Evaluation of Efficacy of some Plant Extracts for the Control of Anthracnose (*Colletotrichum gloeosporioides*) of White Yam (*Dioscorea rotundata* Poir)

D. B. Pwakem, E. N. K Sowley and *F. Kankam
Department of Agronomy, Faculty of Agriculture, University for Development Studies,
P. O. Box TL 1882, Tamale, Ghana

***Corresponding Author: fkankam@uds.edu.gh**

Received: 21st February 2020, Accepted: 22nd September 2020

Abstract
Anthracnose is the most serious leaf and vine epiphytotic disease of yam that causes yield loss. Chemical fungicides could potentially form the basis of sustainable management strategies for anthracnose, however, the inorganic fungicides used in managing plant diseases are not degradable and may persist in the soils. Studies were conducted in vitro and in vivo to evaluate the efficacy of aqueous extracts of Azadirachta indica, Jatropha curcas and Nicotiana tabacum extracts for the control of anthracnose disease of white yam (Dioscorea rotundata Poir). The antifungal activities of 35, 45, 65 and 75% concentrations of each of the plant extracts was assessed in vitro on potato dextrose agar using the food poison technique. The fungitoxicity of the plant extracts against yam anthracnose disease was assessed under in vivo conditions through foliar application of 75% concentrations of each plant extract. The in vitro results showed that each plant extract inhibited significantly ($P \leq 0.05$) the mycelia growth of C. gloeosporioides. The 75% concentration of the plant extracts exhibited the best inhibitory effect considering the percentage mycelial growth it recorded. The results of the field trial revealed that each plant extract at 75% concentration significantly ($P \leq .05$) reduced the incidence and severity of the anthracnose disease. The plant extracts particularly, Azadirachta indica seed extracts produced higher yield. Farmers may use aqueous extracts of Azadirachta indica seed as an alternative to synthetic fungicides for the control of anthracnose disease of yam.

Keywords: Colletotrichum gloeosporioides, disease incidence, severity, plant extracts, Dioscorea rotundata

Lutte contre L'anthracnose de L'igname à L'aide de Plantes Évaluation de L'efficacité de Certains Extraits de Plantes Pour la Lutte Contre L'anthracnose *(Colletotrichum gloeosporioides)* de L'igname Blanche *(Dioscorea rotundata Poir)*

Résumé
L'anthracnose est la maladie épiphytotique de l'igname la plus grave qui cause une perte de rendement. Les fongicides chimiques pourraient constituer la base de stratégies de gestion durable de l'anthracnose, mais les fongicides inorganiques utilisés pour lutter contre les maladies des plantes ne sont pas dégradables et peuvent persister dans les sols. Des études ont été menées in vitro et in vivo pour évaluer l'efficacité des extraits aqueux d'Azadirachta indica, de Jatropha curcas et d'extraits de Nicotiana tabacum pour la lutte contre l'anthracnose de l'igname

blanc (Dioscorea rotundata Poir). Les activités antifongiques de 35, 45, 65 et 75 % de chacun des extraits de plantes ont été évaluées in vitro sur gélose de dextrose de pomme de terre à l'aide de la technique du poison alimentaire. La fongique des extraits de plantes contre la maladie de l'anthracnose de l'igname a été évaluée in vivo par application foliaire de 75 % de chaque extrait de plante. Les résultats in vitro ont montré que chaque extrait de plante inhibait significativement (P 0,05) la croissance mycélienne de C. gloeosporioides. La concentration de 75% des extraits végétaux a montré le meilleur effet inhibiteur compte tenu du pourcentage de croissance mycélienne qu'il a enregistré. Les résultats de l'essai sur le terrain ont révélé que chaque extrait de plante à une concentration de 75 % (P .05) réduisait considérablement l'incidence et la gravité de la maladie de l'anthracnose. Les extraits végétaux en particulier, les extraits de graines Azadirachta indica ont produit un rendement plus élevé. Les agriculteurs peuvent utiliser des extraits aqueux de semences Azadirachta indica comme alternative aux fongicides synthétiques pour lutter contre l'anthracnose de l'igname.

Mots-clés: Colletotrichum gloeosporioides, incidence des maladies, gravité, extraits de plantes, Dioscorea rotundata

Introduction

The use of plants to meet the world's needs is vital to our survival on a global basis. Over 65% of food proteins and more than 8% of food energy is supplied by plants (FAO, 2018). Yam is an important tuber crop which provides food for majority of the people in the tropical and sub-tropical regions (Cormier *et al*., 2019). According to Agre *et al*. (2019), the mean yield of yam on the global scale is about 60 million tons, valued at approximately US$ 14 billion. The area for large scale cultivation of yam is West Africa, contributing about 94% of yam output globally (FAO, 2018). The five world leading countries with the largest total area for yam production are Ghana, Nigeria, Benin, Cote d'Ivoire and Togo (FAOSTAT, 2017).

The first report of the yam anthracnose (*Colletotrichum* spp.) epidemic resulted in yield loss of about 70-80% under ideal conditions (Jehani *et al*., 2019). The anthracnose disease of yam is one of the key biotic factors militating against yam production in Africa, where several yam varieties are susceptible (Sanginga and Mbabu, 2015). The fungus, *Colletotrichum* species can cause about 90% of yield loss in yam (Gwa and Ekefan, 2017). According to Appiah-Kubi *et al*. (2015), about 60% of farmers sampled from four ecological zones in Ghana, engaging in yam and cassava cultivations do not have any knowledge regarding the occurrence of yam anthracnose. Palaniyandi *et al*. (2016) reported that foliar anthracnose caused by the fungus *Colletotrichum gloeosporioides* is the most severe and damaging disease on yam with water yam (*D. alata*) being particularly highly susceptible.

The anthracnose pathogen, *Colletotrichum* sp. commonly affects the leaves, veins, stems, petioles and in certain cases, the tubers. The infections lead to the development of spots and blotches on leaves, bright colored petiole, dieback and in extreme cases, death of the entire plant (Gwa *et al*., 2015). Economic yield losses in yam caused by anthracnose infection have been reported among yam farmers sampled from four ecological zones in Ghana, with about 86% of them having no strategy to control it (Appiah-Kubi *et al.,* 2015). Leaf necrosis and stem dieback caused by anthracnose seriously reduce photo-synthetic surface area of the crop resulting in reduced yield.

Chemical fungicides could potentially form the basis of sustainable management strategies for anthracnose, however, the inorganic fungicides used in managing plant diseases are not degradable and may persist in the soils. Also, such chemicals leave toxic residues in food commodities (Reeves *et al.,* 2019). Frequent use of fungicides could lead to development of resistance within the population of pathogens and poses residual hazardous effects on man and the environment (Rani *et al*., 2017). An alternative candidate to chemical fungicides for the management of anthracnose in a wide range of crops is plant extracts (Kumar and Kudachikar, 2017). Due to increase harmful effects by synthetic fungicides, there is a public outcry for a paradigm shift from the use of synthetic fungicides to the use of better alternative methods such as plant extracts for crop protection (Kaur *et al*., 2019). According to Wilm (2013) a lot of efforts have been made to completely prevent crop yield loss with synthetic chemicals but to no avail. To overcome these problems, Brauer *et al*. (2019) reported that alternative approaches (plant extracts) which are safe, cost effective, and feasible should be used. Neem (*Azadirachta indica*) is now gaining recognition and importance in its pesticidal potency against plant diseases. Research has shown that 5% *A. indica* aqueous leaf extract inhibited the growth of *Aspergillus terreus*, *A. flavus, A. niger, Microsporum gypseum, Candida albicans* and *A. fumigatus* (Ezeonu *et al*., 2018). *Azadirachta indica* leaves were found to be effective in the control of pests and pathogens of yam and resulted in higher yield than the chemical treatments in a field trial in Ghana Mochiah *et al*., 2019). Apart from *A. indica*, several other plants with fungicidal properties exist in Ghana. It will therefore be worthwhile if some of these are evaluated to determine their effectiveness against the anthracnose disease in Ghana. Therefore, the objective of this study was to evaluate the effect some selected plant extracts on the disease incidence and severity of anthracnose of yam in the field.

Materials and Methods

Study area

The experiments were conducted on the experimental farms and in the Spanish laboratory at the Nyankpala campus of the University for Development Studies. The site is located within latitude 9°25'N, longitude 00°58'W with an altitude of 183 m above sea level. The soil is an Alfisol under USDA classification, and Savanna Ochrosol under the Ghanaian system of classification (Nyankpala Agricultural Experimental Station, 1984). The area has a mono modal rainfall, usually from April to November. About 97% of the inhabitants derive their livelihood from agriculture as the main economic activity. Major crops cultivated are; yam, maize, groundnuts, soya beans, pepper and cassava.

In vitro trial

Experimental design

A Completely Randomized Design was used. There were five treatments and each was replicated four times. The main factor was the plant extracts (*Azadirachta indica* seed, *Jatropha curcas* seed and *Nicotiana tabaccum* leaf extracts), thiophanate methyl and the negative control. Each plant extract had five levels but the controls had a level each. The second factor was the isolate (*Colletotrichum gloeosporrioides*). There were 68 experimental units.

Media preparation

Potato Dextrose Agar (PDA) was prepared according to the manufacturer's instructions by dissolving 39 g of PDA (Dickinson and Company Sparks, MD 21152 USA) in 1L of distilled water and autoclave at 121°C for 15 min. The autoclaved PDA was then allowed to

cool and poured into 9 cm diameter sterile Petri dishes and allowed to solidify at room temperature.

Isolation of *C. gloeosporioides*

Based on the method described by Sutton (1992), *C. gloeosporioides* was isolated from naturally infected tubers and leaves of yam in the field (Figure 1). Pieces of tissues were cut from the advancing margin of the lesion, surface sterilized in 5% of sodium hypochlorite solution and washed in three changes of sterilized distilled water. The sterilized tissues were then blot dried on sterilized filter paper and plated on PDA. The plates were incubated for seven days at 28°C and observed every 24 h (Kanchalika *et al*., 2010). After the emergence of mycelial growth, each of the fungal colonies were transferred to fresh PDA plates and incubated at room temperature for 4 days to obtain pure cultures.

Identification of *C. gloeosporioides*

Identification of *C. gloeosporioides* was done based on the method described by Sutton (1992). Fungal mycelium from fresh cultures were examined under the LCD Celestine microscope and identified by comparing their morphological and cultural characteristics with published photographs. Morphological characteristics of *C. gloeosporioides* observed on PDA plates for 10 days were growth patterns, mycelia colour types, fruiting bodies, and the growth rate. These were compared with published photographs (Damm *et al*., 2012).

Pathogenicity test

Pathogenicity test was done according to the method described by Sanders and Korsten (2003). Prior to inoculation, all detached susceptible yam leaves (*Discorea rotundata*) samples in the field were thoroughly washed under running water, swabbed with 70% (v/v) ethanol to reduce surface contamination.

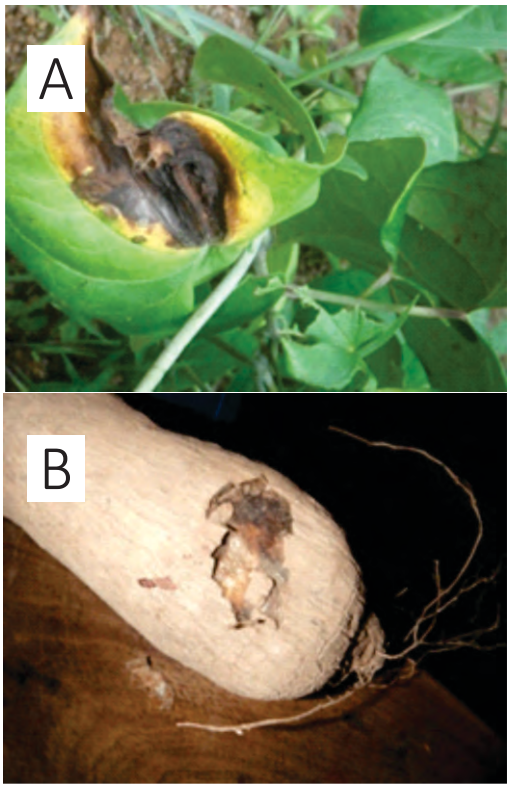

Figure 1: The lesion of infected yam plants used for fungal isolations. (a) infested leaves (b) infested tubers

They were then blot dried in the laboratory for 4 min. The leaves were then wounded by gentle pricking with a sterilized needle while the tubers were bored into with a 5 mm sterilized cork borer. Inoculants were prepared by culturing each fungal isolate on PDA at room temperature for 10 days. Plugs from the 10 day old cultures of *Colletotrichum* spp. (5 mm diameter) were cut from actively-sporulating areas near to colony periphery by using a sterilized cork borer and placed over the wounded part of each sample. Samples inoculated with only a PDA plug were controls. The inoculated leaves and tubers were kept in a moist chamber at room temperature for 10 days. Lesion development

was then measured in mm with a rule. Fungal pathogens were re-isolated on PDA plates and isolates compared with the inoculants based on colony and conidial morphology.

Preparation of plant extracts

Plant extracts were prepared from seeds of *Azadrachta indica, J. curcas* and leaves of *Nicotiana tabacum*. The aqueous seed and leaf extractions were done according to the method described by Sridhar and Vijayalakshmi (2002). One kilogram (1 kg) of seed or leaf sample was gently pounded into powder with a mortar and pestle. The powdered plant material was then soaked in 2 liters (w/v) of sterilized distilled water in a flask and left to stand for 72 h. The mouth of the flask in which it was soaked was covered with aluminum foil to prevent volatility of the active ingredients (*Azadirachtin, Phorbol ester* and *Nicotine*). The mixture was then strained to obtain the filtrate. The filtrate was centrifuged at 4000g for 30 min. to obtain a clear mother extract. The supernatant was filtered through Whatmann No. 1 filter paper and sterilized at 120^{o}C for 30 min to obtain the mother extract.

Effect of aqueous plant extracts on radial mycelial growth of *C. gloeosporioides*

Mycelial growth of *C. gloeosporioides* was determined *in vitro*. The PDA was amended with the mother extract to make 35%, 45%, 55%, 65% and 75% concentration in the Petri dishes. Each Petri dish contained 2 ml of an extract and 20 ml of sterilized PDA. The solidified PDA plates were inoculated at the centre with 5 mm diameter mycelial disc of *C. gloeosporioides* and incubated at 27^{o}C for 7 days (Nene and Thapliyal, 1979). PDA plates without extract served as negative controls whilst those with the thiophanate methyl (2 ml) served as positive controls. The colony diameter of C. *gloeosporioides* was measured and per cent inhibition of mycelial radial growth was calculated using Vincent (1927) formula;

$$\text{Growth Inihibition (\%)} = \frac{\text{Colony diameter of (control-treatment)}}{\text{Colony diameter of control}} \times 100$$

Field trial

Planting materials

Seed white yam (setts) var. "Pona" were obtained from local farmers in Tunayili, Northern Region.

Land preparation and planting

The study was conducted under rainfed conditions in the 2015 yam cropping season. The land was cleared of the existing vegetation. Mounds were constructed using hoes after the site had been deeply ploughed with a tractor. The mounds were 1 m high and 1 m apart. *Dioscorea rotundata* setts were planted in May, 2015. The yam setts were randomly planted one yam per mound in each of the plots at a depth of 10 cm. After planting, each mound was capped with leaves to conserve soil moisture. The application of treatments started from 4 weeks after planting to 16 WAP using a 15 L knapsack sprayer. This was done at 2 weeks interval. The spraying was targeted at the leaves and vine of the yam plant. The spray volume was 150 L/ha.

Staking of yam plants

Staking was done with one stake per stand. It was done at the commencement of yam emergence. This was to help expose the leaves of the yam plants to trap enough sunlight for photosynthetic activities.

Experimental design

The experimental design used was randomized complete block design with four treatments (*A. indica* seed, *Jatropha curcas* seed and *Nicotiana tabaccum* leaf, thiophanate methyl as a standard reference fungicide) and the untreated control

replicated four times.

Data collection

Incidence of anthracnose disease

The yam plants were assessed and scored for disease incidence of typical yam anthracnose symptoms expressed on the leaves and vines of the yam plants for each treatment. All experimental units were observed for each treatment and the number of experimental units with symptoms was recorded. Data were collected immediately after emergence at 3 weeks interval. The percentage incidence was calculated with Cooke (2006) formula.

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseases plants}}{\text{Total number of plants examined}} \times 100$$

Severity of anthracnose disease

All experimental units for each treatment in each block were observed immediately after emergence at 3-weeks intervals. The disease severity was scored on a scale of 1 to 5, where; 1 = no obvious symptoms, 2 = symptoms on 0-24% of leaves, 3 = symptoms on 25-50% of leaves, 4 = symptoms on 51-74% of leaves and 5 = symptoms on 75-100% of leaves (Shatu *et al*., 2012). Cooke (2006) formula was used in calculating percentage severity as follows:

$$\text{Disease severity (\%)} = \frac{\text{Area of plant tissue infected}}{\text{Total area}} \times 100$$

Yam tuber yield at harvest

The weights of harvested yam tubers from each treatment were determined with an electric balance (Model number ACS-15-JE21, Zhongshan Camry Manufacturer and Trading Co., Ltd, China) and the average recorded. This was then converted to tuber yield in t/ha using Kyle's converter (http:www.kylesconverter.com).

Data analysis

Data collected were subjected to one-way Analysis of Variance with GenStat (18th edition). The least significant difference (LSD) test was used to separate the treatment means at 5% significance level.

Results

Pathogenicity test

The results of the pathogenicity test of *Colletotrichum gloeosporioides* is presented in Figure 2. The pathogenicity test shows that *C. gloeosporioides* induced lesions (lesion size of 43.2 cm) in the healthy looking yam leaves after 10 days of inoculation (Figure 2). Symptoms of infections were seen on the inoculated yam leaves. The yam leaves that were not inoculated with the test fungi used as control experiments however, did not show any sign of lesion indicating absence of reproductive propagules in the yam tissues (Figure 2).

Effect of plant extract on growth of *C. gloeosporioides*

The various concentrations of the neem seed extract applied inhibited the mycelial growth of *C. gloeosporioides* (Figure 3a)**.** The 75% concentration of the neem seed extract exhibited the best inhibitory effect considering the percentage mycelial growth it recorded (15%) followed by the 65%, 55%, 45% and 35% concentrations. The higher the concentration of the neem seed extract, the lower the mycelial growth and vice versa. For instance, the 75% and 35% concentrations of neem seed extract promoted mycelial growth by 15% and 80% respectively.

The various concentrations, 35%, 45%, 55%, 65% and 75% of jatropha seed extract inhibited the mycelial growth of *C. gloeosporioides in vitro* (Figure 3b). Higher concentrations of jatropha seed extract gave higher inhibition of the mycelial growth than lower concentrations. The 75% concentration recorded the least mycelial growth (26.33%)

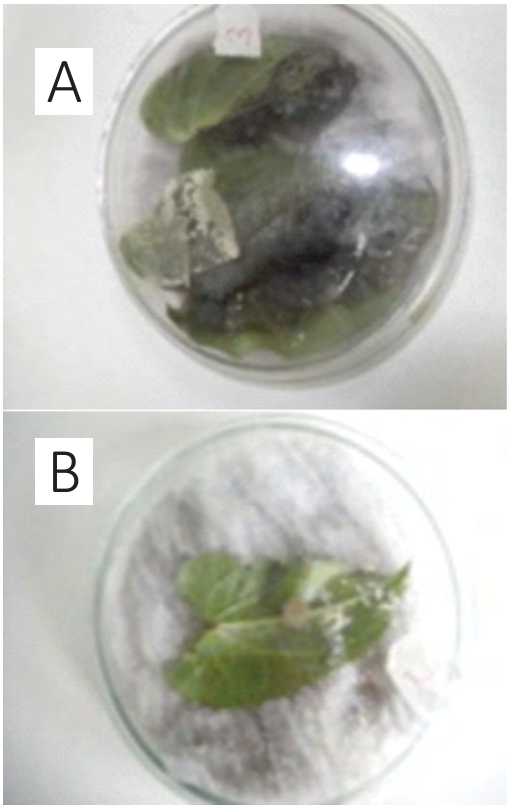

Figure 2: Detached yam leaves showing lesion caused by fungi isolates (a) Lesion caused by *C. gloeosporioides* (b) Control (no organism inoculated) showing no disease symptom development

compared to the untreated control (100%). The various concentrations differed significantly from one another.

The tobacco leaf extract was potent and inhibited the mycelial growth of *C. gloeosporioides in vitro* at its various concentrations (Figure 3c). Tobacco leaf extract at 75% concentration caused the lowest percentage mycelial growth (19.33%) followed by the 65%, 55%, 45% and 35% concentrations. The higher the concentration of the tobacco leaf extract, the higher the suppressive effect on mycelial growth. The various concentrations differed significantly from one another. Thiophanate methyl completely inhibited mycelial growth.

Effect of plant extract on incidence of anthracnose of yam

The plant extracts differed significantly ($P < 0.05$) in inhibiting the anthracnose disease. Plants treated with 75% concentration of neem seed extract recorded the least incidence (2%) at week 12, though not statistically different from the other plant extracts (Figure 4). Neem and jatropha seed extracts at 75% concentration respectively had similar performance (24%) in the various weeks when compared to the negative control (100%) at week 12 (Figure 4). Plants treated with thiophanate methyl, recorded zero (0%) incidence throughout.

Effect of plant extracts on the severity of anthracnose of yam

Each of the plant extracts at 7% concentration was potent and therefore reduced the severity of anthracnose when compared to the untreated control. Plants treated with neem seed extract had the least severity (15%) followed by jatropha seed extract (35%) and tobacco leaf extract (47%). The severity in the untreated control reached 100% by the ninth month (Figure 5). The 75% neem seed extract was comparable to thiophanate methyl, the positive control at the 1st and 3rd months (0%), however there was a gentle rise up to 15% in the ninth month (Figure 5).

Effect of plant extracts on the weight of yam tubers at harvest

The lowest (0.85 kg) and highest (2.00 kg) tuber weight/plant were recorded for the control and neem treatments, respectively (Figure 6). This represented tuber yield range of 8.50 to 20.00 t/ha (Figure 6). There were significant differences ($P < 0.05$) among the tuber weight/plant recorded for the various

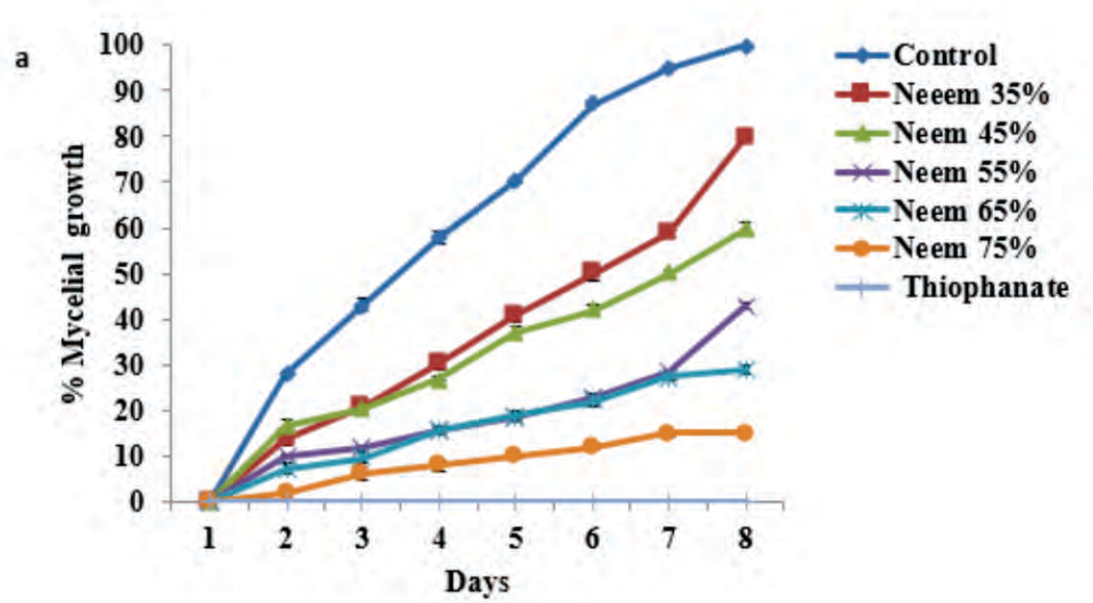

Figure 3a: Mycelial growth of *C. gloeosporioides* during 8 days of inoculation on PDA amended with 35%, 45%, 55%, 65% and 75% of plant extracts **(Neem seed extract)**

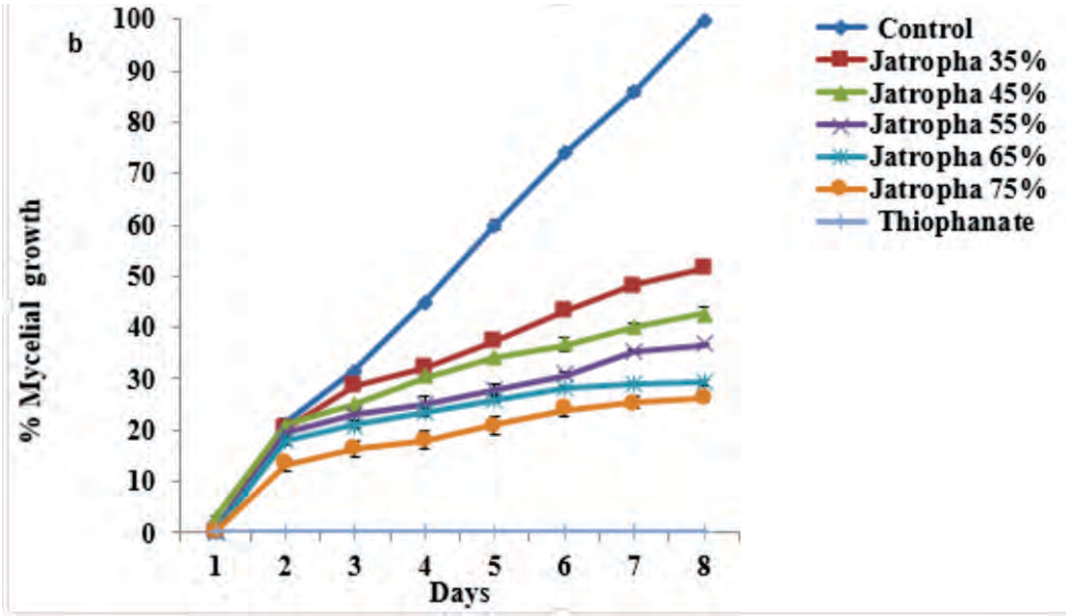

Figure 3b: Mycelial growth of *C. gloeosporioides* during 8 days of inoculation on PDA amended with 35%, 45%, 55%, 65% and 75% of plant extracts **(Jatropha seed extract)**

treatments (Figure 6). The tuber weight/plant recorded for neem seed extract at 75% was (2.00 kg), thiophanate (1.87 kg), and jatropha seed extract (1.54 kg) were significantly higher ($P < 0.05$) than those recorded for tobacco leaf extract at 75% (0.87 kg) and the negative control (0.85 kg) (Figure 6).

Discussions

Pathogenicity test

Colletotrichum gloeosporioides caused disease on the yam leaves resulting in a lesion size of 43.2 cm. The control did not cause any infection. *C. gloeosporioides* was re-isolated and confirmed as the causal agent, thus fulfilling Koch's postulates. According to Alleyne *et al*. (2001) isolates of *C. gloeosporioides* were pathogenic only towards the host plants from which they were isolated. The findings of this study also support Palaniyandi *et al*. (2016) who reported that foliar anthracnose caused by the fungus *C. gloeosporioides* Penz., is the most common damaging disease of yam and severe in the leaves. Also, Kutama *et al*. (2013) isolated *C. gloeosporioides* from yam leaves with foliar lesions in over 96% from all locations. This study confirms a similar observation reported by Ayodele *et al.* (2014) that *C. gloeosporioides* was isolated from the diseased yam leaves and is the most common fungal pathogen causing anthracnose in temperate, subtropical and tropical areas.

Effect of plant extracts on incidence and severity of anthracnose disease of yam

For each plant extract, antifungal activity against *C. gloeosporioides* increased with increasing concentration in the *in vitro* studies. This may be indication, that the

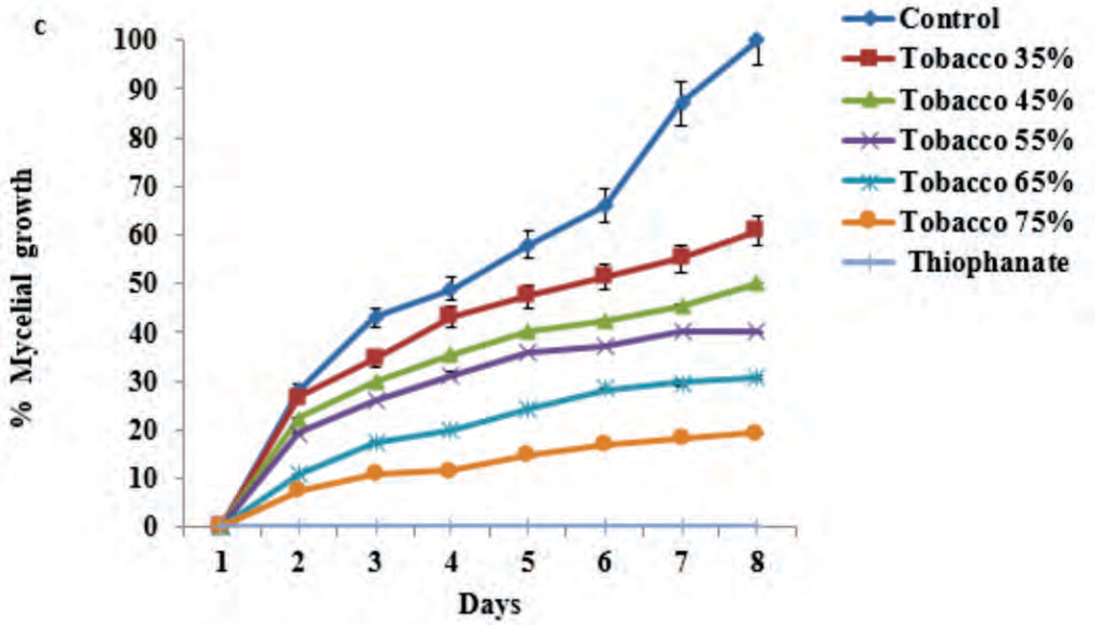

Figure 3c: Mycelial growth of *C. gloeosporioides* during 8 days of inoculation on PDA amended with 35%, 45%, 55%, 65% and 75% of plant extracts **(Tobacco leaf extract)**

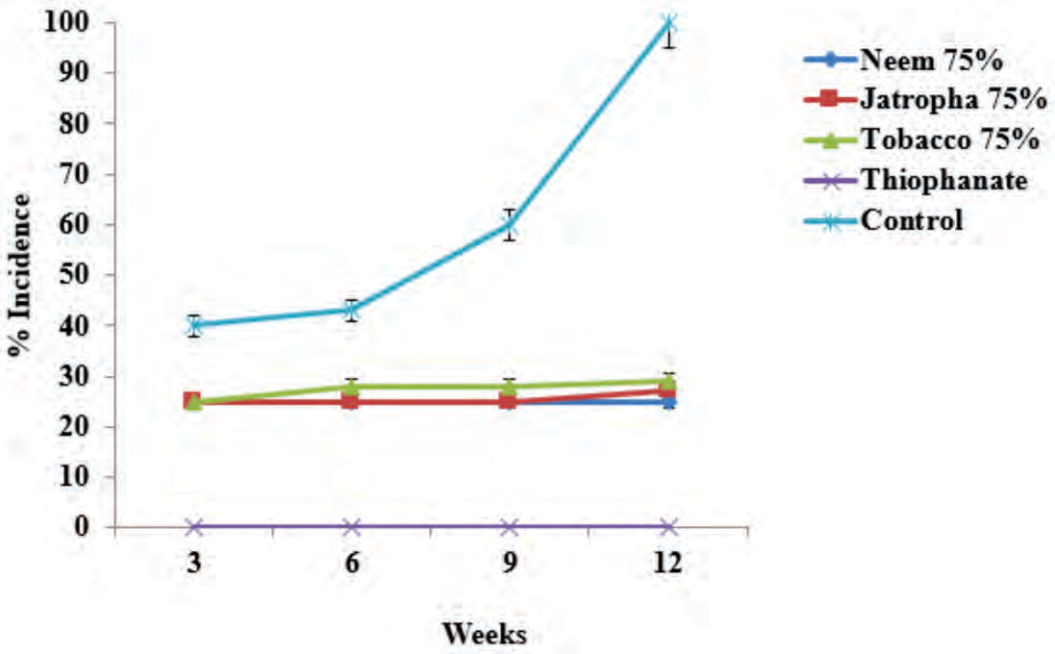

Figure 4: Effect of plant extract on disease incidence after yam emergence

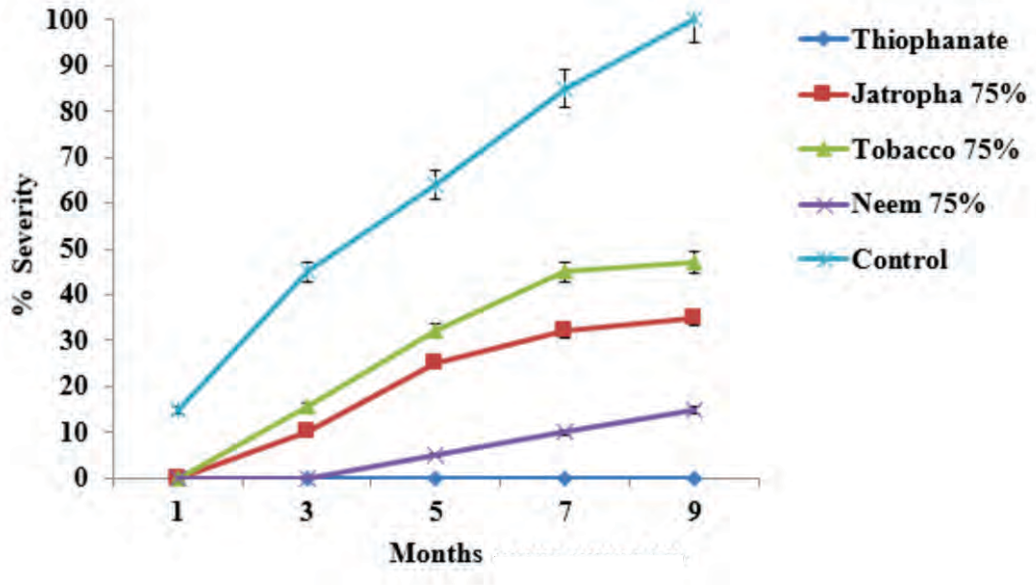

Figure 5: Effect of plant extract on disease severity after yam emergence

quantity of secondary metabolites in a plant extracts correlates with its concentration level. Therefore, the antifungal activity of any extract may be enhanced by increasing its concentration. The plant extracts used in this study inhibited mycelia growth of *C. gloeosporioides*. The antifungal activity of the plant extracts differed according to extract type and concentration. Among the plant extracts, neem seed extract at 75% concentration had the highest antifungal activity against the mycelia growth of *C. gloeosporioides*.

Extracts of *A. indica*, *J. curcas* seeds and *N. tabacum* leaf at 75% concentration reduced the percentage incidence of anthracnose *in vivo*. This finding supports Kwodaga *et al*. (2019) that aqueous and ethanol extract of *A. indica* and *J. curcas* significantly reduced the incidence of anthracnose compared to the untreated control. Essential oils of neem seed showed a higher percentage of inhibition against sporulation and mycelial growth of the anthracnose fungal pathogen (Musakhan and Zacharia, 2017). According to Kwodaga *et al.* (2019) aqueous and ethanol extract of *J. curcas, A. indica, Balanites aegyptiaca, Khaya senegalensis* seeds, *Icacina oliviformis* and *Capsicum annum* fruits inhibited the spore germination and mycelial growth of *C. gloeosporioides* in an *in vitro* study. Saetae and Suntornsuk (2010) reported that the seed cake extracts of *J. curcas* caused complete inhibition of the mycelial growth of *C. gloeosporioides* responsible for anthracnose, dieback, root rot, blossom rot and seedling blight of tropical fruit.

Results from the field trial revealed that plant extracts at 75% concentration, particularly, the neem seed extract, exhibited the greatest fungitoxic action that reduced the severity of the anthracnose disease and prevented its

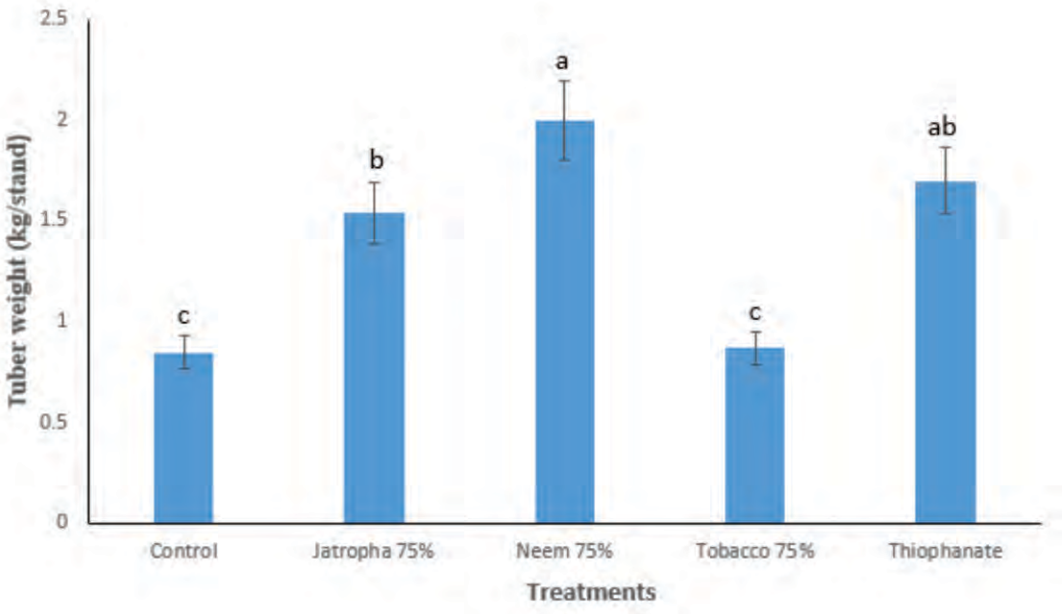

Figure 6: Effects of plant extracts on weight of tubers of yam at harvest

further spread to uninfected plants. This might be due to the fact that plant extracts possess active ingredients that are potent against plant pathogens. These findings agree with Musakhan and Zacharia (2017) who reported that neem seed oil is effective against anthracnose, *Colletotrichum capsica.* Other studies by Kwodaga *et al*. (2019) also reported that plant extracts have the potency to inhibit the mycelial growth of fungi. The bitter taste of *A. indica*, is due to the presence of complex compounds called limnoids (triter penoids). Ten limnoids have been isloated and identified in A. *indica* viz., Salannol, Salannol acetate, Diacetyl salanin, 14-Expoxy Azaradion, Gedunin, Nimbine, D-Acetyl nimbenin, Azadirachin and Azadirachtin.

Effect of plant extracts on yield of yam

Plants treated with the 75% concentrations of plant extracts produced heavier tubers per plant compared to the untreated control. Significant differences ($P < 0.05$) in yield with respect to weight of tubers of plants treated with plant extracts have been attributed to many factors. These factors include low anthracnose incidence and severity, and efficient transfer of assimilates to the sink leading to tuberisation (Jehani *et al*., 2019). Application of 75% concentration of *A. indica* seed, *J. curcas* seed and *N. tabacum* leaf extract on the field appeared adequate for maximizing tuber yield under the conditions of the experiment. This observation agreed with report that plant extracts contain certain substances capable of promoting yield of crops (Kwodaga *et al*., 2019).

Conclusions

The studies revealed that incidence and severity of anthracnose of yam were significantly reduced in plants treated with 75% concentration of plant extracts compared to the untreated control. Generally, the plant extracts positively influenced the yield of yam in terms of weight of tubers at harvest. Neem seed extract was found to be effective in the control of anthracnose disease of yam and resulted in higher yield than the inorganic fungicide treatments in the field trial.

Aqueous crude extracts of neem seeds are generally recommended to farmers since aqueous extracts are relatively cheaper, and easier to prepare. They are equally effective in the control of plants pathogens.

References

Agre, P., Asibe, F., Darkwa, K., Edemodu, A., Bauchet, G., Asiedu, R., Adebola, P. & Asfaw, A. 2019. Phenotypic and molecular assessment of genetic structure and diversity in a panel of winged yam (*Dioscorea alata*) clones and cultivars. *Scientific Reports* 9: 18221.

Alleyne, A.T., O'Garro, L.W. & Delauney, A.J. 2001. Yam anthracnose in the English-speaking islands of the Eastern Caribbean–successes and research advances in disease management. *Tropical Agriculture* 75: 53-7.

Appiah-Kubi, Z., Apetorgbor, A.K., Moses, E. & Appiah-Kubi, D. 2015. Farmers Knowledge of Anthracnose Disease of Cassava and Yam in Four Ecological Zones in Ghana. *Greener Journal of Agricultural Sciences* 5(6): 204-209.

Ayodele, M.A., Huges, J.A. & Asiedu R. 2014. Yam anthracnose disease: Field symptoms and laboratory diagnostics. Research to nourish Africa. *International Institute of Tropical Agriculture – Institut international d'agriculture tropicale – www.iita.org.*

Mochiah, M.B., Osei, K., Atta-Aidoo, Snr., Danso, Y., Lamptey, J.N.L. & Ennin, S.A. 2019. Effect of azadirachtin pre-treatment on major pests, diseases and yield of seed yam. *Journal of Entomology and Nematology* 11(2): 13-

20.

Brauer, V.S., Rezende, C.P., Pessoni, A.M., De Paula, R.G., Rangappa, K.S., Nayaka, S.C., Gupta, V.K. & Almeida, F. 2019. Antifungal Agents in Agriculture: Friends and Foes of Public Health. *Biomolecules* 9: 521.

Cooke, B.M. 2006. Disease assessment and yield loss. *The Epidemiology of Plant Diseases* 2: 227-244.

Cormier, F., Lawac, F., Maledon, E., Gravillon, M-C., Nudol, E. & Mournet, P. 2019. A reference high-density genetic map of greater yam (*Dioscorea alata* L.). *Theory Applied Genetics* 132: 1733-1744.

Damm, U., Cannon, P.F., Woudenberg, J.H.C., Johnston, P.R., Weir, B.S., Tan, Y.P., Shivas, R.G. & Crous, P.W. 2012. The *Colletotrichum boninense* species complex. *Studies in Mycology* 73: 1-36.

Ezeonu, C.S., Imo, C., Agwaranze, D.I., Iruka, A. & Joseph, A. 2018. Antifungal effect of aqueous and ethanolic extracts of neem leaves, stem bark and seeds on fungal rot diseases of yam and cocoyam. *Chemical and Biological Technologies in Agriculture* 5:18.

FAO. 2018. Food and Agriculture Organization of the United Nations Statistics database, FAOSTAT. http://www.fao.org/faostat/en/#data/QC.

FAOSTAT 2017. Food and Agriculture Organization of the United Nations, FAOSTAT, 2017. Rome. http://www.fao.org/faostat/en/#data/QC (seen on 28 April 2019).

Gwa, V.I. & Ekefan, E.J. 2017. Fungal organisms isolated from rotted white yam (*Dioscorea rotundata*) tubers and antagonistic potential of *Trichoderma harzianum* against *Colletotrichum* species. *Agricultural Research & Technology: Open Access Journal* 10(3): 555787.

Gwa, I.V., Bem, A.A. & Okoro, J.K. (2015). Yams (*Dioscorea rotundata* Poir and *D. alata* Lam.) fungi etiology in Katsina-Ala Local Government Area of Benue State, Nigeria. *Journal of Phytopathology and Plant Health* 3: 38-43.

Jehani, M.D., Patel, P.R. & Chaudhary, A.K. 2019. Evaluation of bioagents against *Colletotrichum capsici* caused anthracnose disease of yam (*Dioscorea alata* L.). *Journal of Pharmacognosy and Phytochemistry* 8(3): 4788-4790.

Kanchalika, R., Hong-Kai, W., Fu-Cheng L. & Kasem S. 2010. ISSR for comparison of cross-inoculation potential of *Colletotrichum capsici* causing chilli anthracnose. *African Journal of Microbiology Research* 4(1): 076-083.

Kumar, A. & Kudachikar, V.B. 2017. Antifungal properties of essential oils against anthracnose disease: a critical appraisal. *Journal of Plant Diseases and Protection* 125: 133-144.

Kaur, T., Rani, R & Manhas, R.K. 2019. Biocontrol and plant growth promoting potential of phylogenetically new *Streptomyces* sp. MR14 of *rhizospheric* origin. *AMB Express* 9:125.

Kutama, A.S., Auyo, M.I., Binta, S.B., Lawan, S.A., Umar, S. & Fagwalawa, L.D. 2013. Combating yam anthracnose in Nigeria: A Review. *Standard Research Journal of Agricultural Sciences* 1(3): 21-26.

Kwodaga, J.K., Sowley, E.N.K. & Badii, B.K. 2019. Antifungal activity of plant extracts against *Colletotrichum gloeosporioides* (Penz.) the causative agent of yam anthracnose disease. *Archives of Phytopathology and Plant Protection* 52(1-2): 218-233.

Kyle's converter. 2016. http://.kylesconverter.com/area-density/kilograms-per-square-meter-to-tonnes-per-hectare (Accessed July 2,

2016).

Nene, Y.L. & Thapliyal PN. 1979. Fungicides in Plant Disease Control. Oxford and IBH Publishing House, New Delhi, pp. 163.

Nyankpala Agricultural Experimental Station (NAES). 1984. Annual report 1984. Tamale, Ghana. Pp. 41.

Musakhan, P.R. & Zacharia, S. 2017. Effect of neem-based plant products and plant extracts against anthracnose of chilli (*Capsicum annuum* L.). *Journal of Pharmacognosy and Phytochemistry* 6(5): 171-174.

Palaniyandi, S.A., Yang, S.H. & Suh, J. 2016. Foliar application of extract from an Azalomycin-producing *Streptomyces malaysiensis* Strain MJM1968 suppresses yam anthracnose caused by *C. gloeosporioides*. *Journal of Microbiology & Biotechnology* 26(6): 1103-1108.

Rani, A., Singh, R., Kumar, P. & Shukla, G. 2017. Pros and cons of fungicides: An overview. *International Journal of Engineering Sciences and Research Technology* 6(1): 112-116.

Reeves, W.R., McGuire, M.K., Stokes, M. & Vicini, J. 2019. Assessing the safety of pesticides in food: How current regulations protect human health. *Advances in Nutr*ition 10: 80-88.

Saetae, D. & Suntornsuk, W. 2010. Antifungal activities of ethanolic extract from *Jatropha curcas* seed cake. *Journal of Microbiology & Biotechnology* 20: 319-320.

Sanders, G.M. & Korsten, L. 2003. Comparison of cross inoculation potential of South African avocado and mango isolates of *C. gloeosporioides. Microbiology Research*. 158(2): 143-150.

Sanginga, N. & Mbabu, A. 2015. Root and Tuber Crops (Cassava, Yam Potato and Sweet Potato) Roots and Tubers. Feeding Africa; 21–23 October, 2015. An Action Plan for Africa Agricultural Transformation. Abdou Diouf International Conference Center, Dakar, Senegal. 2015.

Shatu, A., Mathew, D.A., Boniface, K., Olalekan, O., Banwo R.A. & Lava-Kumar, P. 2012. Distribution and incidence of viruses infecting yam (*Discorea* spp.) In Nigeria. *Global Journal of Bio-Science and Biotechnology* 1(2): 163-167.

Sridhar, S. & Vijayalakshmi, K. 2002. Neem: A user's manual. CIKS, Chennai. pp. 24-25.

Sutton, B.C. 1992. The genus Glomerella and its anamorph *Colletotrichum*. In *Colletotrichum: Biology and Pathology Control. CAB International*. pp. 1-25.

Vincent, J.M. 1927. Distortion of fungal hyphae in the presence of certain inhibitors. *Nature* 59: 850.

Wilm, K.H. 2013. Phytopathology - Diseases of Plants. *Our food news* http://www. *Ourfood-news.com/phytopathology Second Edition. (eds B.M. Cooke and B. Kaye), Springer, Netherlands,* pp. 43-75.