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Evaluation of Antifungal Properties of Botanical Extracts in the Management of Common Spoilage Fungi of Rice (*Oryza sativa L.*)

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Abstract Rice is the staple food in Liberia and cultivated throughout the country. Spoilage fungi are responsible for great losses during storage and this threatens the country's food security. This study sought to evaluate the suitability of plant extracts as alternative management option against this problem. Rice samples were obtained from four main rice growing counties (Nimba, Montserrado, Bong' and Lofa) and taken to the University of Eldoret seed science lab for the isolation of fungal contaminants. Randomly selected rice grains were surface sterilized using Sodium hypochlorite and placed on Potato dextrose agar (PDA) to isolate spoilage fungi. Botanical aqueous extracts were prepared from common bean ash, neem, ginger, chilli, and garlic. Six fungi were isolated from the rice seeds (arranged in the order of prevalence; *Aspergillus niger*, *A. flavus*, *Penicillium* sp, *Pyricularia oryzae*, and *Fusarium* sp). The bean ash was the most effective botanical extract achieving 100% inhibition for all the fungi tested except *Fusarium* sp. *Fusarium* sp was the most resistant fungal pathogen with the best inhibition towards it imparted by the synthetic fungicide (tebuconazole) at 56% inhibition. All the botanical extracts used in the study should be further explored as possible sources of more sustainable disease management.

Keywords: *fungi liberia, rice yield, seed sources, extracts, fungicide*

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1. Introduction

Globally, rice (*Oryza sativa L.*) is the most important cereal crop in terms of consumption and production. Besides human consumption, rice is also used as animal feed (fish, poultry, and pigs). China is the leading rice producer with annual production of more than 200 million metric tons (mt) while Nigeria (6.8 mt) leads in Africa followed by Egypt (4.9 mt) [1]. Rice is a key crop in the food and economic spheres of Liberia. The crop is the primary staple in Liberia [2]. Liberia boasts the highest annual per capita consumption in Africa of more than 140 kg in 2010 [3]. Despite this, Liberia only produced 257,995 tons in 2010. Rice farming in Liberia is mainly done by smallholder farmers scattered across the country [4]. All the stages of rice value chain provide livelihood to about two million people [5]. This is a substantive fraction of the entire population of the country.

Despite its importance, rice production in Liberia has been declining and therefore threatening livelihoods of many. This trend persists despite increasing land designated for rice production [6]. This realization comes at a time when rice consumption is projected to increase due to the steadily growing population and constrains of climate change limiting the cultivation of the other cereals. This is a consequence of several factors chief among them is poor storage conditions leading to proliferation of spoilage fungi. Spoilage fungi renders the rice unsafe as some of them produce aflatoxins. In countries where grains form the staple, the population is always vulnerable to the dangers of aflatoxins in cases of poor storage. A case was in Kenya where aflatoxin outbreak claimed the lives of 80 people, the worst ever aflatoxin related mortality ever recorded [7]. Climatic factors also play a pivotal role in favoring the growth of the spoilage fungi. Many studies further suggest that climate change is likely going to increase the likelihood of fungal contamination and hence exposure to aflatoxins [8]. The climate is becoming more hospitable to the spoilage fungi.

Interventions has always involved use of chemical fungicides [9]. They have been described in some quarters as "indispensable to global food security" [10]. Another reason driving up the use of synthetic chemicals is fungicide resistance and invasive fungal species (shift in

the dominant pest) [11,12]. From the assessment of literature, it is indisputable that continued and increased usage of these chemicals is a reality we have to contend with. This notwithstanding, synthetic chemicals are known to have negative impacts on the environment as well as biodiversity. They have been proven to occur widely in the environment with aquatic ecosystems being the most affected [13]. In the environments which they have been shown to occur, they are highly toxic to wider range of organisms other than the primary target. Therefore, such concerns trigger questions about their long-term viability. As already alluded to, increased chemical resistance from the pathogen and a change in the dominating pathogen species have tendency to spur usage of these chemicals [14]. This would also increase the cost of crop cultivation translating to higher prizes of rice and further impart negative consequences on the environment.

Due to these problems, replacing synthetic chemicals with biological products (extracts, oils, cake, powders) have mostly been seen as a sustainable approach [15]. These may as well present with problems as some bio fungicides have also been shown to be entomopathogenic and particularly negatively impacting on bee populations in the world [16]. Integrated approaches have been suggested as a means of addressing the challenges posed both by synthetic chemicals and biological control agents [17]. For example, lipopeptides produced by *Bacillus amyloliquefaciens*, have shown to render *Fusarium graminearum* more sensitive to synthetic fungicides [18]. Benefits accrued here are in two-folds; there would be reduced chemical application and reduction in resistance danger.

This work therefore, was developed to identify feasible and sustainable strategies that can aid farmers manage seed pathogens during storage. The assessment of the diversity of common fungal pathogens responsible for seed deterioration in major rice producing zones was carried out. In addition, the study also evaluated the potential of locally available botanicals to be used as biocontrol of the fungal pathogens.

2. Materials and Methods

2.1. Isolation and Purification of Pathogenic Fungi Affecting Seed Rice Quality in Liberia

Rice seeds sampled from each county was subjected to health test by isolation of the fungal pathogens. Randomly selected seeds from the samples of each variety were soaked in 1% NaOCl for five minutes and rinsed thrice in distilled sterilized water. Cleaned seeds were dried using sterilized filter papers and then placed on moistened sterilized blotter papers in a petri dish for emergence of fungal mycelia. The dish and its content were placed in a temperature regulated growth chambers at 20±2°C and 12 alternating cycles of Ultra violet light for seven days. The seeds were then examined for fungal growth.

The mycelia emerging from the seeds were then carefully transferred with the help of a sterilized needle onto Potato Dextrose Agar (PDA) medium amended with streptomycin. After seven days of growth, the fungal isolates were transferred to freshly prepared pure PDA medium for purification. Pure fungal colonies were kept at 4C for to be used in the experiments that followed.

2.2. Identification of the Fungal Pathogens

The identification of the fungal pathogens involved microscope examination of fungal colony characteristics and morphology of fruiting bodies. Further, color, size, number and shape of spores were assessed using a light microscope.

2.3. *In-vitro* Assessment of Botanicals in Management of Selected Fungal Pathogens

2.3.1. Extracts Preparations

The leaves of Neem (*Azadirachta indica*), common bean leaves, and ginger (*Zingiber Officinalis*) bulb, pepper (*Capsicum annuum*) fruits, garlic (*Allium Sativum*) cloves were collected and 100g of the samples were washed thoroughly with hydrochloride and allowed to dry under room temperature. The botanicals were blended in an electrical blender into extracts, sieved and placed in airtight protective jars separately. The common bean leaves were further dried, burned, and the ashes were sieved into fine powder and put into a tight air jar.

2.3.2. Evaluation of Botanical Extracts Inhibition on Fungi Isolates

Aqueous extracts of the botanicals and the common bean ash were evaluated for their antifungal activity towards *Aspergillus flavus*, *Aspergillus niger* and *Penicillium* sp *in vitro* conditions at different concentrations (0ml, 3ml, 5ml, and 7ml) for aqueous extract and (0g, 0.3g, 0.5 and 0.7g) for common bean ash, using poisoned food technique [19]. The synthetic fungicide (tebuconazole) used as positive control. For the fungicide a stock solution was prepared by dissolving in the required quantity in small amount of sterilized distilled water and diluted further into required concentrations. The extract concentrations of botanicals and fungicides were mixed with 15ml of PDA on sterilized petri plates (9.0 mm) shaken and left to cool and solidify for 15 minutes. After solidification of the medium, the plates were inoculated with active culture of *Aspergillus flavus*, *Aspergillus niger* and *Penicillium* sp, with three replications for each treatment and arranged in completely randomized design in an incubator at temperature of 27 ± 1°C.

The mycelia growth were measured in terms of their radial expansion (diameter change) at an interval of 24 hours until the negative control petri plates were covered. The mycelial growth inhibition (MGI) was calculated using equation 1.

$$MGI\,(\%) = \frac{\left(\begin{array}{l}Growth\ in\ negative\ control\ plate\\ -Growth\ in\ extract\ treatment\end{array}\right)}{Growth\ in\ negative\ control\ plate} \times 100 \quad (1)$$

Microscopy of spore shape, size, color and sporulation were conducted on each treatment. The sample of mycelia under treatment of different extracts were scooped using a sterilized needle onto a slide and stained using lactophenol cotton blue solution and observed under 10X magnification of light microscope.

Data on the mean of common bean ash, chili, garlic, ginger, fungicide and pepper correlation analysis was done to determine the significance relationships between and among the treatments.

3. Results

3.1. Plant Extracts

Antifungal activity was assessed through measurement of the fungal colony diameter on daily basis until the fungi on the negative control plate filled the entire plate. Therefore, the larger the diameter, the weaker the botanical extract. From Table 1 below, *A. niger* was the most susceptible fungi to all the treatments. In nine instances, there was total inhibition as there was no diameter recorded. *Penicillium* sp was the next most susceptible pathogen. Even though there was only one instance of total inhibition, the largest colony diameter recorded for this fungus was only 18mm (Table 1). *A. niger* appeared to be more susceptible when compared to *Penicillium* sp. There was complete inhibition in six instances, however when there was no total inhibition, larger diameters were recorded. There was no complete inhibition of *Fusarium* sp.

3.1.1. Inhibition on *Aspergillus flavus*

Complete inhibition of the growth of the *A. flavus* colonies was observed in all the botanical extracts except for ginger and chilli (Figure 2). However, even for ginger and chilli some inhibition was evident as the rate of growth of the colonies were impeded with varying levels of the concentration. The lowest concentration of ginger (0.3ml) was approximately 57%. This value represented the smallest inhibition percentage for the *A. flavus.*

The other botanicals were all effective against the fungus in all the concentrations tested. In all these, the fungal colony did not grow from the point of inoculation. For ginger and chilli, the growth was impeded with increased concentration of the extra.

The fungicide was used as the positive control. Just like the other treatments, there was complete inhibition of the *A. flavus* colonies. In addition, total disintegration of conidia in all the fungicide concentrations used. From this perspective therefore, fungicide appears to be the strongest in controlling *A. flavus in vitro.*

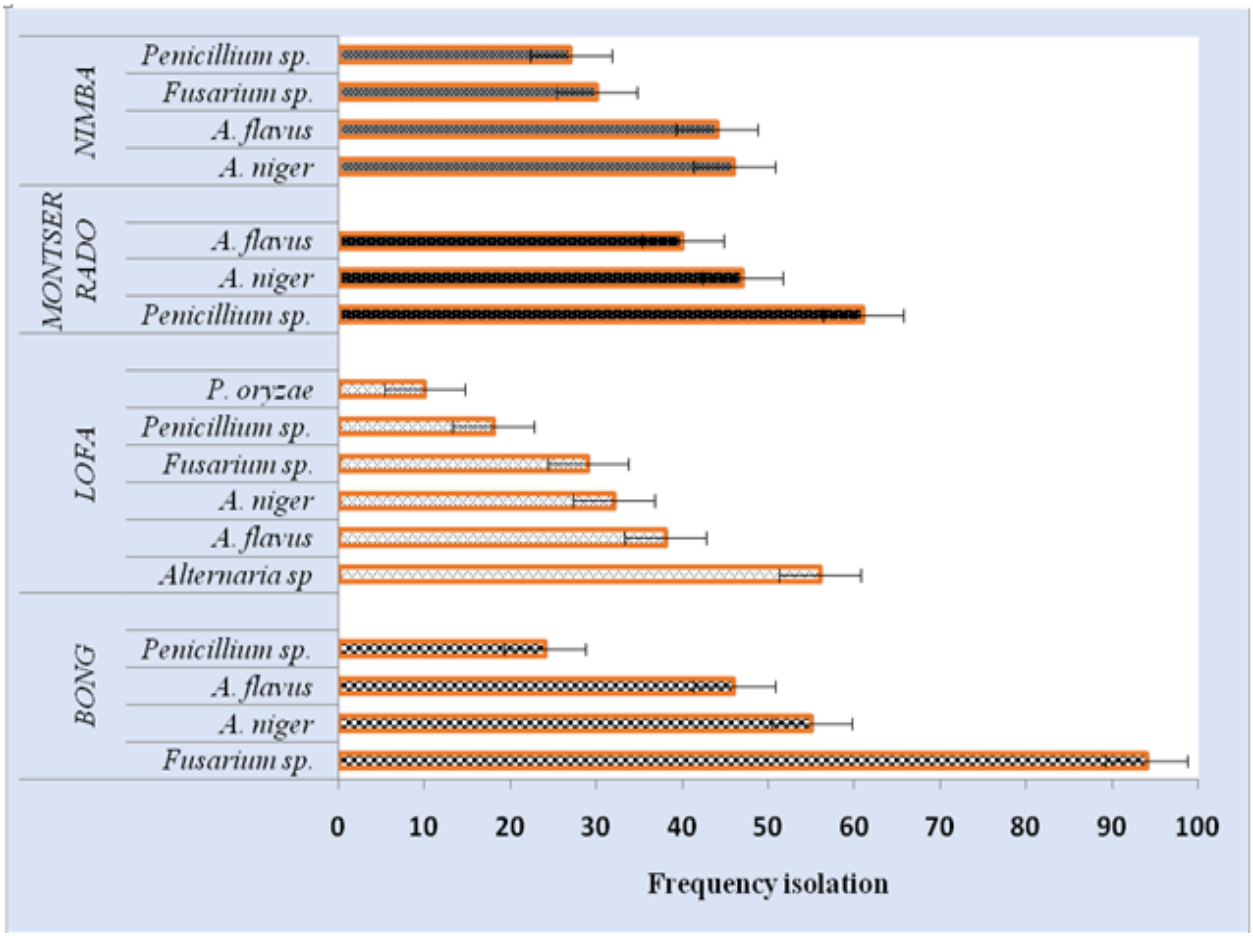

Figure 1. Incidence of Major Fungal pathogens Affecting rice seed quality in Liberia

Table 1. Efficacy of plant extracts against different fungal species isolated from rice

PLANT EXTRACT	FUNGAL SPECIES				MEAN	Tukey's test
	A. flavus	*A. niger*	*Fusarium* sp	*Penicillium* sp		
Bean ash (0.7g)	1.07	0.00	17.95	0.00	**4.76**	a
Tebuconazole (0.7ml)	0.00	0.00	19.14	7.71	**6.71**	b
Garlic (0.7ml)	0.00	0.00	20.29	7.71	**7.00**	bc
Bean ash (0.5g)	1.07	0.00	24.81	4.57	**7.61**	bcd
Tebuconazole (0.5ml)	0.00	0.00	23.57	8.62	**8.05**	cd
Bean ash (0.3g)	1.07	0.00	26.76	5.33	**8.29**	d
Neem (0.7ml)	0.00	11.81	12.62	14.33	**9.69**	e
Chili (0.7ml)	8.43	15.52	11.19	8.24	**10.85**	f
Garlic (0.5ml)	0.00	11.33	25.43	7.71	**11.12**	f
Tebuconazole (0.3ml)	0.00	9.67	27.95	9.57	**11.80**	fg
Neem (0.5ml)	0.00	17.91	15.19	18.05	**12.79**	g
Chili (0.5ml)	9.71	21.67	16.76	10.10	**14.56**	h
Neem (0.3ml)	0.00	19.14	21.57	18.81	**14.88**	h
Garlic (0.3ml)	0.00	21.86	29.38	10.71	**15.49**	hi
Ginger (0.7ml)	13.48	13.76	26.48	10.33	**16.01**	ij
Chili (0.3ml)	12.19	22.43	21.14	11.91	**16.92**	j
Ginger (0.5ml)	18.71	16.00	30.29	12.10	**19.27**	k
Ginger (0.3ml)	26.91	16.95	30.38	14.62	**22.21**	l
MEAN	**5.15**	**11.00**	**22.27**	**10.02**	**12.11**	
Tukey's test	a	c	d	B		

Statistics	Plant extract (PE)	Pathogen (P)	PE x P
Probability	<.001	<.001	<.001
S.E	0.2242	0.1057	0.4484
S.E.D	0.3171	0.1495	0.6342
%CV	17		

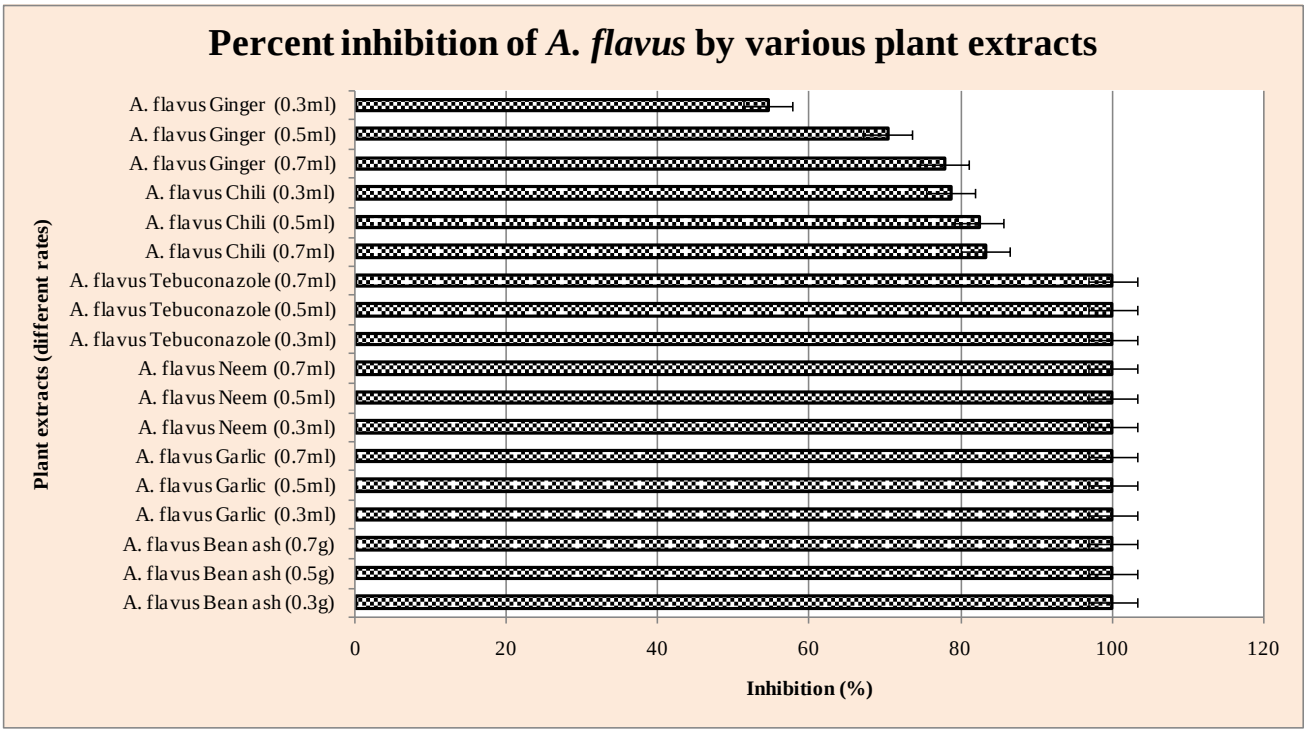

Figure 2. Inhibition of *A. flavus* the various plant extracts. There was complete inhibition of the fungus by all concentrations of Bean ash, Garlic, Neem and Tebuconazole. Chilli and Ginger showed different inhibition potentials based on the concentration levels

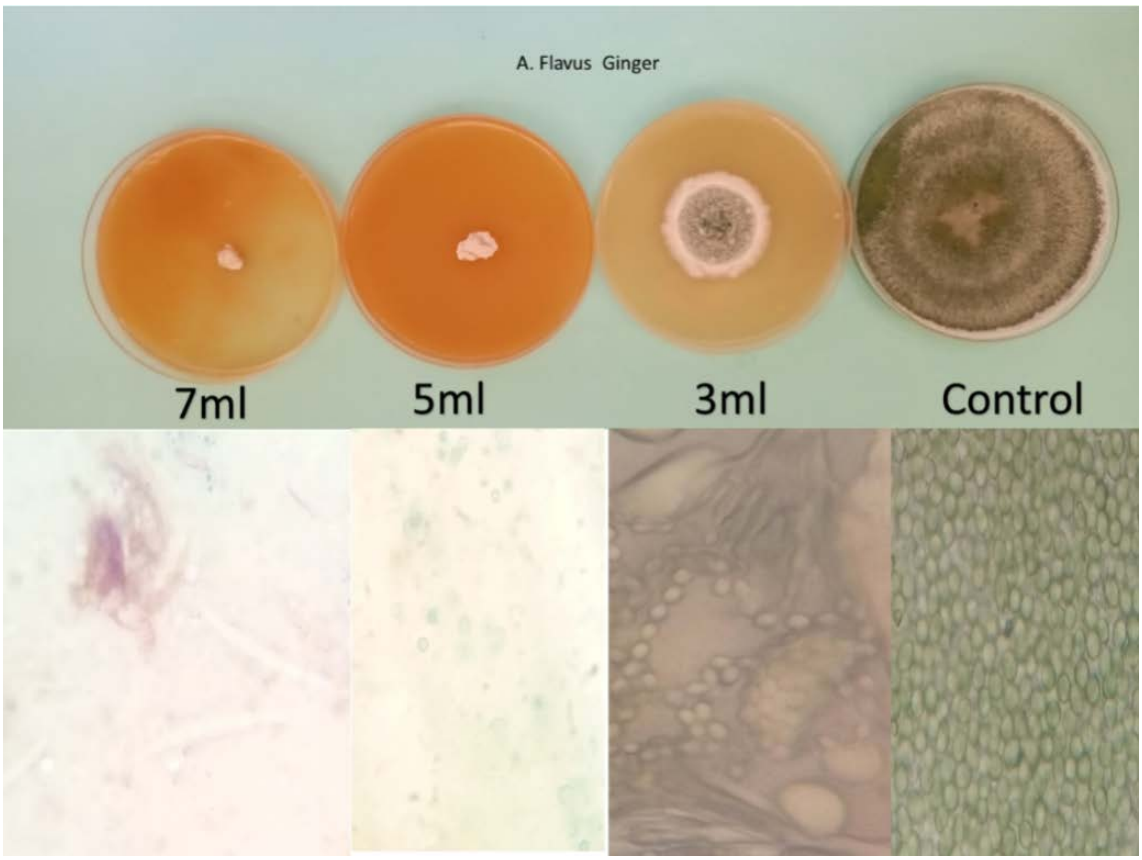

Plate 1. *A. flavus* growing on medium amended with ginger extracts at different concentrations. Below each concentration is micrograph showing sporulation characteristics as affected by the ginger extracts

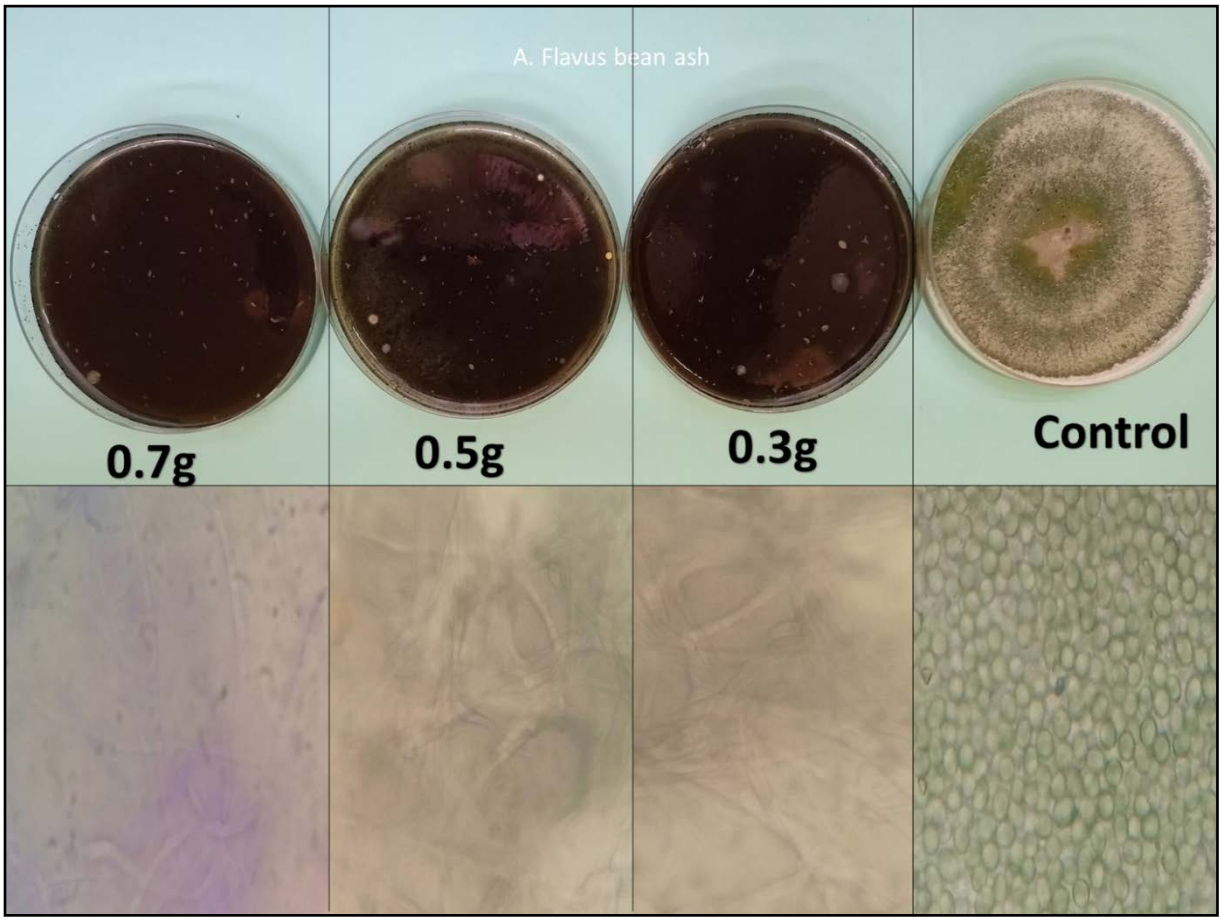

Plate 2. *A. flavus* inoculated onto PDA amended with different amounts of common bean ash (black media). Total inhibition is evidenced by complete lack of growth even when the control plate is fully colonized. There is not a single spore even from the point of inoculation

3.1.2. Inhibition on *Aspergillus niger*

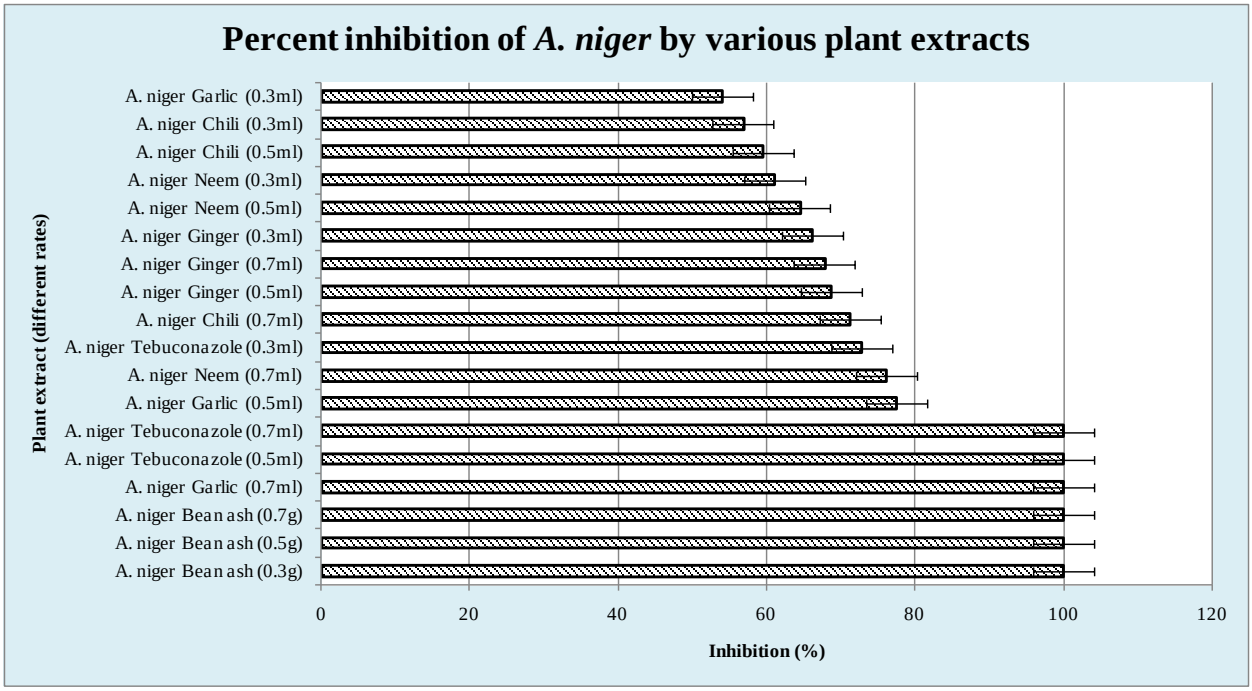

Figure 3. Inhibition of *A. niger* by the various plant extracts. Only the bean ash, highest concentration of garlic and the two highest concentrations of tebuconazole had complete inhibition on the fungus. The rest of the botanical extracts show concentration-dependent inhibition

Unlike *A. flavus, A. niger* was only completely inhibited by all the concentrations of common bean ash. Tebuconazole, which was used as the positive control, showed complete inhibition of *A. flavus* only at 0.5 and 0.7 ml concentration. Only the highest concentration (0.7ml) of garlic extracts resulted in full control of the fungal growth.

The other extracts (ginger, neem and chilli) showed different degrees of control which were substantively different from the negative control. In this group, 0.5 ml concentration of garlic is the one with the strongest concentration of about 78% while 0.3 ml garlic extract concentration was the mildest with approximately 57% inhibition.

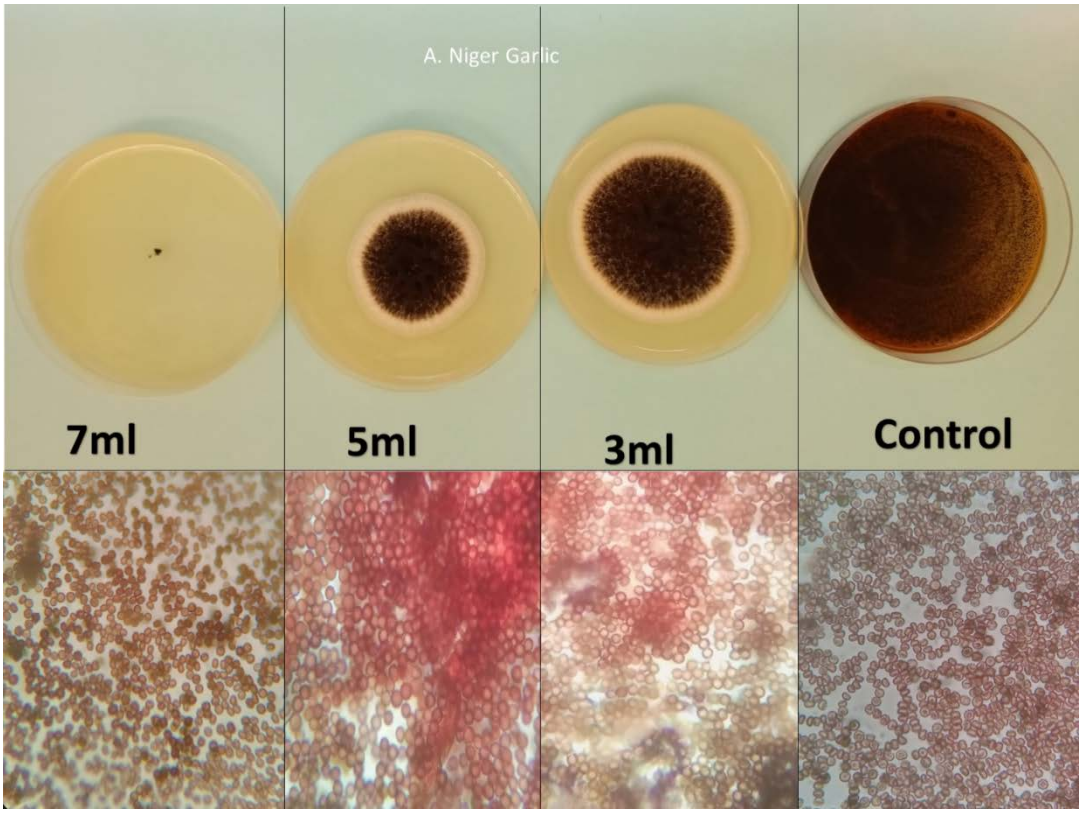

Plate 3. The effect of garlic on *A. niger*. Concentration dependent suppression of the fungal colonies is clearly evident. Sporulation seems uninhibited in all the concentrations

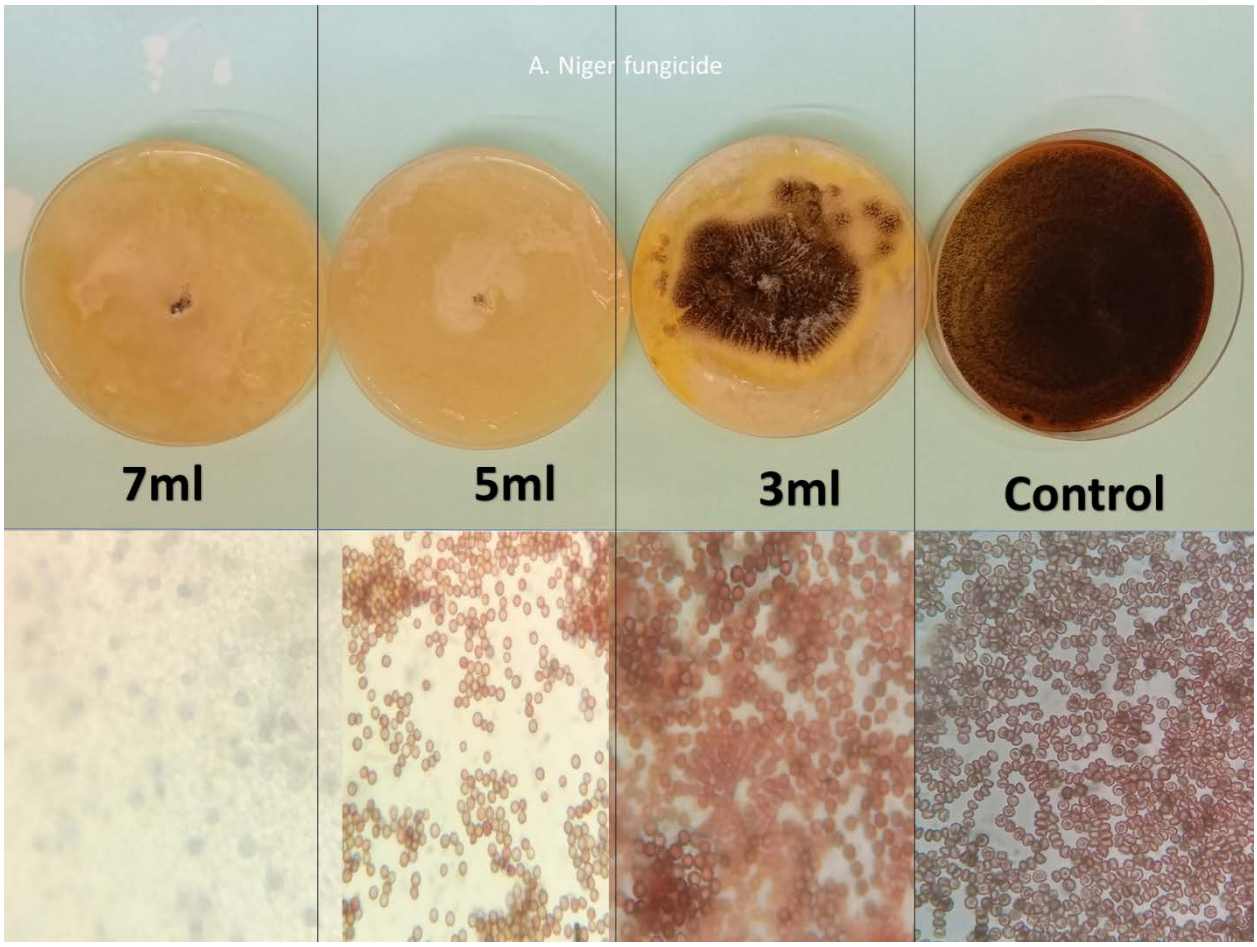

Plate 4. *A. niger* growing in media with different concentrations of fungicide. Growth appeared only in the lowest concentration. Spores were present in the 3 and 5 ml concentration but denser in the 3ml concentration. There are few deformed conidia in the 7 ml concentration of the fungicide

3.1.3. Inhibition on *Penicillium* specie

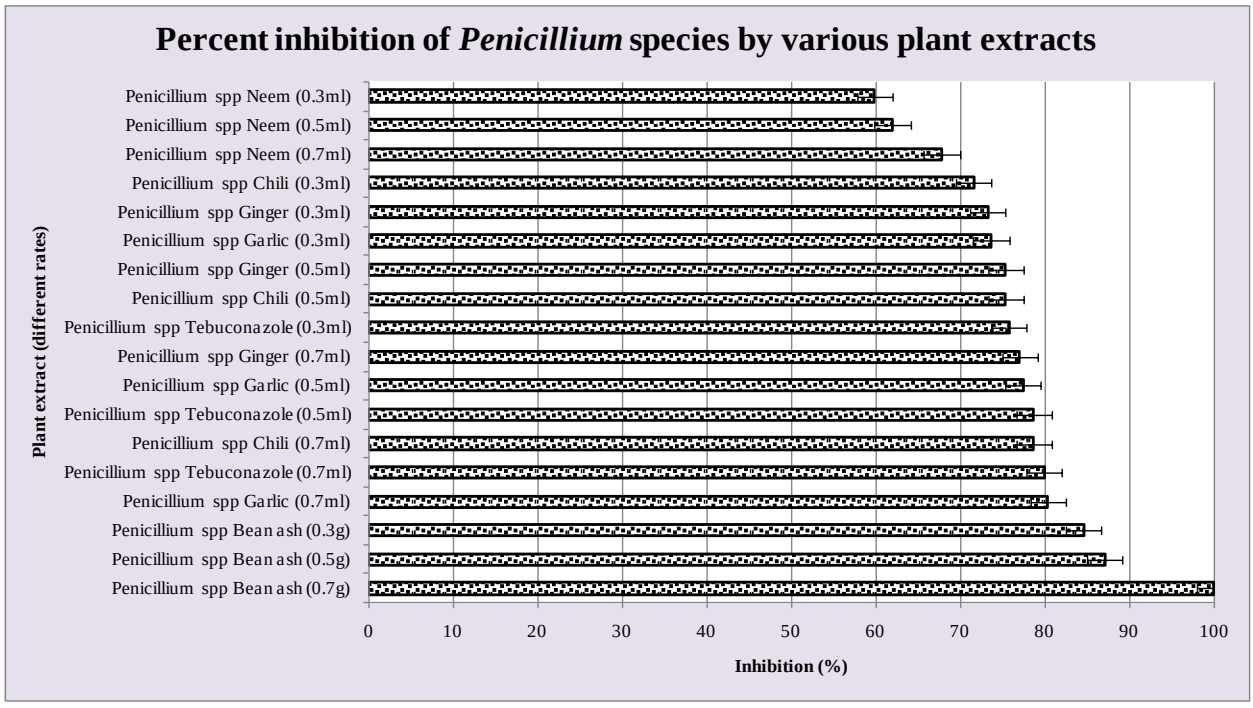

Figure 4. Inhibition of *Penicillium* sp by the various plant extracts. Only the highest concentration of bean ash managed to completely inhibit the growth of *Penicillium* sp. Overall, the bean ash was the strongest inhibitor of the fungus

Compared to both *A. flavus* and *A. niger*, *Penicillium* sp was more resistant to the botanical extracts used in this study. Only one treatment (highest concentration of common bean ash) resulted in total suppression of the *Penicillium* colony.

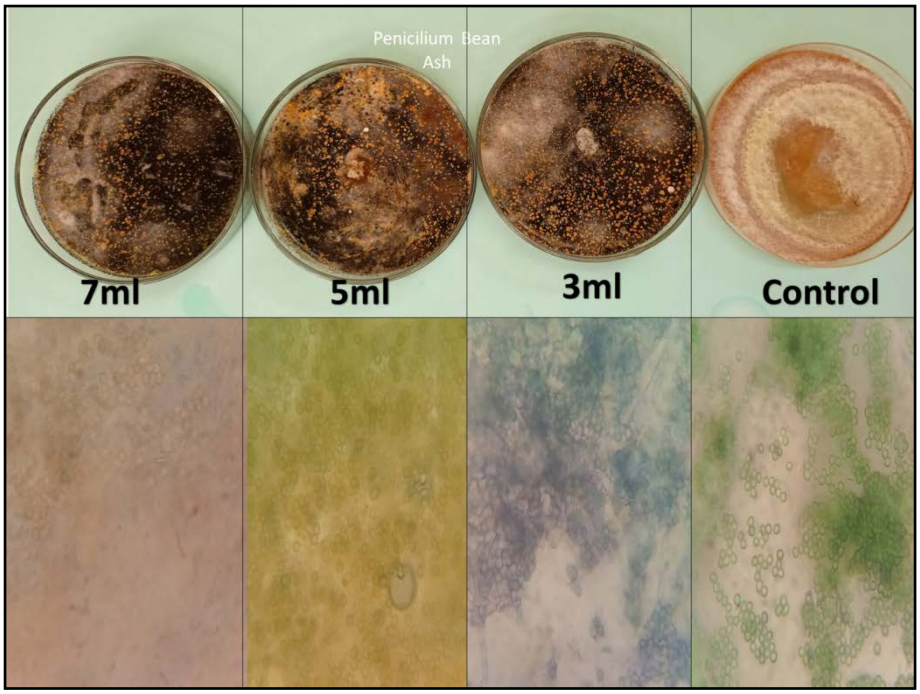

Plate 5. Small *Penicillium* sp colonies can be seen in the 5 and 3 ml concentrations. The treatment however does not seem to have any effect on sporulation as both the 5 and 3 ml treatments resemble the spores obtained from the control plates. Few decaying spores were obtained from 7 ml concentration plate

Still the bean ash extracts were the strongest antifungal agents in this case. Apart from the highest concentration of the bean ash extracts, the other lower concentrations of 0.3 and 0.5 were also strong, inhibiting the fungal growth by 85% and 87% respectively.

On other hand, neem is the mildest inhibitor of the *Penicillium* sp by displaying the least performance. Despite being the poorest performer, higher concentrations of the extracts showed increasing levels of control. The commercial fungicide was also outperformed by the bean ash and 0.7 ml garlic concentration. The highest concentration of tebuconazole only managed to attain a maximum inhibition of 80%.

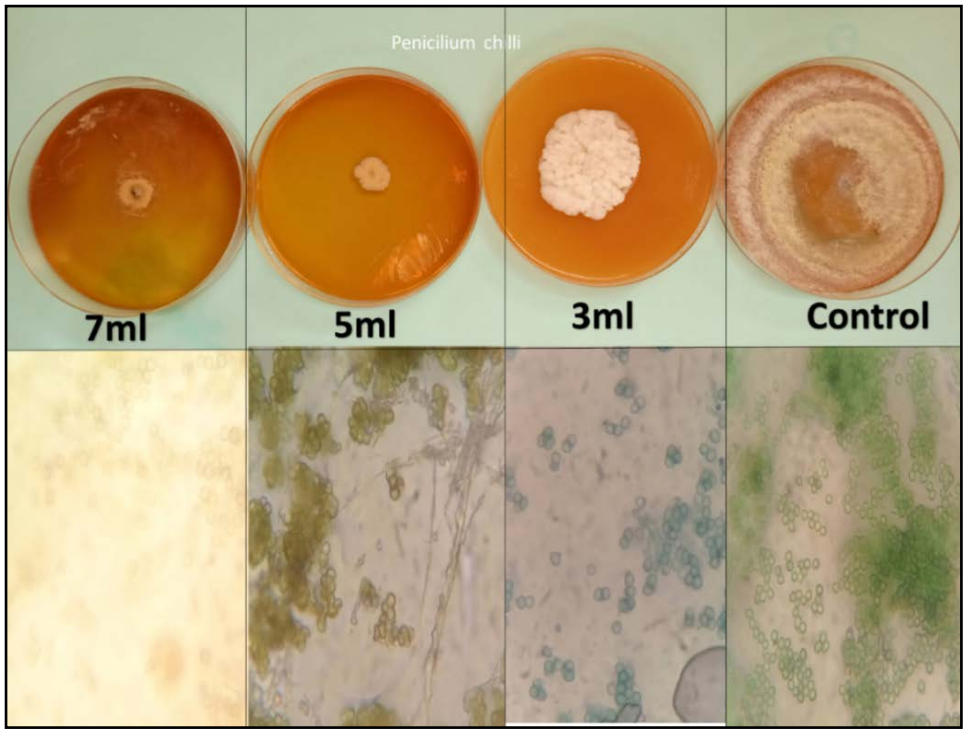

Plate 6. Biological control of *Penicillium* sp using different concentrations of chili extracts. Potency of the extracts is concentration dependent. Sporulation is uniformly and mildly suppressed in the 5 and 3 ml plates. Sporulation was highly inhibited in the 7 ml extract plate

Apart from the bean ash at the top and neem at the bottom, the rest of the extracts ranged from approximately 73-80% inhibition. Judging from this perspective, it can be clearly deduced that in spite of many extracts not attaining 100% colony inhibition, most extracts reached a peak performance on *Penicillium* compared to the previous (both Aspergilli) two pathogens. The weakest inhibition recorded at 60% is comparatively still a very high performance.

3.1.4. Inhibition on *Fusarium* sp

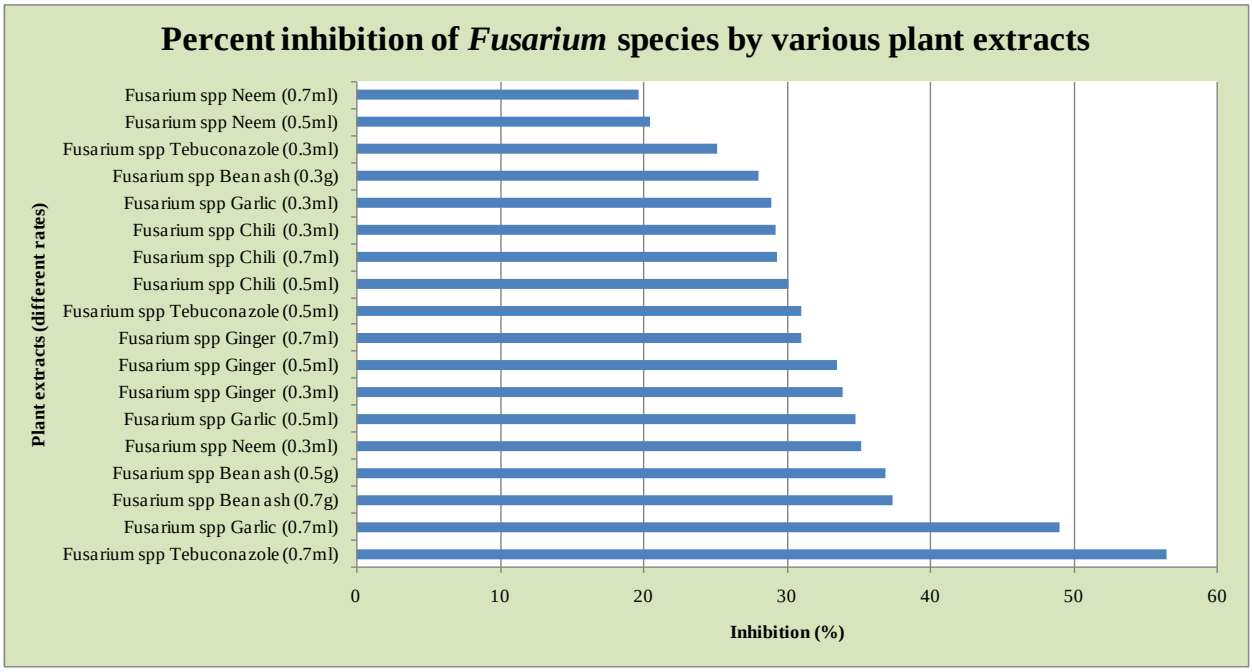

Figure 7. Inhibition of *Fusarium* sp by the botanical extracts used in the study. None of the treatments was able to completely inhibit the pathogen. The synthetic fungicide was the most effective in this case

Of all the fungal pathogens exposed to the botanical extracts, *Fusarium* sp offered the strongest resistance. In other words, the botanical extracts performed the weakest towards this fungus. Even the fungicide, which was used as a positive control did not control this fungus as best as it did for the others already mentioned.

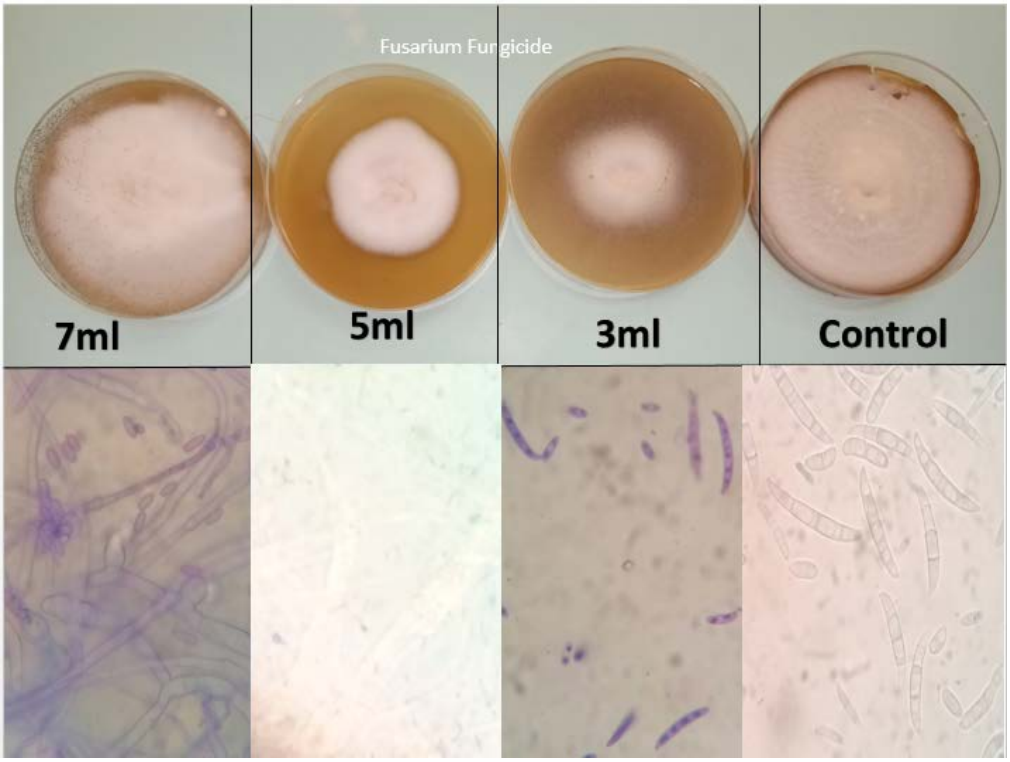

Plate 7. *Fusarium* sp growing on media amended with different concentrations of the fungicide. Dose dependent control of the fungi is clearly evident. The mycelia in the 7 ml colony appears to be slightly less dense compared to the rest of the treatments. Sporulation remains unaffected in all the treatments

It was the only fungal species where complete inhibition of development of fungal colony was never imparted by any of the treatments. Apart from the initial suppression of growth, the rate of growth matched that of the negative control in the entire duration of the study (Figure 7).

In contrast to the other fungal species used in this study, *Fusarium* sp was the slowest grower attaining a diameter size of around 80 (79.67) mm in 7 days. Strongest suppression was imparted by the highest concentration of fungicide (56%) and garlic (48%). It can be noted that such percentages in the other fungal species indicated weakest inhibition. Further, not many of the botanical extracts showed an obvious concentration dependent suppression of the colonies except for the commercial fungicide and garlic.

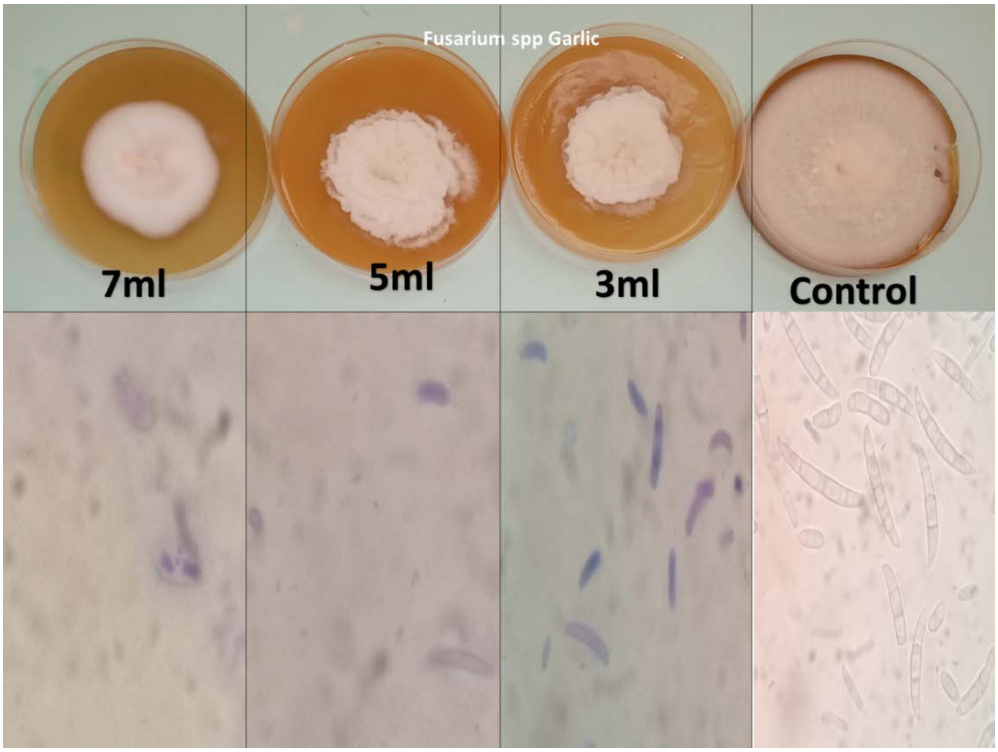

Plate 8. *Fusarium* sp. colonies growing in media amended with different doses of garlic extracts. There is slight prove of dose dependent potency of the garlic extracts. Mycelium seems also to be profoundly affected by the garlic extract. Sporulation potential is also affected by the garlic extract in dose dependent fashion. There is no presence of spores in the 5 and 7 ml extract amended plates

4. Discussion

Stored grains including rice are susceptible to contaminations by a variety of fungal organisms [20]. *Aspergillus* spp and *Penicillium* sp are the two genera of fungi that have greater tendency to contaminate the stored grains [21]. The current study corroborates this observation. Black colonies of *A. niger*, green colonies of *A. flavus* and *Penicillium* sp were isolated from all the rice samples from all the Counties. Further, occurrence of these fungi in the grains is favoured by unsuitable drying environment mainly caused by warm and humid subtropical climates. With the whole of Liberia being close to the coastal strip and experiencing tropical climate, grains' contamination pressure enhanced by favourable climate is indeed high [22]. Unsurprisingly therefore, these two genera of fungi are present in all the rice samples. Apart from *Aspergillus* and *Penicillium* sp, *Fusarium* sp was also found to be present in good number. The extensive presence of these three genera of fungi has also been replicated in another study by [23]. In their study, the rice samples used was obtained from Pakistan. Like Liberia, Pakistan is also a major rice producing country and also experiences the same climatic conditions. These two factors could be crucial contributors to this apparent uniformity.

4.1. Botanical Extracts

The common bean ash, used as powder in the current study, was undoubtedly the best performing botanical biofungicide. The common bean has been shown to possess antimicrobial and antiviral activities [24]. An antifungal peptide from the common bean called vulgarinin has a broad spectrum antifungal activity [25]. Its antifungal action was inhibitory towards phto-pathogenic fungi; *Fusarium oxysporum*, *Botrytis cinerea*, and *Mycosphaerellaar achidicola*. This attribute therefore, bestows it with the ability to control the *Fusarium* sp in the current study. The antifungal activity towards these phytopathogens by legume antifungal proteins is characterized by reduced mycelial growth [26]. The potency of this peptide is perhaps seen in its antifungal activity observed here but also specifically its apparent effectiveness against *Fusarium* spp. Its broad antifungal activity displayed here must be imparted by these two active compounds.

Another antifungal substance that has been isolated from common bean is a defensin labeled P*v*D1 [27]. It was also suppressive to some phyto-pathogenic fungi including several species of *Fusarium*, and *Rhizoctonia solani.* Another chemical with defensin-like sequence was also isolated from common bean with suppressive effect on *M. arachidicola* and *F.* oxysporum [28]. One of the

proven modes of action is the cell-free translation inhibition from many of the antifungal proteins [26]. Impeded mRNA translation would compromise on protein generation and therefore growth. This second mode of antimicrobial activity by the protein based compounds is highly regulated in the cell and may therefore require a live cell for its activity to be observed. Therefore, the use of the bean ash does not entail the exploitation of such compounds.

4.2. Chilli

Like many plants, *Capsicum* spp also has bioactive phytochemicals that have been proven to have both biological and antimicrobial activity. Capsaicin extract has preventive action against *Penicillium expansum*in fruits *in vivo* [29]. It can retard the growth of the fungus in the first two testing weeks. Accordingly, chilli showed the strongest antifungal effect on the *Penicillium* isolates found here. Extracts from *C. chinense*, *C. annuum*, and *C. fructescen* sinhibits the growth of *Botrytis cinerea* by suppressing spore germination *in vitro* [30]. A triterpene saponin labeled CAY-1 isolated from cayenne pepper, has been shown to have antifungal action against *Aspergillus fumigatus*. These prove both the curative and preventive capacity of the *Capsicum* spp ectracts. However, in the current study, chilli didn't prove very effective against most of the pathogens in the current study.

4.3. Garlic

Garlic also proved to be considerably potent to all of the phytopathogens in this study. Numerous studies corroborate observations made here. [31] showed that garlic extracts not only inhibited the fungal pathogens of chilli seeds, but also improved the germination of the seeds. Seed infecting fungi used in their study also included *Aspergillus* spp and *Fusarium* sp as such phytopathogens are almost universal in any seed. The fact that it was able to improve the germination of the chilli seeds infers to its ability to have *in vivo* beneficial activities.

Garlic essential oils are the ones mainly implicated with the antimicrobial activities involving garlic [32]. The garlic essential oils are produced when the cloves are injured and characterizes the pungent smell in the crushed garlic. It used by the plant as its own defence mechanism against pests. Its main mode of action lays in its ability to penetrate cellular membranes and destroy its integrity [33]. The general functioning of the cell is then impeded. This mist be the case for the current study. Garlic cloves used in the current study were first crushed and therefore produced the potent essential oils. The effect of the oils is therefore evidenced by the inhibition of the fungal pytopathogens.

4.4. Neem

Neem extracts completely inhibited the growth of *A. flavus* but was the weakest against *Penicillium* sp and *Fusarium* sp. This does not at all imply that it is a poor biofungicide, it was not just as good as the other biofungicides used here. This plant has great application in animal medicine and recently has been used in the manufacture of slow release fertilizer [34]. The slow release of the nitrogen fertilizer is achieved by inhibiting the microorganisms in the soil that fastens the leaching of the fertilizers. It is such inhibitory activities from the neem plant that is also being exploited in the experiments intending to explore its potential as a biofungicide. It has been shown to perform equally good when compared to a synthetic fungicide and Trichoderma based bio-fungicide against foliar plant pathogens [35]. In this experiment however, it was also proved not to be as effective especially the length of time that its effects is felt on the plant.

As a fungicide neem restricts the germination of fungal spores [36]. If then this is the main mode of action, then its performance in the current study is not surprising. The inoculum was always a mycelial plug where the primary mode of propagation was mycelial growth rather than spore germination. Just like the other botanical extracts, perturbations on spore formation was evident albeit mild. Mainly, the antifungal effects are not long lasting on the leaves [35]. Whether or not it is longer lasting on the seeds needs further experiments on that. However, its functions in aiding longevity of nitrogen fertilizer in the slow release fertilizer technology can be inferred as a credence for its ability to last long in soil and therefore of possible benefit to seeds.

4.5. Ginger

Compared to the rest of the botanical treatments, ginger did not show good antifungal activity towards most of the fungi especially *Aspergillus* spp and *Penicillium* sp. It was comparably strong against *Fusarium* sp. The dynamics between this extract and the other botanicals play in the opposite manner. For the extracts that were particularly strong against the aforementioned pathogens were considerably weak against *Fusarium* spp. Ginger extracts have been shown to completely inhibit the growth of *Fusarium oxysporum* [37]. This fungus is closely related to the *Fusarium* sp used here. The concentration of the extract used however was stronger than the one used here. *Fusarium* spp can also be a foliar pathogen unlike *Aspergillus* spp and *Penicillium* sp. Ginger extracts can therefore be used to complement most of the other extracts used here.

Further, ginger extracts were also equally comparable with synthetic fungicide in controlling *Colletotrichum gloeosporioides* of dragon fruit [38]. The concentration of the extracts were however stronger than the ones used here. This fungus is closely related to *Fusarium* sp more than it is related to *Aspergillus* and *Penicillium*. Main mode of action in the ginger's antifungal activity is the distortion of the hyphae and inhibition of spore formation [39]. Changes in mycelial formation was definitely observed in the current study as well. However, the *Fusarium* sp used in the current study was not a prolific spore producer, making it difficult to assess the effectiveness of any of the extracts to alter sporulation. One inherent difference between *Fusarium* sp and the other three fungal isolates was in the rate of growth. *Fusarium* sp was the slowest growing fungi and therefore perhaps susceptible to ginger extracts.

5. Conclusion

Results from this study affirm that the rampant use of uncertified seeds results in diseases plants as shown by the isolation of the six seed borne pathogens. *Aspergillus niger, A. flavus* and *Penicillium* sp were isolated from the seed samples from all the four counties. Large population of Liberia therefore, is exposed mycotoxins produced by these fungi. The other three fungal isolates were not equally rampant. The botanical extracts displayed varying levels of antifungal activities with the common bean ash being the most effective by completely inhibiting the growth of most fungi. *Fusarium* sp was the most resistant of the fungi towards all the botanicals. The botanicals used here therefore shows great promise as alternative sustainable sources of fungicides.

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