

ARTICLE

Management of *Fusarium anthophilum* (Pathogen of Cereals and White Yams) Using Different Measures

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ABSTRACT

Fusarium species (including *Fusarium anthophilum*) have many insidious effects on mankind, animals, and plants. Their attack may lead to diseases or spoilage, and the production of mycotoxins. This study was conducted to find solutions to the infections by *F. anthophilum*. Three sub-trials (botanical, chemical and biocontrol sub-trials) were set up using completely randomized design, and each treatment was replicated thrice. The percentage inhibition of *F. anthophilum* in the botanicals-alone sub-trial (i.e., *Eucalyptus*, *Euphorbia*, *Andrographis*, and *Melaleuca* spp.) at 50% and 100% concentrations ranged from 20% to 100%. At 72, 120, and 168 HAI (hours after inoculation), *Eucalyptus* (all concentrations) controlled the pathogen significantly more, followed by *Melaleuca* (all concentrations). All the botanicals (at both concentrations) controlled *Fusarium* sp. significantly more compared to the control. Based on the second sub-trial: the best synthetic fungicide+*Trichoderma harzianum* treatment was Mancozeb100%, and the percentage inhibition by these combined chemical+biocontrol treatments ranged from 28% to 50%. Mancozeb100%, followed by Metalaxyl+Cu(I) O 100% produced the highest inhibition. All chemical treatments were significantly different compared to the control (120 hours after inoculation). Based on the third sub-trial: the best Botanical+*T. harzianum* treatment was Alligator pepper100% followed by Tumeric100%. The percentage inhibition of *Fusarium* sp. by these treatments ranged from 28% to 70%. Alligator pepper100% followed by Tumeric100%, then Tumeric50%, and *Eucalyptus*100% ... were significantly different compared to the control. Combining different agents was effective in controlling the pathogen. However, lower percentage inhibitions were obtained. More research on integrating the control agents is being admonished.

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1. Introduction

Globally, the highest quantity of yams (54 million metric tons of yams annually) comes from West Africa: Benin, Togo, Ghana, Côte d'Ivoire and notably Nigeria. Nigeria is the highest world producer of yams^[1,2]. Yams serve various socio-economic roles; as a source of food, medicines, and industrial raw materials. Cereals (i.e., maize, millet, sorghum, barley, and rice) are major staple foodstuffs that sustain most of the world's population. These very important agricultural produce are susceptible to infection by *Fusarium* species, which cause wilting as the major symptom, and ultimately death of the plant.

However, these infections by *Fusarium* species have other insidious consequences. Nelson et al.^[3] demonstrated that isolates of *F. anthophilum* (A.Braun) Wollenw and seven other *Fusarium* species produced the mycotoxin - fumonisin B1 in culture. These researchers scored *F. anthophilum* and *F. dlamini* as minor pathogens because they did not find these two species in association with corn or other major food grains. This was the first report of the production of fumonisins by *F. anthophilum*, *F. dlamini*, and *F. napiforme*. This scoring was based on their presence in cereal production systems only.

The production of mycotoxins was not considered by Nelson et al.^[3] even though the health hazard may result in the rejection of the agricultural produce for export or consumption. Additionally, *Fusarium* species produce many mycotoxins (like zearalenone, zearalene, deoxynivalenol or nivalenol, T-2 toxin, diacetoxyscirpenol, etc.) which have economic importance due to their toxicity to animals, humans, and plants. These fungi are commonly associated with grains, and agricultural produce^[4,5]. Thus many species of *Fusarium* need to be managed to mitigate their effects on agriculture and society. This is necessary considering the high yield losses (due to tuber rot, and grain contamination) as well as the excessive cost of treating cases of mycosis like fusariosis.

Nahar and Mushtaq^[6] reported that *F. anthophilum* and five other *Fusarium* species infect sunflower (*Helianthus annuus*) and most of them are soil-borne plant pathogens. Ndifon and Lum^[2] reported that *F. anthophilum* and seven other fungi species were isolated from rotted white yam (*Dioscorea rotundata* Poir) tubers. These tuber rot agents cause heavy yield loss of yam tubers in store annually.

Control of mycopathogens using synthetic pesticides is still very much in vogue based on their efficacy and timeliness. Abdullah et al.^[7] stated that *Fusarium* species, in general, are resistant to the older azoles (e.g. itraconazole and fluconazole), and echinocandins. *Fusarium* species

show variable resistance to triazoles. These researchers revealed that Amphotericin B is the most active drug, followed by voriconazole, posaconazole, isavuconazole, and natamycin. However, fluconazole, itraconazole, and micafungin have little effect on the treatment of fusariosis.

Isman^[8] expressly pointed out that the impact of botanicals in agriculture is still highly limited (only pyrethrum and neem are well-established pesticides commercially). Nowadays some plant essential oil pesticides are available commercially although the use of rotenone seems to be declining. Regulatory barriers and the availability of competing products (newer synthetic pesticides, products from fermentation, and anti-microbials) that are cost-effective and relatively safe compared to their predecessors are factors militating against the use of botanicals. However, botanicals have a niche in integrated pest and disease management, organic farming, and post-harvest protection of food even in developing countries.

On another promising note, Verma et al.^[9] reported that *Trichoderma* species control pathogens using mycoparasitism, competition (for space and nutrients), antibiosis (through secretion of enzymes and secondary metabolites), and induction of plant defence system. *Trichoderma* species produce a wide range of commercial enzymes (namely; cellulases, hemicellulases, proteases, and α -1, 3-glucanase), which are essential in the industry. *Trichoderma* species and other microbes may be rallied and set in battle array against pathogenic fungi like *F. anthophilum*. Based on the foregoing informative discourse, this study was carried out to assay the potential of utilizing botanical, bio-control, and chemical measures to manage *F. anthophilum* infections.

2. Materials and Methods

2.1 Site of the Study

This study was carried out at Alex Ekwueme Federal University Ndufu-Alike, Abakaliki (at 6.069°N by 8.199°E). Here the mean relative humidity is usually above 70% for 9 months per annum. Thus plant disease outbreaks are very common in the area. This university is located in the derived savannah ecological zone of Nigeria with well-drained iron-rich loamy soils which are excellent for yam and cereal cultivation.

Based on Figure 1, the patterns of the up/down bars show that the cross-over points are in August-September when the heavy rainfall coupled with low maximum temperatures result in damp weather. Moreover, the mean relative humidity is at its peak from July to September. These conditions may favour severe plant disease outbreaks.

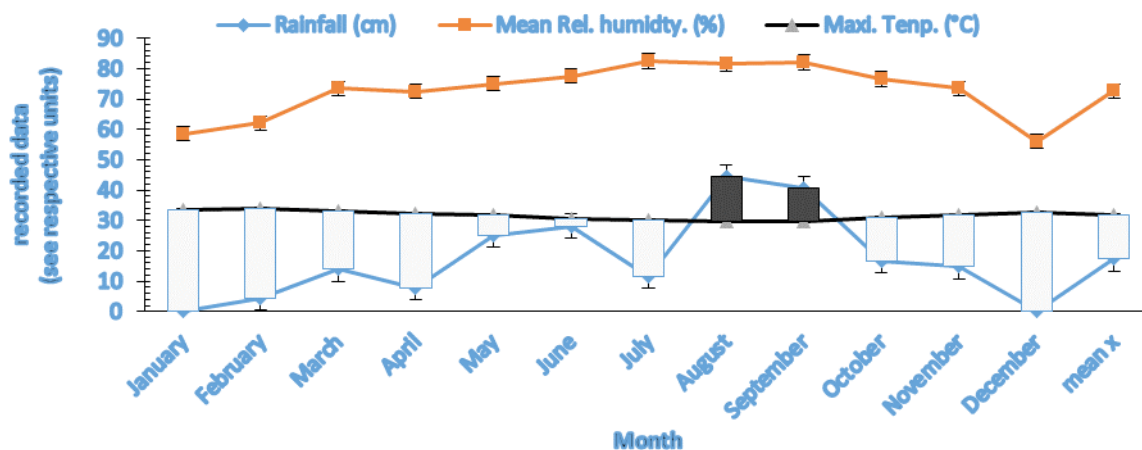


Figure 1. Climatic pattern for Abakaliki (Ebonyi State) showing the monthly rainfall, monthly mean relative humidity and maximum monthly temperatures for the area and its environs

* The error bars were calculated using standard error

Sources: 35-year climate trends. Meteoblue® Weather 2006-2020. Climate-data.org. Timeanddate.com 1999-2020 as compiled by Ndifon EM. 2020, FAG, AE-FUNAI, Nigeria.

2.2 Isolation and Identification of the Fungi Utilized in the Trials

The infected white yam tubers utilized for this research were obtained from south-eastern Nigeria. While the *Trichoderma species* was isolated from farm-land soils collected from yam farms in south-eastern Nigeria. The fungi (*Fusarium anthophilum* and *Trichoderma harzianum*) were isolated using potato dextrose agar (PDA) which was autoclaved at 120°C and 15 psi for 15 min according to the manufacturer's (LifeSave Biotech; USA) instructions. The isolated fungi were sub-cultured to obtain pure cultures, which were used to identify the fungi with the aid of literature on fungi morphology^[10,11].

2.3 Trial 1: Antimycotic Effects of Botanical Extracts (Alone) on *Fusarium anthophilum*

The experiment was laid out in the Faculty of Agriculture laboratory using a completely randomized design (CRD) with 11 treatments, and each treatment was replicated thrice. The treatment set included control, Metalaxyl+Copper (I) oxide (MetCu(I)O) 50%, MetCu(I)O 100%, Melaleuca 100%, Melaleuca 50%, Euphorbia 100%, Euphorbia 50%, Eucalyptus 50%, Andrographis 50%, Andrographis 100%, and Eucalyptus 100%.

The plant extracts (i.e., Eucalyptus (*Eucalyptus globulus*), Cajeputi (*Melaleuca cajeputi*), Asthma plant (*Euphorbia hirta*), and Creat or green chiretta (*Andrographis paniculata*)) were weighed at the rate of 333.3 g leaves per L of distilled water) to make 100% concentration. Metalaxyl (12%)+Cop-

per (I) oxide (60%) is a synthetic commercial wetttable powder fungicide. The plant extracts were obtained by blending the tissues, soaking them in sterile distilled water for seven hours, and then straining the suspension through double-layered Whatman No. 1 filter paper.

2.4 Trial 2: Management of *Fusarium anthophilum* Using Botanicals Concomitant with a Biocontrol Agent

The experiment was laid out in Petri dishes using completely randomized design and each treatment was replicated three times. The treatment set consisted of seven treatments (viz Tumeric 100%, Tumeric 50%, Alligator pepper 100%, Alligator pepper 50%, Eucalyptus 100%, Eucalyptus 50%, and a control (inoculated with *Trichoderma* sp. and the pathogen only)). Thus *Trichoderma harzianum* isolate AIBN was incorporated into all the Petri dishes. The control was inoculated with *F. anthophilum*. This trial was inoculated by placing the different cultures at the edge of the Petri dish. Alligator pepper is *Aframomum melegueta*, and tumeric is *Curcuma longa*. The plant extracts were prepared as discussed above.

2.5 Trial 3: Management of *T. anthophilum* Isolate Using Selected Synthetic Fungicides Concomitant with a Biocontrol Agent

The experiment was laid out in Petri dishes using completely randomized design and each treatment was replicated three times. The treatment set consisted of seven treatments (viz; MetCu(I)O) 50%, MetCu(I)O 100%,

Mancozeb 100%, Mancozeb 50%, and a control). The control was inoculated with *Trichoderma* sp. and the pathogen only. Thus *Trichoderma harzianum* isolate AIBN was incorporated into all the Petri dishes. The control was inoculated with *F. anthophilum*. This trial was inoculated by placing the different cultures at the edge of the Petri dish. The commercial grades of Mancozeb 80% WP and Metalaxyl (12%)+Copper (I) oxide (60%) were utilized for this trial (utilized each at 5.0 g/L to give 100% concentration i.e. 100 µL/plate).

2.6 Data Collection (for All the Sub-trials)

The radius of each *F. anthophilum* colony was measured using a transparent ruler at 24-hour intervals starting from day 1 until each sub-trial was terminated. The percentage inhibition of the pathogen was calculated using the following equation.

$$PI = ((C - T)/C) \times 100\%$$

where,

PI = Percentage inhibition of the growth of the pathogen

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

T = Perpendicular radius of the pathogen colony in the treated plate

NB: * perpendicular refers to 'right angle' in this context^[12].

2.7 Data Analysis

The data were subjected to the analysis of variance (ANOVA) procedure, and the means were separated using Duncan's multiple range test (DMRT) (as obtainable with Genstat® Discovery 2nd Edition statistical package). Descriptive statistics were used to illustrate the trends in the growth of the pathogen and its management (as obtainable with IBM statistical package for social sciences (SPSS) version 25 and Microsoft Excel 365 procedure).

3. Results

3.1 The Trends of the Percentage Inhibition of the Pathogen

Percentage inhibition of the mycelial growth of *Fusarium anthophilum* due to application of low concentration of plant extracts *in vitro* is presented in Figure 1. It revealed that the best treatment was Andrographis 50% followed by Eucalyptus 50%. The percentage inhibition of *F. anthophilum* by plant extracts at 50% concentrations ranged from 22.5% to 100%.

The percentage inhibition of the mycelial growth of *F. anthophilum* due to the application of a high concentration of plant extracts *in vitro* is presented in Figure 2. The best treatment was Eucalyptus 100% followed by Melaleuca

100%. The percentage inhibition of *F. anthophilum* by plant extracts (alone) ranged from 20% to 100%.

Percentage inhibition of the mycelial growth of *F. anthophilum* due to application of *Trichoderma* species+chemical fungicides *in vitro* is presented in Figure 3. It shows that the best treatment was Mancozeb 100% followed by MetCu(I)O 100%, then Mancozeb 50%, and finally MetCu(I)O 50%. The percentage inhibition of the mycelial growth of *F. anthophilum* by synthetic fungicides+*Trichoderma* sp. ranged from 28% to 50%.

Percentage inhibition of mycelial growth of *F. anthophilum* due to application of Plant extracts+*Trichoderma* species is presented in Figure 4. It shows that the best treatment was Alligator pepper 100% followed by Tumeric 100%, then Tumeric 50%, Eucalyptus 100%, Alligator 50%, and Eucalyptus 50% in descending order of magnitude. The percentage inhibition of mycelial growth of *F. anthophilum* by plant extracts+*Trichoderma* sp. ranged from 28% to 70%.

3.2 Separation of the Treatment Means

The means were separated using the ANOVA procedure. The separation of the means of the radii of *F. anthophilum* due to the application of a low concentration of plant extracts *in vitro* is presented in Table 2. It shows that at 72 HAI, Eucalyptus 50% controlled the pathogen significantly more, followed by Melaleuca 50%, then Andrographis 50%, Euphorbia 50%, and MetCu(I)O 50%. At 120 HAI, Eucalyptus 50% controlled the pathogen significantly more, followed by Melaleuca 50%, then all the other treated plots compared to the control.

At 168 HAI, Eucalyptus 50% controlled the pathogen significantly more, followed by Melaleuca 50%, then the other treated plots compared to the control. All the treated plots controlled the pathogen significantly more compared to the control at 72, 120, and 168 HAI.

The separation of the means of the radii of mycelia of *Fusarium anthophilum* due to the application of a high concentration of plant extracts is presented in Table 3. It shows that at 72 HAI and 120 HAI, Eucalyptus 100% caused significantly more inhibition of the pathogen compared to the other treatments.

The ranking of the means of the treatments revealed that the performance of Eucalyptus 100% was followed by Melaleuca 100%, but all the other treatments (i.e. Euphorbia 100%, MetCu(I)O 100%, and Andrographis 100%) were at par.

At 168 HAI, the same trend of significant differences between the treatment means was observed, although Andrographis 100% controlled the pathogen significantly more than Euphorbia 100%, and MetCu(I)O 100%. All

the treated plots controlled the pathogen significantly more compared to the control at 72, 120, and 168 HAI.

Separation of the means of the radii of mycelia of *Fusarium anthophilum* due to the application of high concentrations of chemical fungicides+ *Trichoderma* species are presented in Table 4. It shows that all the treatments were significantly different compared to the control at 120 HAI. The treatment with significantly highest inhibition rate was Mancozeb 100%, followed by MetCu(I)O 100%,

then Mancozeb 50% and finally MetCu(I)O 50%.

Concerning the separation of the means of the radii of mycelia of *Fusarium anthophilum* due to the application of botanicals+ *Trichoderma* species *in vitro*, the results are presented in Table 5. At 120 HAI, Alligator pepper 100% produced the highest significantly different inhibition of the pathogen followed by Tumeric 100%, then Tumeric 50% and Eucalyptus 100%. Tumeric 50% and Eucalyptus 100% were at par.

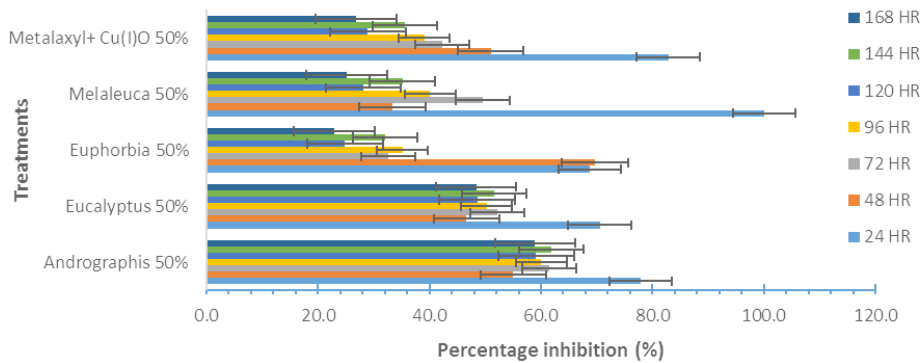


Figure 2. Percentage inhibition of mycelial growth of *Fusarium anthophilum* due to application of low concentration of plant extracts *in vitro* from 24-168 HAI

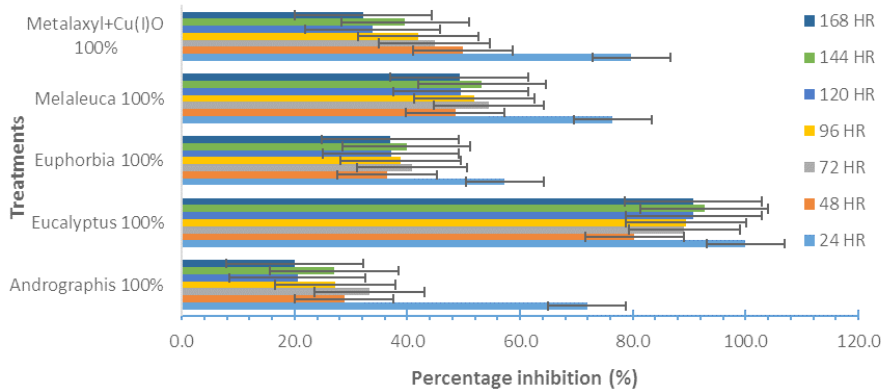


Figure 3. Percentage inhibition of mycelial growth of *Fusarium anthophilum* due to application of high concentration of plant extracts *in vitro* from 24-168 HAI

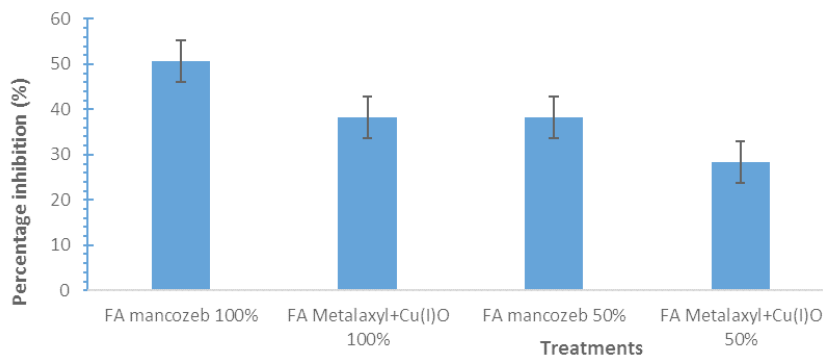


Figure 4. Percentage inhibition of mycelial growth of *Fusarium anthophilum* due to application of chemical fungicides+*Trichoderma* species at 120 HAI

FA = *Fusarium anthophilum*

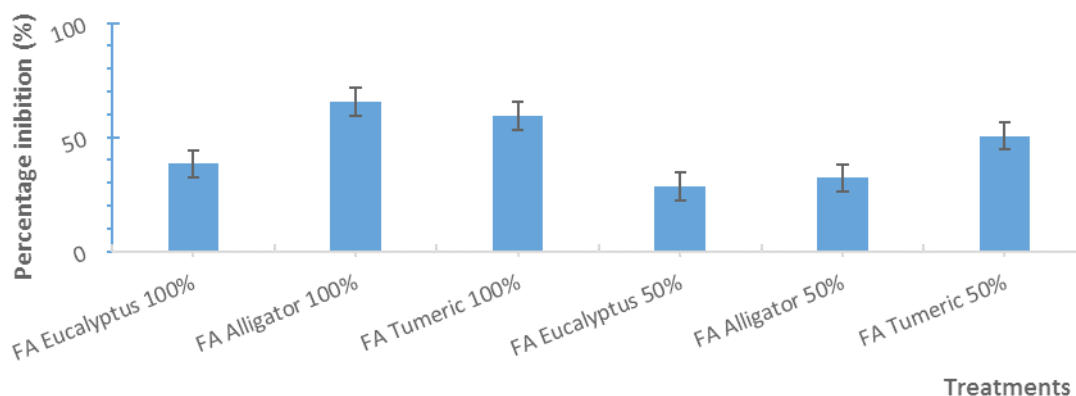


Figure 5. Percentage inhibition of mycelial growth of *Fusarium anthophilum* due to application of botanicals+*Trichoderma* species *in vitro* at 120 HAI

Table 1. Separation of the means of the radii of *Fusarium anthophilum* due to application of low concentration of plant extracts *in vitro*

TREATMENTS	72 HR	120 HR	168 HR
Control	4.3d	6.2c	9.0c
Andrographis 50%	3.2c	5.0b	7.0b
Eucalyptus 50%	1.0a	1.1a	1.1a
Euphorbia 50%	2.9c	4.6b	6.9b
Melaleuca 50%	2.2b	4.4b	6.7b
Metalaxyl+Cu(I)O 50%	2.8c	4.7b	6.1b
LSD	0.63	0.70	1.00
SED	0.29	0.30	0.40
CV%	13.00	9.10	8.70

Means followed by the same letter(s) are similar using DMRT ($P \leq 0.05$)

Table 2. Separation of the means of the radii of mycelia of *Fusarium anthophilum* due to application of high concentration of plant extracts

TREATMENTS	72 HR	120 HR	168 HR
Control	4.3d	6.2d	9.0e
Andrographis 100%	2.9c	5.0c	7.2d
Eucalyptus 100%	0.5a	0.6a	0.8a
Euphorbia 100%	2.7c	4.7c	6.0c
Melaleuca 100%	2.1b	3.5b	4.9b
Metalaxyl+Cu(I)O 100%	2.8c	4.9c	6.4c
LSD	0.48	0.69	0.99
SED	0.22	0.32	0.45
CV%	10.70	9.50	9.70

Means followed by the same letter(s) are similar using DMRT ($P \leq 0.05$)

Table 3. Separation of the means of the radii of mycelia of *Fusarium anthophilum* due to application of chemical fungicides+*Trichoderma* species *in vitro*

TREATMENTS	RANKING AT 120H
FA mancozeb 100%	1.33a
FA Metalaxyl+Cu(I)O 100%	1.67ab
FA mancozeb 50%	1.67ab
FA Metalaxyl+Cu(I)O 50%	1.93c
FA Control	2.67d
SED	0.21
LSD	0.47
CV%	13.80

Means followed by the same letter(s) are similar using DMRT ($P \leq 0.05$)

Table 4. Separation of the means of the radii of mycelia of *Fusarium anthophilum* due to application of botanicals+*Trichoderma* species *in vitro*

TREATMENTS	RANKINGS AT 120H
FA Alligator 100%	0.93a
FA Tumeric 100%	1.10ab
FA Tumeric 50%	1.33abc
FA Eucalyptus 100%	1.67bc
FA Alligator 50%	1.83c
FA Eucalyptus 50%	1.93c
FA Control	2.67d
SED	0.26
LSD	0.57
CV%	19.70

Means followed by the same letter(s) are similar using DMRT ($P \leq 0.05$)

4. Discussion

The findings of this study on the possibility of utilizing plant extracts as alternatives to synthetic pesticides affirm those of Akanmu et al. [13] who showed that the extracts of *Jatropha curcas* and *Melia indica* significantly reduced the severity and the growth of *F. anthophilum*, *F. verticillioides* and *F. oxysporum*.

Ndifon et al. [12] revealed that dressing seeds and soil using ginger and garlic significantly controlled *Fusarium* wilt disease in *Solanum aethiopicum* crop. While Wavare et al. [14] reported that aqueous extracts of the flowers of marigold (*Tagetes erecta*) exhibited potential antifungal activity against *Sclerotium rolfsii*. Seed treatment (using *Pseudomonas fluorescens* + *Trichoderma harzianum* + marigold flower aqueous extract) proved effective in increasing seedling vigour index of chickpea in paper towel assay and also reduced collar rot disease incidence of chickpea (70.56%) under greenhouse conditions. These reports show clearly that plant extracts have the potential to act as pesticide agents against pathogens.

Another report by Oyelana et al. [15] revealed that leaf extracts of four *Ficus* species inhibited eight fungi species (including *Fusarium oxysporum* and *F. solani*), and two bacterial species (viz; *Pseudomonas* and *Klebsiella* spp.) isolated from infected *Dioscorea rotundata* tubers. This report corroborated the findings of this present study.

Botanicals may also have multiple effects on the systems as corroborated by Tamokou et al. [16] who reported that the crude extracts and compounds from *Vismia rubescens* exhibited both antibacterial, and antifungal activities. The effects varied among the microbial species (3 bacteria species and four yeast species).

Likewise, Kumari et al. [17] reported that aqueous extracts of neem cake and vermicompost inhibited the mycelial growth of *Helminthosporium pennisetii*, *Curvularia lunata*, and *Colletotrichum gloeosporioides* f. sp. mangiferae. Another report by Hussain et al. [18] revealed that six plant extracts (including *Azadirachta indica* and *Eucalyptus camaldulensis*) inhibited five fungi species (including *Aspergillus* and *Fusarium* spp.) by suppressing mycelial growth. Thus we can see that botanicals may be good substitutes for synthetic pesticides, even though most of them are not pest specific.

Moreover, Ali-Shtayeh and Abu Ghdeib [19] showed that many aqueous extracts of plants inhibited *Microsporium canis*, *Trichophyton mentagrophytes*, and *Trichophyton violaceum*. For instance, the extracts of *Capparis spinosa* and *Juglans regia* completely prevented the growth of dermatophytes like *M. canis* and *T. violaceum*.

Raji and Raveendran [20] reported that extracts from five

plant species inhibited *Aspergillus niger*. Sneha et al. [21] reported that garlic and ginger inhibited *S. rolfsii*. These and more research on the efficacy of botanicals as plant pathogen control agents abound and strongly affirm the findings of this current study.

In the present study synthetic fungicides effectively controlled *F. anthophilum*. Ndifon and Lum [2] reported that all the synthetic fungicides utilized, gave higher inhibition of *A. niger* compared to all the plant extracts. The level of inhibition was more with Mancozeb than with Metalaxyl+Cu(I)O. Ndifon [22] reported that Mancozeb achieved 8-100% inhibition, but Mancozeb+Carbendazim achieved 36-100% inhibition of *Globisporangium ultimum*. This confirmed the findings obtained using Mancozeb+*Trichoderma* sp. Sneha et al. [21] reported that Mancozeb (i.e. Dithane M45) caused 100% growth inhibition of *S. rolfsii*, unlike Bavistin which failed to inhibit the growth of *S. rolfsii* at all concentrations.

These reports show that control of plant pathogen varies with the isolates and species of the pathogen, which agrees with the findings of this current study. It was noticed that in the presence of the biocontrol agent the synthetic fungicides failed to give 100% inhibition of the pathogen. This may be a pointer to some antagonistic effect or the biocontrol agent may be stimulating the pathogen as well as controlling it, etc.

Gwa and Nwankiti [23] controlled *Fusarium moniliforme* isolated from infected *Dioscorea rotundata* tubers using antagonistic isolates of *Trichoderma harzianum*. Ndifon [22] reported that all the biocontrol agents (isolates of *Trichoderma* and *Cladosporium* species) inhibited the mycelial growth of *G. ultimum* by 10%-90%.

While Al-Saeedi and AL-Ani [24] reported significant inhibition of seven soil-borne pathogenic fungi isolates (especially *Alternaria* sp.) by two isolates of *T. harzianum*. These findings agree with the current findings that *T. harzianum* is a good biocontrol agent against fungal pathogens. After all, Sharma et al. [25] reported that *T. harzianum* and *Trichoderma viride* are the most widely used species in the genus *Trichoderma*. In this genus, *Trichoderma* has been exploited for pest and pathogen control on about 87 different crops and about 70 soilborne and 18 foliar pathogens in India alone.

At more than 250 µg mL⁻¹ chlorothalonil; alone or in the presence of *Pseudomonas aeruginosa* (isolates GSE 18 and GSE 19) completely controlled *Phaeoisariopsis personata* late leaf spots of groundnuts [26]. This study confirmed the findings that combining different control agents can be used to manage fungi agents.

Concerning secretion or production of secondary metabolites, Kumar et al. [27] showed that some isolates of

Trichoderma species were endowed with abilities to produce significant amounts of chitinase and β -1,3-glucanase activities, which allowed them to out-compete or inhibit the test pathogens (viz., *Sclerotium rolfsii*, *Colletotrichum gloeosporioides*, and *Capsicum capsici*).

Meanwhile, Gajera and Vakharia^[28] reported that among 12 isolates of *Trichoderma* species (i.e.; *T. harzianum*, *T. viride*, and *T. virens*), *T. viride* isolate 60 was the best biocontrol agent against *A. niger*, based on their lytic enzyme activities. De los Santos-Villalobos et al.^[29] observed that one of the isolates (*T. asperellum* isolate T8a) was able to control *Colletotrichum gloeosporioides* *in vitro* and *in vivo*. This could be due to the involvement of enzymes (i.e., cellulases rather than chitinase or glucanase). These secondary metabolites may have been involved in the current trial, but the reason for the biocontrol agent not performing at its highest rate is not clear. Alternatively, the botanicals and synthetic agents may have affected the biocontrol agent negatively thus affecting the inhibitory ability of the treatments utilized.

Sanasam et al.^[30] reported that plant extracts of garlic and turmeric inhibited *S. rolfsii*. These and more research on the efficacy of botanicals as plant pathogen control agents abound and strongly affirm the findings of this current study. In the present study synthetic fungicides effectively controlled *F. anthophilum*. Ndifon and Lum^[2] reported that all the synthetic fungicides produced higher inhibition of *A. niger* compared to the plant extracts.

These reports show that control of plant pathogen varies with the isolates and species of the pathogen, which agrees with the findings of this current study. It was noticed that in the presence of the biocontrol agent the synthetic fungicides failed to give 100% inhibition of the pathogen.

5. Conclusions

Fusarium anthophilum is a major pathogen of white yams and cereals that produces dangerous mycotoxins. The management of *F. anthophilum* using chemical, biocontrol, and botanical measures revealed that *Eucalyptus*, *Andrographis*, *Melaleuca* and *Euphorbia* species inhibited *F. anthophilum* significantly. Combinations of Eucalyptus+, Alligator pepper+, Tumeric+, [Metalaxyl+Copper (I) oxide]+, and Mancozeb+*Trichoderma harzianum* isolate AIBN also successfully inhibited mycelial growth of *F. anthophilum*. These control measures can be effectively utilized to manage infections of *F. anthophilum*, while research on the control measures continues.

Conflict of Interest

This research did not receive any specific grant from

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