Control of postharvest cassava spoilage fungi using local herbs of Umudike, Nigeria

Chinedu G. Ohaegbu[1], *Anayochukwu C. Ngene[1], Chidinma A. Udeaja[1], Michael U. Ukwuru[2]

[1]*Department of Microbiology, Michael Okpara University of Agriculture, Umudike, Nigeria*
[2]*Department of Food Science and Technology, Federal Polytechnic Idah, Nigeria*
**Correspondence: ngene.anayochukwu@mouau.edu.ng*

Abstract

This research work was carried out to control post-harvest cassava (*Manihot esculenta* Crantz) spoilage fungi using extracts of three herbs namely *Andrographis paniculata*, *Spondias mombin* and *Chromolaena odorata*. Fungi were isolated from diseased harvested cassava tubers, characterized and identified phenotypically and tested for pathogenicity on healthy harvested cassava tubers. The pathogenic fungal isolates were screened for their susceptibility to water and ethanolic extracts of the selected plant species. Results showed the presence of seven fungal species including yeast, *Aspergillus niger, Penicullium notatum, Fusarium oxysparium, Mucor* sp., *Rhizopus* sp. and *Botryodiplodia theobromae. A. niger* was the most prevalence with 100% occurrence while the other recorded as 88.8% (yeasts), 55.6% (*Rhizopus* and *P. notatum*), 44.4% (*F. oxysporum*), 33.3% (*Mucor* sp.) and 22.2% (*B. theobromae*). Four fungal species namely *Aspergillus, Penicillum, Fusarium* and *Botryodiplodia* showed pathogenicity to varying extents, and were subjected to antifungal activity tests using the extracts. The extracts caused varying levels of radial growth inhibition of the different test organisms. The water extracts caused 38–46% (*C. odorata* extract), 36– 45% (*S. mombin*) and 50–58% (*A. paniculata*) inhibition of the pathogens while their respective ethanol extracts inhibited the organisms by 63–75%, 66–76% and 69–88% in comparison to 89–97% recorded for mancozeb, a commercial fungicide. The inhibition of the pathogen isolates varied significantly with *Botryodiplodia* being the least inhibited (38–69%) while *Penicillum* was the most inhibited fungus (36–88%). Inhibition of *Aspergillus* and *Fusarium* species was recorded as 41–83% and 38–84%, respectively. The ethanolic extracts were found to be more potent than the water extracts while the extracts of *A. paniculata* was the most potent and that of *C. odorata* was the least effective.

Keywords: *Andrographis paniculata,* Antifungal activity, Cassava fungi, *Chromolaena odorata,* Herbal extracts, Post-harvest spoilage, *Spondias mombin.*

Introduction

A vital staple crop that is widely grown in tropical and subtropical countries, especially in South America and Sub-Saharan Africa, is cassava (*Manihot esculenta* Crantz), a shrubby perennial of the Euphorbiaceae family (McKey *et al*., 2017). As the main source of carbohydrates for more than 800 million people worldwide, it is essential for global food security (Parmar *et al*., 2017). Cassava, also referred to as a famine reserve, is resilient because it can grow in unfavorable soil conditions with little rainfall and may be harvested whenever it is needed (Onyenwoke and Simonyan, 2016).

In Nigeria, the world's largest producer of cassava, the crop is used to produce various foods such as garri, akpu (fermented cassava), and tapioca. Cassava tubers are rich in starch (over 30%), vitamin C and calcium, while its leaves are high in vitamin A and protein, making it a versatile crop for both food and animal feed (AIC, 2018). Despite its many advantages, cassava faces significant challenges related to post-harvest spoilage. It is highly perishable and prone to rapid deterioration after harvest, primarily due to microbial and pest attacks. Post-harvest spoilage is caused by fungal pathogens such as *Aspergillus niger*, *Rhizopus* spp. and *Penicillium* spp., which lead to discoloration, unpleasant odors, nutrient loss, and mycotoxin production. Mycotoxins, including aflatoxins and ochratoxins produced by *Aspergillus flavus* and other fungi, pose severe health risks, including liver cancer, and are highly stable, resisting destruction through boiling or processing (Natural Resources Int. Ltd, 2020). Proper drying and storage at low moisture levels are critical to preventing fungal contamination and preserving cassava quality (Nainggolan *et al*., 2024).

There is a growing interest in investigating natural alternatives due to the growing frequency of fungal spoiling and the drawbacks of synthetic antifungal medications, such as their expense and the emergence of resistant fungal strains. Plant extracts have shown strong potential to control fungal diseases in crops because of their antifungal phytochemical contents, which include anthraquinones, polyphenols, saponins, and glycosides (Javaid and Khan, 2016; Akueshi *et al*., 2020; Jabeen *et al*., 2022).

In order to reduce post-harvest cassava rotting fungi, this study was carried out to examine the effectiveness of three tropical plant species *viz. Chromolaena odorata*, *Spondias mombin* and *Andrographis paniculata*. Due to their antibacterial qualities, these plants have been utilized extensively in traditional medicine; nevertheless, their potential for use in agriculture has not been fully investigated. This study was carried out to assess the antifungal efficacy of water and ethanolic extracts from these plants against important fungal infections implicated in cassava rotting, given the demand for organic and sustainable treatments.

Materials and Methods

Source of materials

The cassava tubers were sourced from Cassava Farm in the cassava research program of National Root Crops Research Institute, Umudike. The three local herbs *viz. C. odoroata*, *S. mombin* and *A. paniculata* were collected from homestead farms in NRCRI staff quarters, Gate 1, Umudike. Laboratory and other facilities were obtained from Ceslab Global, Analytical Laboratory Chukwu Avenue, Government College, Umuahia.

Collection of botanical samples

Cassava tubers were collected from three cassava varieties including TME 419, NR 8082 and TMS 30572. The collected specimens were taken to the laboratory and allowed to stay under ambient environment and observed daily until disease condition was established as portrayed by softening, discoloration, offensive odor, visible mycelia growth etc. The test botanicals used were *C. odorata* (awolowo), *S. mombim* (ichikara) and *A. paniculata* (ububo). The plants were collected and taken to the horticulture unit of NRCRI for authentication of their respective botanical identities. Thereafter, they were taken to the laboratory for use in the research work.

The test leaf samples were prepared prior to their use for extract production. First, the leaves were separately examined visually for the presence of extraneous materials, dirt, insect eggs/larvae etc.), as well as unhealthy leaves (discoloured, shriveled, or those with disease symptoms (leaf spots etc.). The "bad" ones were removed and the "good" ones were washed in clean water to remove dust and dirt and they were allowed to drain dry. They were then spread on a laboratory tray and dried in the oven at 65 ºC until they were settled enough. Then they were separately ground in a laboratory mill and sieved through 1 mm sieve to obtained powdered sample for use. This was stirred in a screw capped, labelled sample bottle and used within 48 h.

Media preparation

Sabouraud dextrose agar (SDA) was used. It was prepared according to the directives of the manufacturers. In this regard, 65 g of the powdered medium was mixed with distilled water to make a total of 1.0 L in a flask. The mixture was sterilized by autoclaving at 121 ºC for 15 min to obtain a sterile clear solution. The prepared medium was allowed to cool (in a molten state) before it was used.

Isolation of fungal pathogens from cassava tubers

The diseased cassava tuber was surface disinfected by swapping with cotton wool soaked in 79% ethanol solution. It was then cut open, to reveal the inside, using a flamed kitchen knife. The boundary area between the spoilt and the healthy portions was chosen and cut-out in bits. A part of the bad were crushed in a surface sterilized laboratory porcelain motor and transferred into a sterile screw capped labelled sample bottle and used the same day. The other portion of the cut bits were put in a separate sample bottle and used the same day for direct placement on medium.

Two methods were used for isolation of fungi from the diseased cassava tubers *viz.* spread plate technique and direct placement methods. In spread plate method, 1 g of the crushed test sample was diluted serially to prepare up to 10^{-4} dilution. A loop full of inoculation was aseptically transferred from 10^{-3} and 10^{-4} dilutions and placed on separate sterile SDA plates. With the aid of a bent glass rod, the inoculum in each case was spread evenly over the plate lawn and incubated at room temperature for 5 days. The incubated plates were observed daily for growth.

Direct placement culture involved the use of pieces of the diseased cassava portion as inoculant. It was done to enable fungi adherents on the diseased cassava bits, to grow out. Accordingly, using a flamed pair of forceps, the bits cut-out from the diseased cassava tuber were carefully picked and three bits were placed on the surface of a sterile SDA in Petri dish at equidistant positions. Each placed bit was pressed gently and incubated at room temperature. The plates were observed daily for growth.

Another method was also done for those fungal species that appeared in both cultures. In this method, the cut portions from the boundary areas of the decaying cassava tuber were soaked in 100 mL of sterile distilled water in a screw capped sample bottle and allowed to stand for 24 h with occasioned shaking, at room temperature. After this, the soak water was recovered by screening the mixture through 1 mm departure sterile sieve. The recovered soak water was used as the inoculation source (Okon *et al.*, 2024). Exactly 1 mL inoculum was aseptically collected from each of the test cassava-soaked water and separately transformed to an empty sterile Petri dish. Then, carefully, approximately 15 mL of molten SDA was poured into the Petri dish and mixed very well by gentle swirling movements. The

inoculated Petri dishes were allowed to cool to room temperature and solidified. Then they were appropriately labelled, wrapped up and incubated as described earlier. They were observed daily for growth.

Purification and identification of fungal isolates

On establishment of growth in the cultured plates, the resulting mixed cultures were purified by isolation to obtain pure cultures. The mixed culture plates were examined and distinct colonies were identified from which inoculant were separately collected aseptically with the acid of a flamed cork borer (5 mm). The collected cores were carefully placed on the surface of a sterile SDA medium in plate and the sub-cultured plates were incubated as described earlier being observed daily for growth. When growth appeared in the sub-culture plates, the plates were examined closely for uniformity of the colonies as a mark of purity. The obtained pure cultures were used for isolation and characterization and subsequently identified.

The obtained pure cultures were studied and their respective colony and fractional characteristics were recorded. The colonies of the pure cultures were examined visually and their respective colony characteristics were recorded including the extent of growth, color, pigmentation, form of the colony margins, visible mycelia etc. as well as the underneath of the culture in plate. Observed features were recorded for crosscheck with existing information in manuals and atlas. Moreover, each colony was subjected to microscopic examination. In this regard, a slide mount was made and stained with lactophenol cotton blue and observed under the microscope using X40 magnification objective lens. Features of the organisms were recorded including directional growth of conidiophores or sporangiophores, presence of septate, branches and the form of the apex (head) as well as the shape, color etc. of the fruiting bodies (spores or conidia). The observed features were recorded for crosscheck with the manuals.

To identify the characterized isolates, the recorded characteristics were compared with those available in standard manuals. The organisms with the maching characteristics were identified accordingly. The method described by Gautam and Avasthi (2019) was used.

Pathogenicity tests

Tests were carried out on healthy and fresh cassava tubers to determine which of the fungal isolates could cause diseases similar to the ones observed in the cassava tuber from where they were isolated. In this regard, the surface of the healthy and freshly harvester cassava tuber was cleaned with ethanol cotton swab. Then a flamed corkborer (5 mm) was used to make a core by the side of the cassava tuber about 5 mm deep and the cylindrical flash was carefully and aseptically recorded and kept into a sterile sample bottle with corer. Carefully, a disc was cut out from a pure culture of the test isolate using a flamed corkborer and put inside the core on the tuber and the fleshly cylinder was replaced inside the inoculated hole and sealed with sterile gel. A control hole was similarly made with the same flamed corkborer but the cylinder was removed and replaced without inoculum. It was also sealed with sterile gel like the test. The inoculated tuber was allowed to stay in ambient environment being observed daily for signs of disease condition. This process was done for each fungal isolate.

On establishment of disease conditions such as softening, discoloration, moisture exudate, visible fungal mycelia etc., the test was stopped and the cassava tuber was cut transversely along the line of inoculation to reveal the inside. The extent of progression of rot inside the tuber relative to the control, was used as a yardstick to measure pathogenicity. The isolates implicated as pathogens were used in antifungal bioassays using botanical extracts.

Antifungal activity test on plant extracts

Extracts of the three test plants were produced in both water and ethanol separately using the method described by Okon *et al.* (2024). In this method, 50 g of each powered leaf were mixed with the respective solvent, agitated thoroughly and then left to stand for 48 h at room temperature (30$\pm$2 ºC). After this, the soaked plant samples were shaken vigorously and filtered through a sterile muslin cloth first and then through sterile Whatman filter paper No. 1. The filtrate was collected into a weighed sterile glass beaker and later evaporated to dryness to remove the solvent. The beakers were reweighed with the dry extract and the weights of the extracts were determined.

Test for the control of the pathogenic fungi isolated from diseased cassava tubers was done using the radial growth inhibition technique (Awua, 2015; Entonu *et al*., 2023). The method involved the mixing of the test organisms with the extract and inoculating the same on sterile SDA medium. A measured quantity of the plant extract 0.14 mL was mixed with 0.2 mL of 72-h broth culture of the test fungal isolate. Then a loopful of the mixture placed at the center of the plate on top of the sterile SDA medium. A loopful of the organism in the broth but without extract was placed at the center of a separate SDA plate to serve as control. This was done for each of the test pathogen and the plates were labelled, wrapped and incubated at room temperature. They were observed daily until the fungi in the control plate spread to the perimeter of the Petri dish. Then the experiment was stopped and the diameters of the colony in the control and the test cultures were measured and their radii were calculated. A standard was set up in which each test

organism was mixed with a standard antifungal agent mancozeh and cultured as described above.

The given below formula was used for the calculation of radial growth inhibition (RGI).

$$\text{RGI (\%)} = \frac{\text{RC} - \text{RT}}{\text{RC}} \times \frac{100}{1}$$

RC = Radius of the organism in the control culture plate
RT = Radius of the organism in the test culture plate (containing the extract)

Relative potency of the test plant extracts was calculated in comparison with the inhibition caused by the standard antifungal drug mancozeb. The formula below was used for the calculation:

$$\text{Reactive potency (\%)} = \frac{\text{IT}}{\text{IS}} \times 100$$

IT = inhibition of the test extract
IS = Inhibition of the standard drug

Statistical analysis

All the obtained data were subjected to analysis of variance (ANOVA) using the statistical package of social sciences version 23 with separation at ($P \leq 0.05$ using Duncan's Multiple Range test.

Results

Fungi isolated from diseased cassava tubers

Seven fungal species including *Aspergillus, Penicillium, Fusarium, Mucor, Rhizopus, Botryodiplodia* and yeast were isolated from the three cassava varieties. The occurrence of the organisms varied in the different cassava tubers with *Aspergillus* species being present in all the test samples (100% occurrence) while *Botryodiplodia* was isolated from a few with mean occurrence of 22.2%. The mean gross occurrence of the isolates showed yeasts (88.9%), *Fusarium* (44.4%), *Penicillium* (55.6%), *Mucor* (33.3%) and *Rhizopus* (55.6%). Moreover, there were different levels of occurrences of the different fungal isolates in the different types of cassava. Only the *Aspergillus* isolate was present in all cassava varieties. Yeasts were present in all the samples of unicasts 1 and 2 but was not found in one, sample 2 unicast 4 while *Fusarium* was in only one sample in each of unicast 1 and 2 but was not found in unicast 4. Comparatively, the unicast 4 (sweet cassava) appeared to be more vulnerable to the fungal infestation while the bitter cassava (unicast 1 and 2) were less susceptible (Table 1).

Pathogenicity tests of the isolated fungi

Three of the seven isolates did not demonstrate pathogenicity as they did not cause significant level of rot on fresh and healthy cassava tubers. *Mucor*, *Rhizopus* and the yeasts were non-pathogenic while other mold isolates showed pathogenicity. The lengths of rots caused by the molds in healthy cassava tubers varied with the cassava varieties and the isolate type. *A. niger* caused rots of lengths between 12 mm in TME 419 to 18.5 mm in the sweet cassava. Similarly, the rots caused by *F. oxysporum* varied in length between 9.5 (TME 419) and 14 mm (TMS 30572). The rot lengths in *Penicillium* inoculated healthy cassava tubers were from 13 to 18 mm while *B. theombromae* caused rot of length between 7.5 and 9.5 mm. *A. niger* appeared to be the most pathogenic isolate causing higher degree of rots than any other pathogen. The results also showed that the different cassava varieties exhibited varying levels of resistance to the test organisms. The bitter cassava TME 419 variety was the least affected by the pathogenic microbes with rot lengths of 7.5 to 13 mm while the other varieties exhibited rot length of 9.0 to 18 mm (TMS 30572) and 9.5 to 18.5 mm. In comparison with the controls, the non-pathogenic isolates caused insignificant level of rot with pseudo-rots of 3 to 4 mm, which were not significantly different from the 3 mm recorded with the control and observed as the effect of the wound created during the inoculation processes. The four test pathogens were considered for further research in antifungal tests using the plant extracts (Table 2).

Phytochemical screening of plants

Table 3 shows results of phytochemical screening of the three-test plant (leaves). The results indicated the presence of many different phytochemicals but at varying levels of detections. Generally, the detected phytochemicals include alkaloids, saponins, tannins, flavonoid, phenols and cyanogenic glycosides. Alkaloids were detected at moderate level (++) in *Chomolaena odorata* and *Spondias mombin* but was high (+++) in *Andrographis paniculata* leaves. Tannin was the highest (+++) in *C. odorata* while *S. mombin* and *A. paniculata* leaves contained moderate (++) detectable tannins. Flavonoids were detected in all the three leaf samples at moderate levels (++) while steroids were found in low detectable levels (+) and phenols were in moderate levels in all three samples. Whereas saponins were found in moderate level (++) in *C. odorata*, and low (+) in *S. mombin* and *A. paniculata* leaves. Cyanogen was low in all the three samples (+).

Antifungal activity of botanicals

Table 4 shows the antifungal activities of the test leaf extracts of the different plants against the different post-harvest cassava pathogens. There was significant difference between the activities of the water extracts and those of the ethanol extract of the same plant on one hand and the activities of the plant extracts and that of the standard antifungal drug (mancozeb) on the other hand. Also, there were variations in the levels of the activity of each extract against the different fungal pathogens. Radial growth

of *A. niger* was inhibited in the range of 41.20% to 84.14% by the extracts. The ethanol extracts were generally more active with growth inhibitions ranging from 74.88% (*C. odorata*) to 83.14% (*A. paniculata*) than the water extracts where growth inhibitions were in the range of 41.20% (*S. mombin*) to 58.35% (*A. paniculata*). The inhibition of growth of *F. oxysporum* due to herbal extracts was in the range of 37.68% (*C. odorata*) to 51.52% (*A. paniculata*) for the water extracts and from 66.56% (*S. mombin*) to 83.74% (*A. paniculata)* for the ethanol extracts. *Penicillium notatum* was inhibited from 35.98% to 52.65% (water extracts) and from 71.05% to 88.26% (ethanol extracts). The inhibition of *B. theobromae* was lower than the other pathogens ranging from 37.78% to 49.81% (water extracts) and from 63.33% to 68.89% (ethanol extracts).

Comparatively, the extract of *A. paniculata* was the most potent against the fungal pathogens recording growth inhibitions in the tunes of 49.81% to 58.36% for the water extract and 68.89% to 88.26% for the ethanol extract. Also, the extracts of *S. mombin* was the least potent having inhibition activity of 37.78% to 45.38% (water extract) and 65.74% to 76.03% (ethanol extract). The result further showed *A. niger* to be the most inhibited fungal pathogen with growth inhibitions of 41.20% to 58.36% (water extracts) and 74.88% to 83.14% (ethanol extracts) while *B. theobromae* was the least inhibited with records of growth inhibitions of 37.78% to 49.81% (water extracts) and 63.33% to 68.89% (ethanol extracts). The result also showed that all the plant extracts had lower growth inhibition than that of the commercial fungicide mancozeb where growth inhibition was between 88.80% (*B. theobromae)* and 97.21% (*A. niger*) as shown in Table 4.

Discussion

The findings of this study revealed that cassava tubers, after harvest, are highly susceptible to fungal infections, leading to rapid spoilage. A total of seven fungal species were isolated from diseased cassava tubers, with *Aspergillus niger*, *Fusarium oxysporum*, *Penicillium notatum* and *Botryodiplodia theobromae* identified as the major pathogenic organisms. The other isolates, including yeasts, *Rhizopus* and *Mucor*, did not show significant pathogenicity suggesting that these fungi may act as secondary invaders, colonizing cassava tubers. This aligns with the findings from previous research indicating that *Rhizopus* and *Mucor* are typically saprophytic and often follow primary fungal infections (Krishna, 2024).

The variation in fungal occurrence patterns among different cassava varieties suggests that some varieties possess higher resistance to fungal infection, while others are more susceptible to post-harvest spoilage. This observation highlights the importance of selecting cassava varieties with inherent resistance to fungal pathogens as a strategy for reducing post-harvest losses. The antifungal potential of the three tested plants namely *C. odorata*, *S. mombin* and *A. paniculata*was evident, with all extracts demonstrating varying degrees of inhibition against the fungal pathogens. Phytochemical analysis confirmed the presence of bioactive compounds such as alkaloids, saponins, tannins, flavonoids, steroids, phenols and cyanogenic glycosides, which are known to exhibit antimicrobial properties (Uzuegbu and Okoro, 1999; Mabadahanye, 2020). The higher antifungal activity of the ethanol extracts compared to the water extracts suggests that ethanol may extract a broader range of bioactive compounds, thereby enhancing antimicrobial efficacy (Nortjie *et al*., 2022). This supports the hypothesis that solvent polarity plays a critical role in phytochemical extraction and antimicrobial potency (Javaid *et al.,* 2023; Rafiq *et al.,* 2024).

Among the three plants, *A. paniculata* exhibited the highest antifungal activity, likely due to its higher alkaloid content, while *C. odorata* showed the lowest inhibition of fungal growth. Interestingly, the study revealed that the plant extracts were more effective against spore-bearing molds like *Aspergillus* and *Penicillium* than against less spore-forming fungi such as *F. oxysporum* and *B. theobromae* (Mans, 2022). This observation may be attributed to differences in fungal spore structure and resistance mechanisms.

Although the commercial fungicide mancozeb exhibited higher growth inhibition than the plant extracts, the study emphasizes the promising potential of these local botanicals as eco-friendly, organic alternatives for controlling post-harvest cassava spoilage. The lower efficacy of the crude plant extracts compared to the commercial fungicide suggests that purification and concentration of the active phytochemicals could significantly enhance their antifungal potency (Švecová, 2010).

Conclusion

This study not only highlights the significant role of fungal pathogens in cassava spoilage but also underscores the potential of tropical plant extracts as natural antifungal agents. In the light of the results obtained from this work, it was observed that the antifungal activities of the different plant extracts were fairly low when compared with existing commercial drug mancozeb. The relative lower performance of the plant extract was attributed to their relative crudity, which could be enhanced by purification. Further research should be focused on isolating and characterizing the active compounds from these plants that will open new pathways for developing sustainable biocontrol strategies in agriculture.

Novelty statement

This study presents a pioneering approach to controlling post-harvest spoilage of cassava tubers by evaluating the antifungal potential of ethanol and water extracts from three tropical plants namely *C. odorata*, *S. mombin* and *A. paniculata*. The research not only identified key fungal pathogens contributing to cassava decay but also demonstrated the comparative efficacy of natural plant extracts, offering a sustainable and eco-friendly alternative to synthetic antifungal agents. The findings contribute significantly to agricultural biotechnology by highlighting the underexplored potential of these local botanicals for post-harvest disease management.

Contribution of authors

CGO conceptualized the study and developed the methodology. CAN drafted the manuscript and performed the data analysis. CAU implemented the methodology and contributed to the analysis. MUU critically reviewed and revised the manuscript.

Conflict of interests

Authors declare no conflict of interest.

Table 1: Occurrence of fungal isolates in different diseased cassava tubers.

	Yeasts	***Aspergillus***	***Fusarium***	***Penicillium***	***Mucor***	***Rhizopus***	***Botryodiplodia***
V1 a	+	+	-	-	-	+	-
b	+	+	+	+	-	+	+
c	+	+	-	+	-	+	-
Occurrence (%)	100	100	33.3	66.7	0	66.7	33.3
V2 a	-	+	-	+	-	+	-
b	+	+	+	-	+	-	-
c	+	+	+	+	-	+	-
Occurrence (%)	66.7	100	66.7	66.7	66.7	66.7	0
V3 a	+	+	-	-	-	-	-
b	+	+	-	-	+	+	-
c	+	+	+	+	-	-	+
Occurrence (%)	100	100	33.3	33.3	33.3	33.3	33.3
Total	9	9	9	9	9	9	9
Number of positive testing	8	9	4	5	3	5	2
Overall Occurrence (%)	**88.9**	**100**	**44.4**	**55.6**	**33.3**	**55.6**	**22.2**

Table 2: Result of pathogenicity tests of the fungal isolates from the diseased cassava tuber.

Cassava varieties	**Growth (mm)**						
	Aspergillus	***Fusarium***	***Penicillium***	***Botryodiplodia***	***Mucor***	***Rhizopus***	**Yeast**
TME 419	12.00	9.50	13.00	7.50	1.00	1.50	1.00
NR 8082	14.20	10.00	15.00	8.50	1.50	1.60	1.00
TMS 30572	18.50	14.00	18.00	9.50	1.80	1.70	1.90

Table 3: Phytochemical analysis of plants.

Test plants	**Alkaloids**	**Saponins**	**Tannins**	**Flavonoids**	**Steroids**	**Hydrogen cyanide**	**Phenols**
Chromolaena odorata	++	++	+++	++	+	+	++
Spondias mombin	++	+	++	++	+	+	+
Andrographis paniculata	+++	+	++	++	+	+	++

\+ = Detected at low level
++ = Detected at moderate level
+++ = Detected at high level

Table 4: Inhibition in radial growth of different fungal isolates due to water and ethanolic extracts of three plant species.

Plant extract	Radial growth inhibition (%)			
	Aspergillus niger	***Fusarium oxysparium***	***Penicillum notatum***	***Botryodiplodia theobromae***
Chromolaena odorata water extract	46.47 ± 2.08^{d}	37.68 ±0.87^{d}	42.89 ±2.91^{d}	42.57 ±4.45^{c}
C. odorata ethanol extract	74.88 ± 4.89^{b}	71.37 ±5.51^{b}	74.21 ±2.00^{b}	63.33 ±2.89^{b}
Spondias mombin water extract	41.20 ±0.04^{d}	45.38 ±1.98^{c}	35.98 ±2.63^{d}	37.78 ±3.85^{c}
S. mombin ethanol extract	76.33 ±1.28^{b}	66.56 ±2.54^{b}	71.05 ±2.31^{b}	65.74 ±3.94^{b}
Andrographis peniculata water extract	58.36 ±1.92^{c}	51.82 ±1.58^{c}	52.65 ±3.76^{c}	49.81 ±4.65^{bc}
A. peniculata ethanol extract	83.14 ±2.72^{a}	83.74 ±7.12^{a}	88.26 ±5.99^{a}	68.89 ±1.92^{b}
Mancozeb	97.21 ±0.64^{a}	95.30 ±0.94^{a}	96.73 ±1.49^{a}	88.80 ±1.25^{a}

Values are means ± standard deviation of triplicate determinations. Means with different superscripts in the same column are significantly different at $P \leq 0.05$.

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