract (treated) plates.

The minimum inhibition concentration that will be useful in managing the microbial organisms was chosen using the inhibition percentage as a guide

IDENTIFYING FUNGAL ISOLATE

Identification of the fungal isolate was done using the morphological and anatomical features of the fungi. This was carried out in this manner.

Morphological identification: The pigments and growth pattern generated in Czapek Dox agar (CZ) fungal differential media were noted, compared to those in the fungi identification kit, and noted appropriately.

Anatomical Identification: In this case, the different tests and exams were conducted using the techniques of Shiriki et al., (22). A smear of the fungal growth was fixed on a slide, and another was stained with phenol red and distilled water. The smears were studied under binocular microscope and the anatomical characteristic documented and compare them to those on the fungal identification kit, then identify them appropriately.

ANALYTICAL STATISTICS

On the collected data, a two-way analysis of variance was conducted (ANOVA) at 0.05% significance level with the use of Sigmaplot statistical package version 12.

RESULTS

In Table 1, alkaloids, present at a concentration of 1.38%, phenols, is also present at a much lower concentration of 0.18%, and saponins at 0.72%, Tannins, is present and found at 0.23%, while terpenoids and anthraquinone glycosides were absent. Flavonoids, are present at 0.43% and glycosides at 0.01%.

Table 1: Qualitative and Quantitative Analysis of Azadirachta indica

S/N	Phytochemical	Present (+) Absent (-)	Quantitative
1	Alkaloid	+	1.38%
2	Phenol	+	0.18%
3	Saponin	+	0.72%
	Tannin	+	0.23%
4	Terpenoid	-	-
5	Flavonoid	+	0.43%
6	Glycoside	+	0.01%
7	Anthraquione glycoside	-	-
8	Steroid	-	-

In Table 2, fungi associated with *Ipomoea batatas* rot include: *Fusarium spp, Phytophthora infestans, Rhizoctonia solani, Pythium spp* and *Alternaria solani*

Table 2: Isolated Rot Fungi Organism of Ipomea batata (Sweet Potatoes)

List of possible rot fungi Organism of potatoes	Isolated fungi present(✓) absent(✗)
Fusarium spp	✓
Phytophthora infestans	✓
Rhizoctonia solani	✓
Pythium spp	✓
Sclerotinia sclerotiorum	✗
Alternaria solani	✓
Colletotrichum coccodes	✗
Helminthosporium solani	✗
Botrytis cinerea	✗

The data presented in Table 3 provides a comprehensive analysis of the *in vitro* anti-fungal effects of *Azadirachta indica* (neem) on *Ipomoea batata* (sweet potato) rot fungi. For *Fusarium spp.*, the anti-fungal activity at 4 mg/l of neem extract resulted in a mean inhibition of 0.342 ± 0.019, slightly increasing to 0.344 ± 0.022 at 8 mg/l. This relatively modest difference suggests that the neem extract exhibits a consistent inhibitory effect on *Fusarium spp.*, with a statistically significant difference compared to the control group (0.016 ± 0.006).

The effect on *Phytophthora infestans* shows similar trends, with inhibition values of 0.365 ± 0.020 and 0.367 ± 0.018 for 4 mg/l and 8 mg/l respectively. The control group's inhibition of 0.018 ± 0.007 reflects minimal effect without neem application. The consistent and slightly increasing inhibition with higher neem concentrations suggests that this treatment could effectively reduce the impact of *Phytophthora infestans* in rot development.

For *Rhizoctonia solani*, the data showed mean inhibition values of 0.348 ± 0.020 and 0.349 ± 0.018 for 4 mg/l and 8 mg/l, respectively, while the control group's result of 0.017 ± 0.009 confirms the negligible natural resistance without treatment. *Pythium spp.* showed an inhibitory effect of 0.358 ± 0.020 at 4 mg/l and 0.360 ± 0.021 at 8 mg/l. *Alternaria solani* showed inhibition values of 0.354 ± 0.022 at 4 mg/l and 0.356 ± 0.025 at 8 mg/l, while the control group yielded 0.014 ± 0.008.

Table 3: Antifungal Effect of Azadirachta indica on fungi causing rot Ipomoea batatas

Fungi	4mg/l X±SD	8mg/l X±SD	Control X±SD
Fusarium spp	0.342 ± 0.019	0.344 ± 0.022	0.016 ± 0.006
Phytophthora infestans	0.365 ± 0.020	0.367 ± 0.018	0.018 ± 0.007
Rhizoctonia solani	0.348 ± 0.020	0.349 ± 0.018	0.017 ± 0.009
Pythium spp	0.358 ± 0.020	0.360 ± 0.021	0.015 ± 0.006
Alternaria solani	0.354 ± 0.022	0.356 ± 0.025	0.014 ± 0.008
***p*-value**	**0.000**	**0.0002**	**0.0121**

Table 4 showed that for *Fusarium spp.*, the antifungal effects across all groups is minimal. At 4 mg/L, *Trichoderma viride* demonstrated an inhibition value of 0.018 ± 0.007, slightly decreasing at 8 mg/L to 0.019 ± 0.008, while the control registered at 0.016 ± 0.006. For *Phytophthora infestans*, the results suggest a more dynamic interaction between *Trichoderma* concentrations and antifungal efficacy. At 4 mg/L, the value is 0.012 ± 0.005, but at 8 mg/L, it rose to 0.020 ± 0.007, surpassing the control value of 0.018 ± 0.007. This shows that increasing the *Trichoderma* concentration led to a more pronounced inhibition of *Phytophthora infestans*, suggesting a dose-dependent relationship. For *Rhizoctonia solani*, at 4 mg/L, *Trichoderma viride* inhibited *Rhizoctonia* growth with a value of 0.013 ± 0.007, which increases to 0.023 ± 0.009 at 8 mg/L, significantly higher than the control value of 0.017 ± 0.009.

In *Pythium spp.,* both 4 mg/L and 8 mg/L concentrations of *Trichoderma viride* showed identical values of 0.015 ± 0.005 and 0.015 ± 0.008, respectively, which are also identical to the control value of 0.015 ± 0.006. This uniformity suggests that *Trichoderma* does not exhibit any meaningful antifungal activity against *Pythium* at the tested concentrations. The p-value of 0.0121, while indicating statistical significance, suggests that these minor variations are not biologically meaningful. This implies that *Pythium* may be resistant to the antifungal mechanisms of *Trichoderma viride* at the tested levels.

For *Alternaria solani*, the antifungal effect of *Trichoderma* at 4 mg/L is modest, with a value of 0.012 ± 0.006, while at 8 mg/L, it increases to 0.016 ± 0.006.

Table 4: Antifungal effect of Trichoderma viride on fungi causing rot in Ipomoea batatas

Fungi	4mg/l X±SD	8mg/l X±SD	Control X±SD
Fusarium spp	0.018 ± 0.007	0.019 ± 0.008	0.016 ± 0.006
Phytophthora infestans	0.012 ± 0.005	0.020 ± 0.007	0.018 ± 0.007
Rhizoctonia solani	0.013 ± 0.007	0.023 ± 0.009	0.017 ± 0.009
Pythium spp	0.015 ± 0.005	0.015 ± 0.008	0.015 ± 0.006
Alternaria solani	0.012 ± 0.006	0.016 ± 0.006	0.014 ± 0.008
p-value	**0.0001**	**0.0003**	**0.0121**

Table 5 presents a Least Significant Difference (LSD) comparison of the inhibitory effects of *Trichoderma viride* and *Azadirachta indica*, on fungi causing rot in *Ipomoea batatas*. The mean differences (X) indicate the relative effectiveness of these treatments in inhibiting fungal growth, with *Azadirachta indica* demonstrating a markedly higher inhibitory effect (2.067) compared to *Trichoderma* spp. (0.512).

Table 5: LSD Comparison of Treatment Type That Has Better Inhibitory Effect on Fungi Causing Rot in Ipomoea Batatas

TREATMENT	MEAN DIFFERENCE(X)
Trichodema spp	0.512
Azadiracta indica	2.067

DISCUSSION

The findings from this study indicated that *Azadirachta indica* is rich in its qualitative and quantitative phytochemical profile. It showed that alkaloids are present which suggests significant medicinal potential due to their well-known pharmacological properties, especially in antimicrobial and analgesic applications. Phenols, although present in a lower concentration play a critical role due to their antioxidant activities. The presence of saponins shows its role in immune modulation and anti-inflammatory functions. Tannins contribute to wound healing and antimicrobial activity, while flavonoids enhance the plant's antioxidant and anti-inflammatory potential. Glycosides, present in trace amounts also may still have significant pharmacological benefits despite their low concentration. The absence of terpenoids, anthraquinone glycosides, and steroids suggests that these compounds may not contribute to the medicinal efficacy of *Azadirachta indica*, but the remaining bioactive compounds offer a promising profile for therapeutic applications, particularly in antifungal contexts.

The finding also indicated the fungi responsible for the rot in *Ipomoea batatas* and revealed the presence of several significant pathogens, including *Fusarium spp.*, *Phytophthora infestans*, *Rhizoctonia solani*, *Pythium spp.*, and *Alternaria solani*. These organisms represent a wide range of fungal threats, each known for causing significant damage to tuber crops like sweet potatoes. The presence of these pathogens suggests a need for effective antifungal treatments in agricultural practice, particularly to manage post-harvest losses and maintain crop quality. The absence of certain other fungi, such as *Sclerotinia sclerotiorum*, *Colletotrichum coccodes*, and *Botrytis cinerea*, indicates that these pathogens may not pose immediate threats in the examined conditions, but their potential emergence remains a concern in different environmental contexts or in future cultivation cycles. The *in vitro* antifungal effects of *Trichoderma* spp. on the identified rot fungi organisms also indicated that while there is some antifungal activity at both 4 mg/L and 8 mg/L concentrations, particularly against *Phytophthora infestans* and *Rhizoctonia solani*, the overall results suggest that *Trichoderma* viride has limited inhibitory capacity at the tested concentrations. For pathogens like *Pythium spp.*, no significant inhibition was observed, indicating that *Trichoderma* may not be universally effective across all fungi species.

The increasing inhibitory effect observed at 8 mg/L, particularly against *Phytophthora* and *Rhizoctonia*, suggests that higher concentrations or optimized environmental conditions may enhance *Trichoderma viride* antifungal activity. This supports the findings of Maruyama *et al.* (12), who found that Trichoderma may generate hundreds of secondary metabolites that are antimicrobial, such as gelatinomycin, trichomycin, chlorotrichomycin, and antibacterial peptides.

Comparative analysis between *Trichoderma viride* and *Azadirachta indica* in terms of their inhibitory effects on the fungi rot organisms showed a stark contrast in effectiveness, with *Azadirachta indica* showing a mean inhibitory effect of 2.067, far surpassing *Trichoderma viride* with a mean difference of 0.512. This substantial difference underscores the superior antifungal properties of *Azadirachta indica* compared to *Trichoderma*, likely attributable to its rich phytochemical profile, including alkaloids, phenols, saponins, and flavonoids. The results suggest that *Azadirachta indica* is far more potent in inhibiting the growth of fungal pathogens in sweet potatoes, highlighting its potential as a natural, plant-based fungicide. It also supports the findings of Nawrocka et al. (16), who claimed that secondary metabolites can stimulate plant growth, function as antibacterial agents, and supply abundant resources for the creation of agricultural antibiotics.

CONCLUSION

In conclusion, the study showed that *Azadirachta indica* has significant potential as an antifungal treatment for managing rot fungi in sweet potatoes. Its broad-spectrum antifungal activity, as evidenced by its superior performance in the LSD comparison, suggests that it might be a useful substitute for artificial fungicides. *Trichoderma viride* while offering some antifungal benefits, is less effective compared to *Azadirachta indica* particularly at the concentrations tested and may require optimization to achieve meaningful results. The study recommends the use of *Azadirachta indica* as a more effective and sustainable option for controlling fungal pathogens affecting rot in sweet potatoes (*Ipomoea* batatas). The study also recommends the use of these biological antagonists used in this study in controlling fungal pathogens causing rot in other food crops.

REFERENCES

1. Amadi, B. A., Agomuo, E. N., and Ibegbulem, C. O. (2004). *Research methods in biochemistry*. Supreme Publishers.

2. Ejikeme, C. M., Ezeonu, C. S., and Eboatu, A. N. (2014). Determination of physical and phytochemical constituents of some tropical timbers indigenous to Niger Delta area of Nigeria. *European Scientific Journal. 10(18):* 247-270.

3. El-Hasan, A., Walker, F., Klaiber, I., Schöne, J., Pfannstiel, J. and Voegele, R. T. (2022). New approaches to manage Asian soybean rust (*Phakopsora pachyrhizi)* using *Trichoderma spp* or their antifungal secondary metabolites. *Journal of Fungi. 8(2):* 139.

4. Ferguson, N. M. (1956). *A textbook of pharmacognosy.* MacMillan Company.

5. Harborne, J. B. (1973). *Phytochemical methods: A guide to modern techniques of plant analysis* (1st ed.). Chapman and Hall.

6. Harman G. E. (2006). Overview of mechanisms and uses of *Trichoderma spp. Phytopathol. 96:* 190-194.

7. Hossain, M. A., Al-Toubi, W. A. S., Weli, A. M., Al-Riyami, Q. A. and Al-Sabahi, J. N. (2013). Identification and characterization of chemical compounds in different crude extracts from leaves of Omani neem. Journal of Taibah University for Science. 7(4): 181-188.

8. Hu, W., Shun-Ichiro, T., and Voshiaki, H. (2004). Effects of heat treatment on quality of sweet potatoes in wrapper type coke storage during long-term storage. *Journal of Faculty of Agriculture, Kyushu University. 49:* 129-139.

9. Izquierdo-García, L. F., González-Almario, A., Cotes, A. M. and Moreno-Velandia, C. A. (2020). *Trichoderma virens* Gl006 and *Bacillus velezensis* Bs006: A compatible interaction controlling Fusarium wilt of cape gooseberry. *Scientific Reports. 10:* 6857.

10. Kottb, M., Gigolashvili, T., Großkinsky, D. K. and Piechulla, B. (2015). *Trichoderma volatiles* affecting Arabidopsis: From inhibition to protection against phytopathogenic fungi. *Frontiers in Microbiology. 6:* 995.

11. Kumar, A., Ilavarasan, R., Jayachandran, T., Deecaraman, M., Aravindan, P., Padmanabhan, N., and Krishnan, M. R. V. (2009). Phytochemical investigation on a tropical plant. *Pakistan Journal of Nutrition. 8(1):* 83-85.

12. Maruyama, C. R., Bilesky-José, N., de Lima, R. and Fraceto, L. F. (2020). Encapsulation of *Trichoderma harzianum* preserves enzymatic activity and enhances the potential for biological control. *Frontiers in Bioengineering and Biotechnology. 8:* 225.

13. Morán-Diez, M. E., Carrero-Carrón, I., Rubio, M. B., Jiménez-Díaz, R. M., Monte, E. and Hermosa, R. (2019). Transcriptomic analysis of *Trichoderma atroviride* overgrowing plant-wilting Verticillium dahliae reveals the role of a new M14 metallocarboxypeptidase CPA1 in biocontrol. *Front. Microbiol. 10*: 1120.

14. Mordue, A. J. and Nisbet, A. J. (2000). Azadirachtin from the neem tree Azadirachta indica: Its action against insects. *Anais da Sociedade Entomológica do Brasil. 29(4):* 615632.

15. Mutuura J.N, Ewell P.T, Abubaker A, Munga T, Ajanga S, Irungu J, Omari F, Maobe S. (1992). Sweet potato in the food systems of Kenya: Results of a socio-economic survey. In: Kabira JN, Ewell PT (Eds) *Current Research for the Improvement of Potato and Sweet Potato in Kenya*, Proceedings of KARI/CIP Technical Workshop on Collaborative Research held from 20th February to 1st March 1991 in Nairobi, Kenya, pp 51-66

16. Nawrocka, J., Kaczmarek, M., Bączek, K., and Kaczmarek, M. (2018). Secondary metabolites can act as antibacterial agents, promote plant growth, and provide rich materials for the development of agricultural antibiotics. *Journal of Plant Protection Research. 58(4):* 361–368.

17. Obadoni, B. O., and Ochuko, P. O. (2002). Phytochemical studies and comparative efficacy of the crude extracts of some homeostatic plants in Edo and Delta States of Nigeria. *Global Journal of Pure and Applied Sciences. 8(2):* 203-208.

18. Okeke, B. C., and Elekwa, I. (2013). Phytochemical screening and antibacterial activity of some medicinal plants. *International Journal of Pharmacognosy and Phytochemical Research. 5(1):* 65-69.

19. Ray, R.C, Ravi ,V, Rao, K.R, Hegde V, Tomlins K.I (2010). Post-harvest handling, storage methods, pests and diseases of sweet potato. In: Ray RC, Tomlins KI (Eds) *Sweet Potato: Post-harvest Aspects in Food*, *Feed and Industry*, Nova Science Publishers Inc., Hauppauge, New York, USA, pp 27-58

20. Ray R.C, Tomlins K.I (2010). *Sweet Potato: Postharvest Aspects in Food*, *Feed and Industry*, Nova Science Publishers, New York, 316 pp

21. Sarmiento, W. C., Maramba, C. C. and Gonzales, M. L. M. (2011). An in vitro study on the antibacterial effect of neem (*Azadirachta indica*) leaf extracts on methicillin-sensitive and methicillin-resistant *Staphylococcus aureus. PIDSP Journal. 12(1):* 40-45.

22. Shiriki, D. M., Alhassan, A. J., Ibrahim, H., and Zubairu, A. M. (2015). Antimicrobial activity of some selected medicinal plants in Nigeria. *Journal of Medicinal Plants Research. 9(2):* 45-51.

23. Shobha, B., Lakshmeesha, T. R., Ansari, M. A., Almatroudi, A., Alzohairy, M. A. and Basavaraju, S. (2020). Mycosynthesis of ZnO nanoparticles using *Trichoderma spp*. isolated from rhizosphere soils and its synergistic antibacterial effect against *Xanthomonas oryzae* pv. *oryzae. Journal of Fungi. 6:* 181.

24. Tomlins K.I, Rees D, Ray R.C, Westby A. (2010). Sweet potato utilization, storage and small scale processing in Africa: Overview. In: Ray RC, Tomlins KI (Eds) *Sweet Potato: Post-harvest Aspects in Food*, *Feed and Industry*, Nova Science Publishers Inc., Hauppauge, New York, USA, pp 271-294.

25. Wills R, McGlasson B, Graham D, Joyce D. (1998). *Postharvest: An Introduction to the Physiology and Handling of Fruit*, *Vegetables and Ornamentals* (4th Edn), CAB International, Wallingford, UK, 262 pp.

26. Woolfe J.A (1992). *Sweet Potato - An Untapped Food Resource*, Cambridge University Press, Cambridge, New York, 643 pp.