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INVENTORY OF MAJOR POST-HARVEST DETERIORATION AGENTS OF THE NATIONAL YAM GENETIC RESOURCES COLLECTION AT THE CNRA FOOD CROPS RESEARCH STATION IN BOUAKÉ

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ABSTRACT

Yam is a significant food source for populations in West Africa. During storage, diseases and infestations deteriorate the quality of the tubers, reducing their shelf life. To improve yam conservation during storage in Côte d'Ivoire, a study was conducted to identify the main pathogens and pests associated with yam tuber rot during storage. Sampling was carried out from the national yam genetic resources collection to collect tubers showing signs of rot. Two types of rot were observed, each with different coloration. Dry rot was black, brown, maroon, or green, while wet rot was brown, white, or black. On Dioscorea alata tubers, the cumulative frequency of dry rots (83.33%) was higher than that of soft rots. 60% of dry rots showed a black color. As for the tubers of the Dioscorea rotundata species, the cumulative frequency of soft rots was 48%, lower than that of dry rots with a frequency of 52%. The black color with a rate of 51% was higher than the other colors (maroon (34%); brown (14%); green (1%). Four fungal genera (*Botryodiplodia* sp., Aspergillus sp., Colletotrichum sp., and Fusarium sp.) and one pest insect (*Euzopherodes vapidella*) were identified in this study. *Botryodiplodia* sp. was the most isolated fungus with a frequency of 48 %. Pathogenicity tests were conducted on each isolated pathogen, with Aspergillus sp. proving the most virulent. The hybrid variety TDr10/00006 demonstrated the highest resistance to these microorganisms.

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Keywords: Pathogens, yam, post-harvest, rot, Côte d'Ivoire

1. INTRODUCTION

Yam is a tuber cultivated in tropical areas of Africa, the Caribbean, Oceania, and South Asia, belonging to the family Dioscoreaceae and the genus *Dioscorea* (Swamy 2024). This tuber is a staple food for more than 500 million people in some countries in Africa, the Caribbean, Oceania, and Latin America (Kouadio *et al.,* 2022; Faostat 2019). In West Africa, where most of the production occurs, yam is one of the primary sources of starch for populations in the five major producing countries: Nigeria, Ghana, Côte d'Ivoire, Benin, and Togo (Faostat 2022).

In Côte d'Ivoire, yam plays an essential role in food crop production, covering 63.72 % of the food crop area with an estimated production of about 7.45 million tonnes in 2019 (Faostat 2022). However, various abiotic and biotic constraints prevent yam from contributing more significantly to the food supply of many developing countries (Tariq *et al.,* 2024). Damage during yam storage caused by rodents, insects, and microorganisms leads to losses ranging from 20 to 30 % (FAO 2022). Nevertheless, the high-water content of yam tubers, coupled with injuries sustained after harvest, exposes them to microorganisms (Tschannen *et al*., 2003). In Côte d'Ivoire, 30 % of post-harvest losses are due to tuber rot (Camara *et al.,* 2021). These rots, caused by fungi, bacteria, and insect larvae, result in rapid degradation of yam tubers, affecting their quality and shelf life. Given the importance of these losses in Côte d'Ivoire and in the absence of adequate techniques for the storage of fresh tubers, particular emphasis must be placed on improving the preservation of yams during storage. Thus, for better conservation of tubers, it will be essential to understand the diversity of pathogens and pests present in the collection. To do this, it was necessary to identify the harmful strains of these pathogens and pests. This study, therefore, aimed to identify the primary pathogens and pests associated with rot in yam tubers (*Dioscorea rotundata* and *Dioscorea alata*) during storage in the national yam genetic resources collection.

2. MATERIALS AND METHODS

2.1 Study site

This study was conducted at the Food Crops Research Station (SRCV) of the National Center for Agronomic Research (CNRA) in Bouaké, located on the Sakassou road. It is situated at 7°69' N latitude and 5°03' W longitude, at an altitude of 376 meters (Nzué *et al*., 2022). The region is characterized by a tropical humid climate with four seasons (Jones *et al*., 2012), namely a long dry season (November to February), a long rainy season (March to June), a short dry season (July to August), and a short rainy season (September to October). The soils are ferrallitic and gravelly, moderately saturated, and shallow, with a sandy-clay texture (Ettien 2004). The annual average

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rainfall is 1200 mm, with an average temperature of 25.73°C and an annual sunshine duration of 2200 hours (Traore *et al.* 2013).

2.2 Materials

2.2.1 Plant Material

The plant material consisted of 178 accessions of *Dioscorea rotundata* (Fig. 1a) and 214 accessions of *Dioscorea alata* (Fig. 1b) from the national yam collection. Healthy-looking tubers from two varieties of each species were used to conduct pathogenicity tests (TDr10/00006 and Krenglè for *D. rotundata* and TDa01/00002 and Ma01 for *D. alata*). The criteria for choosing these clones were essentially yield, culinary quality, fine texture and organoleptic quality. These two species are the most cultivated and economically profitable in Côte d'Ivoire.

Figure 1: Yam tubers during storage

a: Dioscorea rotundata; b: Dioscorea alata

2.2.2 Technical Equipment

The technical equipment used included white plastic bags for storing samples showing symptoms of rot. A steam sterilizer (ISO13485) was used for culture medium sterilization. A binocular microscope with a camera attachment was used for fungal strain identification. A balance was used to weigh solid components for the culture medium. A 7 cm cork borer was used for fungal disc inoculation.

2.3 Methods

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2.3.1 Sample Collection

Yam samples were collected from the storage room after two months of storage. Sampling involved taking excrescences from tubers showing signs of rot due to microorganisms or insect larval predation. The samples were placed in plastic bags and taken to the laboratory. In the laboratory, the appearance and coloration of the samples were observed and described.

Cross-sectional and longitudinal cuts were made to describe both external and internal symptoms. This description helped determine the frequency of varieties affected by microbial and insect-caused rot during storage. The frequency of rot in affected samples (Fp) was calculated using the following formula

$$Fp = \frac{\text{Number of varieties affected}}{\text{Total number varieties presentes in the collection}} \text{ X } 100 \quad (1)$$

2.3.2 Isolation of the Main Pathogens Associated with Symptoms

- **Culture Medium Preparation**

The PDA (Potato Dextrose Agar) medium was used for the isolation of pathogenic fungi. To prepare 1 liter of PDA medium, 20 g of potato puree, 20 g of glucose, 20 g of agar, and 1 liter of distilled water were mixed. The medium was sterilized in an autoclave at 121°C for 30 minutes under 1-bar pressure. After cooling, the medium was distributed into 9 cm Petri dishes under a laminar airflow hood in the presence of a sterile flame. The plates were left for at least 15 minutes to solidify before explant inoculation.

- **Inoculation of Plant Explants**

Small portions from the excrescences of rotting tubers were taken. These explants were disinfected with 10% diluted sodium hypochlorite (5-6% NaOCl) for 1 minute, then placed on sterile blotting paper to remove excess water. They were inoculated onto Petri dishes containing the PDA medium. The plates were sealed with parafilm, labeled, and incubated for 2 to 4 days at room temperature.

- **Purification of Pathogens**

The fungal isolates developed from the explants were sub-cultured several times on new sterile PDA media until pure fungal isolates were obtained (Ranjitha & Sathiavelu 2024).

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2.3.3 Identification of Pathogens and Pest Insects

- **Identification of Fungal Isolates**

The identification of fungal isolates was done using Franck Dugan's (2017) identification key. The description of cultural characteristics included color, conidial morphology, growth pattern, and mycelial colonies of the isolates. Macroscopic description was first performed on the colonies during the early growth phase, i.e., 3 days after incubation, and at 20 days for aged isolates.

A small part of the excrescence of each isolate was mounted between a slide and a coverslip for microscopic observation. Organs such as mycelium, spores, conidia, and conidiophores were described for rapidly growing fungi 4 days after subculturing and for slow-growing fungi 7 days after subculturing.

- **Identification of Pest Insects**

Tubers showing symptoms of rot due to insect pests were taken to the laboratory. The pupae with tuber fragments were placed in a closed jar with a net at ambient air. After 24 hours, morphological changes occurred, transforming the pupae into insects. They were identified using Jacques *et al*.'s (2016) identification key, based on the description of morphological features such as color, antennae, mouthparts, and wings, with the help of a binocular magnifier.

2.3.4 Frequency of Fungal Isolation

The isolation frequency of fungal genera was determined according to Walder's (1996) formula:

$$FI\ (\%) = \frac{NI}{NTI}\ X\ 100 \qquad (2)$$

FI: Isolation Frequency in percentage.

NI: Number of Isolations of a fungal genus from all samples.

NTI: Total Number of Isolations of all fungal genera

2.3.5 Pathogenicity Test of the Main Isolated Fungi

- **Inoculation of Main Isolated Fungi**

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The tubers were washed with tap water and then disinfected with 10% diluted sodium hypochlorite for 15 minutes. Subsequently, they were sliced into 6 cm-thick discs using a sterile knife. A 7 cm diameter cork borer was used to make a 1 cm deep hole in the center of each disc. A fungal inoculum in the form of a disc was taken from one-week-old fungal colonies and placed into the hole made on the yam disc, ensuring contact between the fungal mycelium and the bottom of the hole. The hole was sealed with the respective yam cylinder, with one fungus inoculated per yam disc. Control discs without inoculation were also prepared. All the discs were stored in sterile plastic containers with blotting paper soaked in sterile distilled water to maintain high relative humidity for 7 days (Fig. 2). This operation was performed in triplicate (Assiri *et al*. 2017).

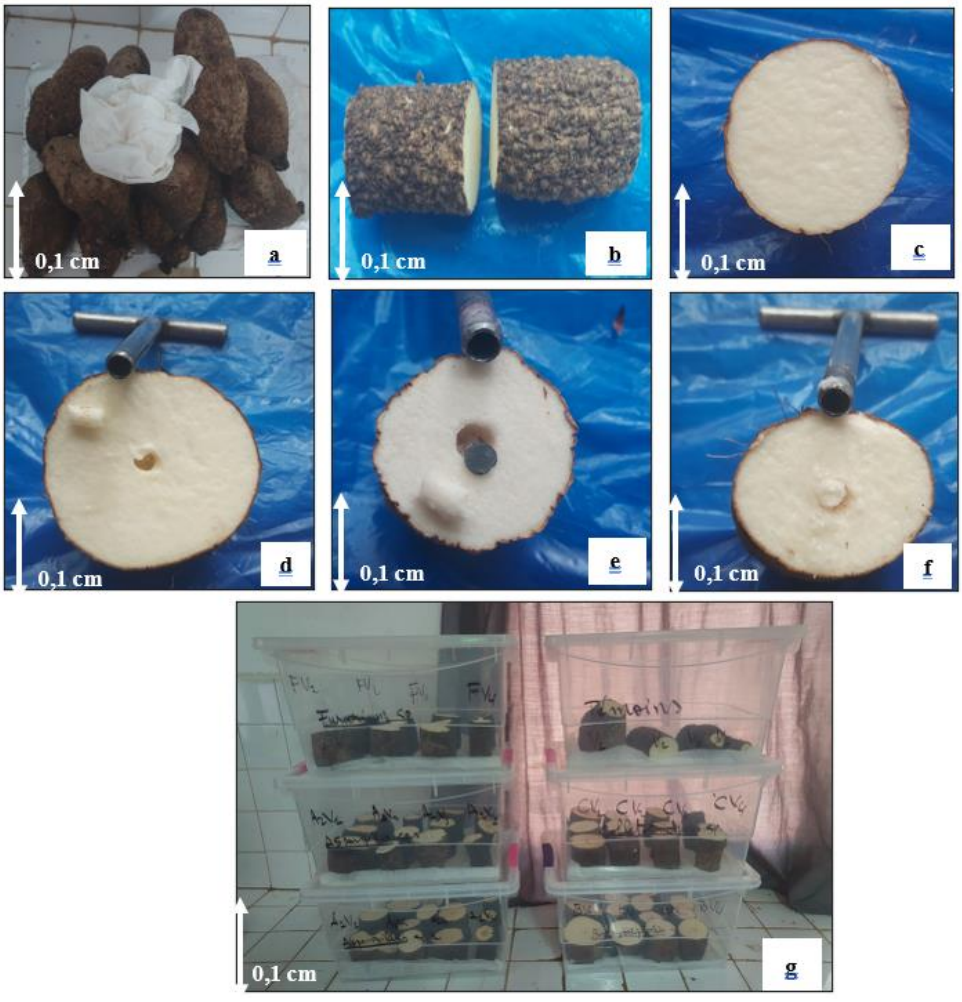

Figure 2: Procedure for the pathogenicity test

a: healthy tubers; b: 6 cm disc; c: surface used to make the hole; d: 1 cm hole made with the cork borer; e: fungal inoculum in disc form; f: sealing with the respective fragment; g: storage containers for the samples.

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- **Koch's Postulate**

Koch's postulate was used in this study to establish a causal link between the isolated pathogens and the yam rot samples. The excrescence from rot symptoms after the pathogenicity test was placed on new sterile culture media and re-isolated following the essential steps of Koch's postulate (Bhunjun *et al*. 2021).

- **Description of Symptoms and Volume of Rot**

The symptoms caused by the different pathogens were described after 7 days of incubation. The description was done after refreshing the infested surface to determine the volume of rot. A cross-sectional cut was made on each disc using a sterile knife. The height and diameter of each rot were measured, and the volume of rot was calculated using the formula of Mascher & Défago (2000):

Volume of rot (Vp) in cm^3

$$Vp = \pi^2 \times h \quad (3)$$

Where r = radius (in cm) and h = height of the rot (in cm).

2.3.6 Statistical Analysis

The collected data were entered into the computer using Excel software. They were subjected to a two-factor analysis of variance (ANOVA II) using Statistica version 7.1 software. The analysis of variance with two classification criteria (ANOVA II) was used to compare pathogen-induced rot according to variety. In case of significant differences, means were separated using Turkey's test at the 5% threshold. The significance of the test is determined by comparing the probability (P) associated with the test statistic with the theoretical value $\alpha = 0.05$. When $P \geq 0.05$, there is no difference between the means. On the other hand, when $P < 0.05$, there is a significant difference.

3. Results and Discussion

3.1 Frequency of Characteristic Fungal Rot Symptoms Observed on Yam Species *Dioscorea alata* and *Dioscorea rotundata*

The symptoms observed on these species varied depending on the yam variety. Five (5) varieties showed symptoms characteristic of fungal pathogens, representing a rot rate of 2 % (Fig. 3). Both soft and dry rot were observed on *Dioscorea alata* tubers, with a cumulative frequency of dry rots (83.33 %) higher than soft rots. Sixty percent of the dry rot showed black coloration. These

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included white-colored soft rot, brown-colored dry rot, and black-colored dry rot. The dominant symptoms were dry rot (83.33 %), with 60 % showing black coloration (Fig. 4).

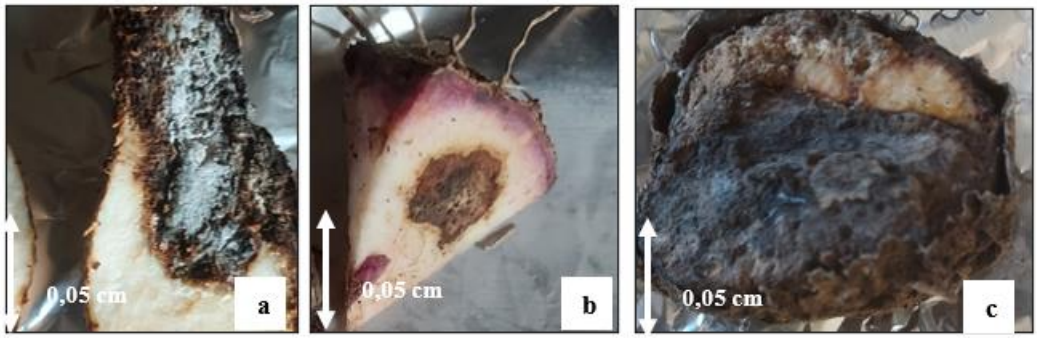

Figure 3: Fungal rots observed on *Dioscorea alata*)

a: white-colored soft rot; b: brown-colored dry rot; c: black-colored dry rot

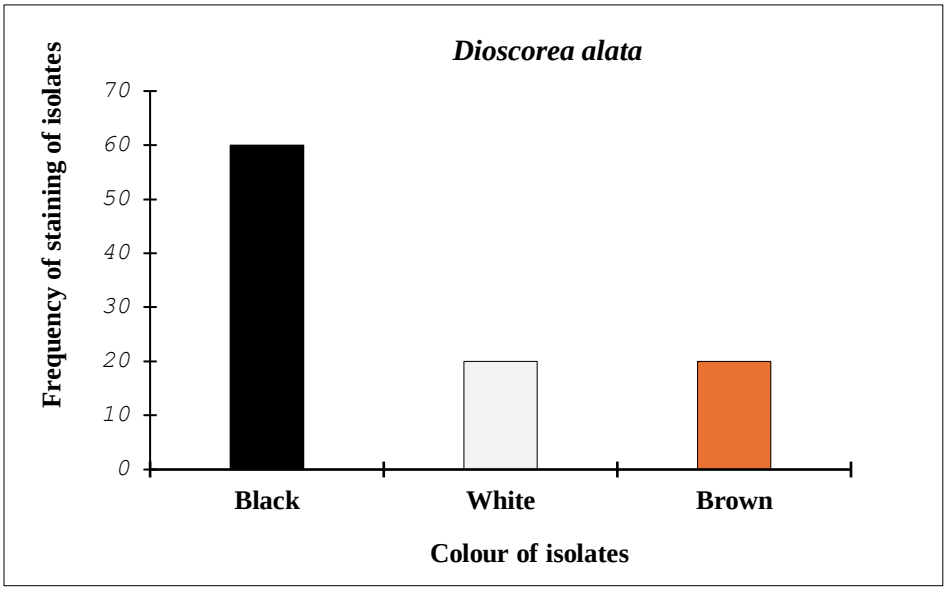

Figure 4: Frequency of coloration of fungal isolates on yam rot in *Dioscorea alata*

The frequency of rot symptoms caused by fungal pathogens varied across different yam varieties. Two types of rot (soft and dry) were observed on *Dioscorea rotundata* tubers (Fig. 5). The cumulative frequency of soft rot was 48%, lower than that of dry rot (52%). Seventy-four (74) varieties from the collection showed rot symptoms, with sixty (60) exhibiting characteristic fungal pathogen symptoms. Four types of fungal isolate coloration were observed (Fig. 6): brown (34%), brownish (14%), greenish (1%), and black (51%).

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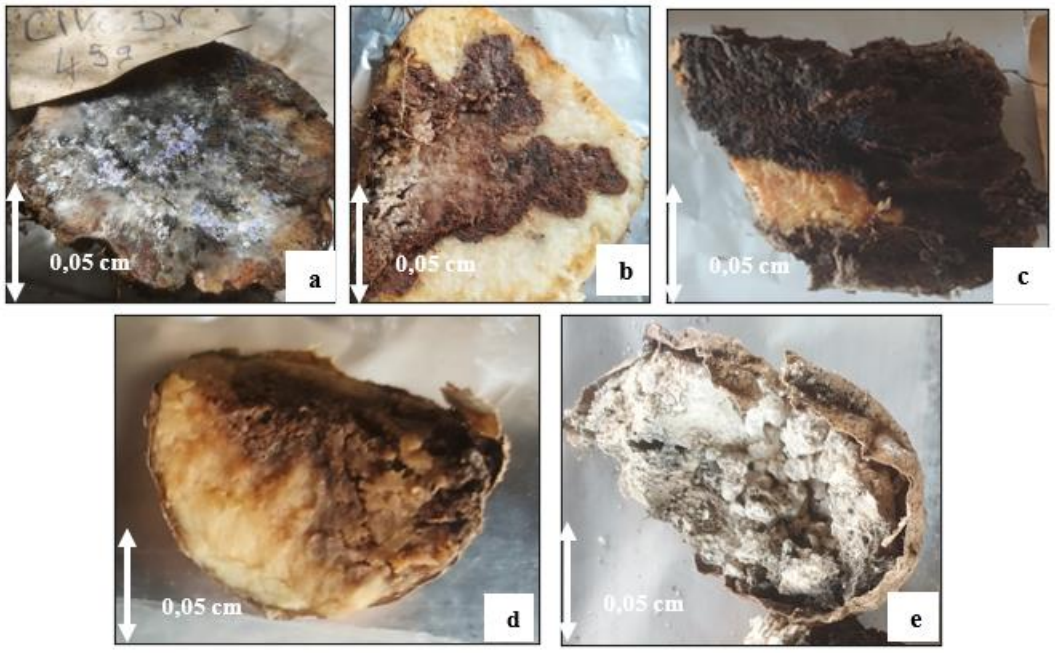

Figure 5: Fungal rots observed on *Dioscorea rotundata*

a: black-colored soft rot; b: brown-colored soft rot; c: black-colored dry rot;
d: brown-colored soft rot; e: brown-colored dry rot.

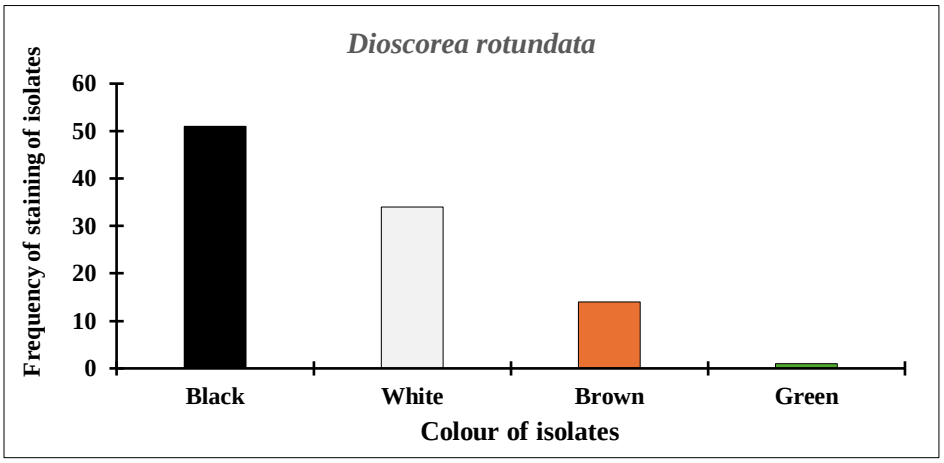

Figure 6: Frequency of coloration of fungal isolates on yam rot in *Dioscorea rotundata*

Rot symptoms characteristic of pathogens varied among yam varieties during this study. Two types of rot (dry and wet) with different colorations were observed on the sampled tubers. Three to four colorations were respectively observed on *Dioscorea alata* and *Dioscorea rotundata* tubers.

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These included black, brown, brownish, white, and green rot. Most of the collection's rot consisted of dry rot with black coloration. This difference in rot could be due to the strong parasitic pressure exerted by pathogens during storage. Similar observations were made by Assiri *et al*. (2010) on *Dioscorea alata* var. "bètè-bètè" and *Dioscorea cayenensis-rotundata* var. "krenglè" in two markets in the Abidjan district (Adjamé and Abobo communes). The roots observed by these authors on yam tubers varied and mainly consisted of dry or soft rot with green, brown, or brownish coloration. Our results align with the findings of these authors. The similarity in rot could be attributed to the isolated fungal genera.

Dioscorea rotundata tubers were found to be more susceptible to pathogens than *Dioscorea alata* tubers during storage. This sensitivity in *Dioscorea rotundata* species could be due to its higher moisture content, ranging from 65 % to 73 % for *Dioscorea alata* and reaching up to 80 % for *Dioscorea rotundata* (Girardin and Nindjin 2015; Kouadio *et al*. 2022). This moisture level is a significant factor for pathogen development during storage. Similar observations were made by Assiri *et al*. (2010) on *Dioscorea alata* variety "bètè-bètè" and *Dioscorea rotundata* variety "krengle" in two markets in the Abidjan district. These authors showed that yam varieties belonging to the *D. cayenensis-rotundata* complex were the most susceptible to rot during storage. Dooshima *et al*. (2015) also found that in addition to fungal pathogens, bacteria attack yam tubers during storage. This similarity could be explained using the same storage techniques for yam tubers.

3.2 Frequency of Insect Infestation Symptoms in Both Yam Species

Five (5) varieties of *Dioscorea rotundata* showed rot caused by predation from insect larvae during storage, resulting in a rot rate of 3 %. However, twenty-two (22) varieties of *Dioscorea alata* exhibited similar symptoms, representing a rot rate of 8 % in the collection (Fig. 7).

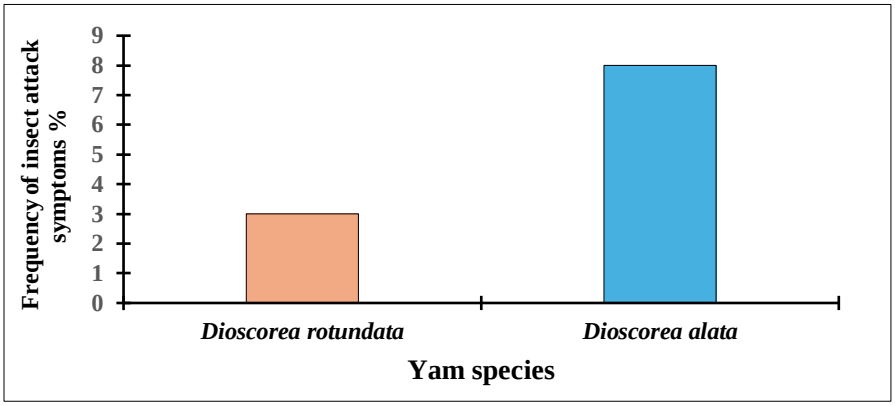

Figure 7: Rot frequency due to insect larvae predation on the two yam species

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Longitudinal and cross-sectional cuts allowed observation of these organisms (Fig. 8).

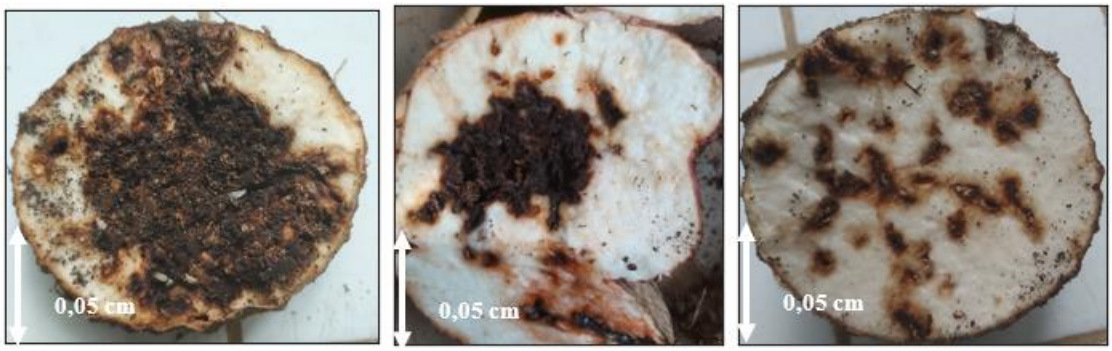

Figure 8: Rots due to insect larvae predation

Dioscorea alata tubers were more sensitive to *Euzopherodes vapidella* during storage compared to *Dioscorea rotundata*. This sensitivity of *Dioscorea alata* during storage could be attributed to the fragility of its skin. This fragility is a factor that promotes the development of these insects. This result aligns with the findings of Girardin and Nindjin (2015), who showed that *Dioscorea alata* was more susceptible to pest insects during storage with 63% of stored tubers being infested by moths and weight losses of 25% attributed to the insects, while *Dioscorea rotundata* had limited susceptibility.

3.3 Identification of Fungal Isolates and Pests during Storage

3.3.1 Identification of Fungal Genera Isolated

The diversity of rot symptoms presents on yam tubers during storage enabled the isolation of four fungal genera. The identified genera were *Botryodiplodia* sp., Aspergillus sp., *Colletotrichum* sp., and *Fusarium* sp.

- **Macroscopic and Microscopic Description of Fungal Genera Isolated**

The isolates of *Botryodiplodia* sp. exhibited a spiny mycelium on the top and a fibrous texture inside the Petri dish, initially white and turning completely black at maturity (Fig. 9 a and b). The thallus growth was circular and regular with centered radiation. Microscopic observations revealed black conidia at the periphery and brown conidia inside. They were cylindrical (cacao bean-shaped) and septate (two septa). The conidia had paraphyses and were encased in a central sheath (Fig. 9 c).

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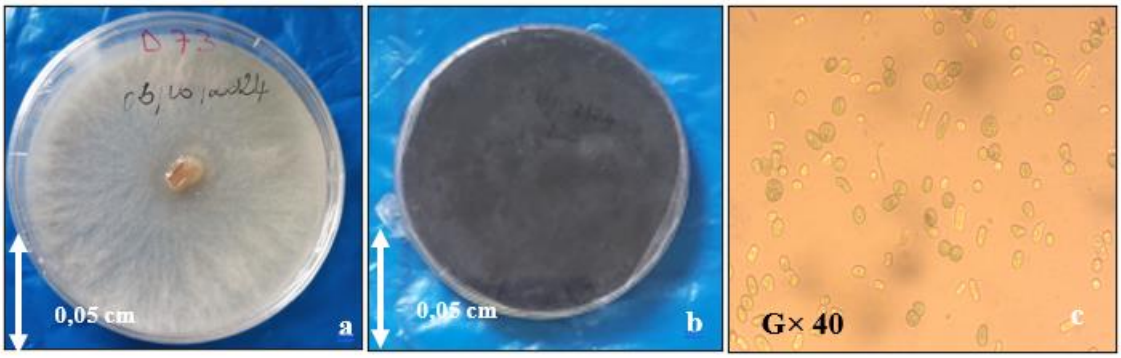

Figure 9: Macroscopic and microscopic view of *Botryodiplodia* sp.

a: white colony in early growth; b: black colony at maturity; c: black rounded spores

Two species of *Aspergillus sp.* were observed in this study. Macroscopically, the first species had white coloration, turning black after a few days (Fig. 10 a). The colony edges appeared pale yellow and produced radial cracks. Microscopically, conidia were observed, which tended to split, and the conidiophores had stalk-like shapes (Fig. 10 c). The second species presented a black, fluffy mycelium colony at maturity (Fig. 11 a and b). The hyaline thallus exhibited septate mycelium with many upright conidiophores terminating in vesicles (Fig. 11 c).

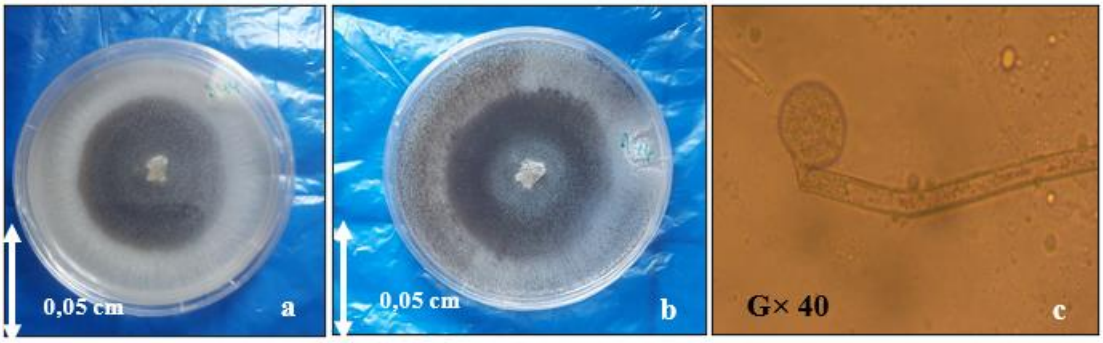

Figure 10: Macroscopic and microscopic view of Aspergillus sp. 1

a: colony in early growth; b: fully black colony at maturity; c: stalk-shaped thallus

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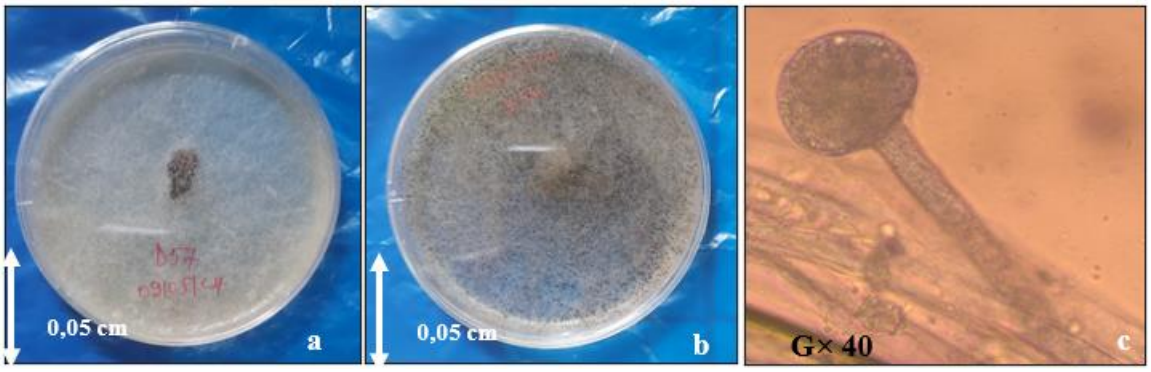

Figure 11: Macroscopic and microscopic view of *Aspergillus* sp. 2

a: fluffy white colony in early growth; b: black colony at maturity; c: stalk-shaped thallus

The isolates of *Colletotrichum* sp. presented a white, fluffy mycelial colony with a grayish or whitish reverse (Fig. 12 a and b). Microscopic observations revealed isolated conidia with cylindrical and fusiform shapes (Fig. 12 c).

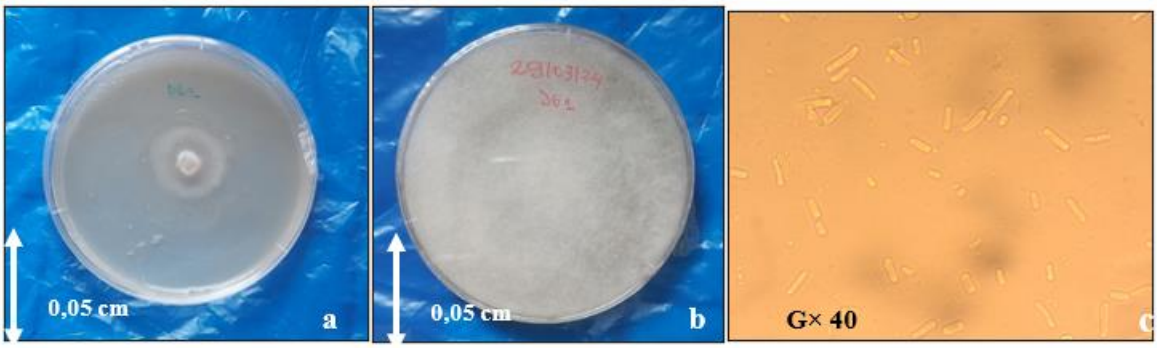

Figure 12: Macroscopic and microscopic view of *Colletotrichum* sp.

a: white colony in early growth; b: gray colony at maturity; c: cylindrical spore

The isolates of *Fusarium* sp. presented a red-whitish mycelial colony resembling cotton in culture (Fig. 13 a and b). The conidiophores were variable, thin, and simple, irregularly branched or bearing true whorls of phialides, either simple or grouped. The hyaline conidia were variable, and the macroconidia had several slightly curved cells with pointed ends (Fig. 13 c).

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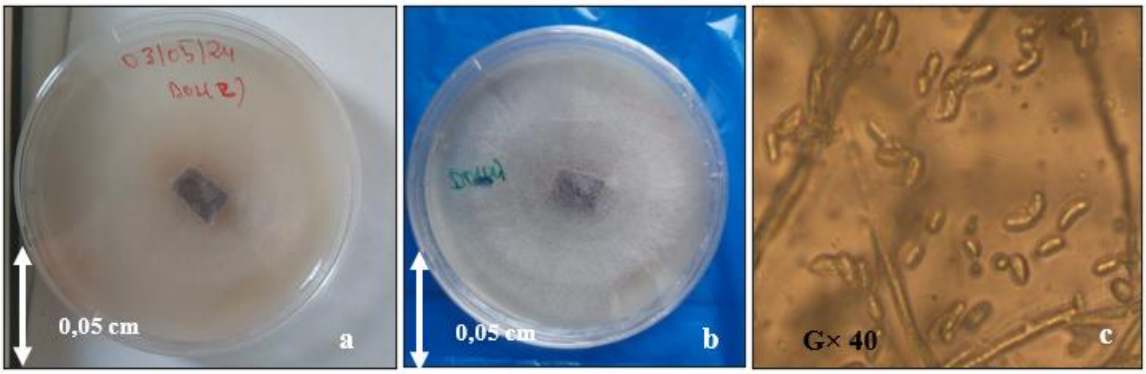

Figure 13: Macroscopic and microscopic view of *Fusarium* sp.)

a: red-whitish colony in early growth; b: white colony at maturity; c: slightly curved spores

3.3.2 Identification of Pest Insects

A lepidopteran named *Euzopherodes vapidella*, belonging to the family Pyralidae, was identified. The hind wings were grayish, and the forewings were brownish. These insects had sucking-type mouthparts and filiform antennae (Fig. 14).

Figure 14: Dorsal and ventral view of *Euzopherodes vapidella*

In total, four (4) fungal genera were identified during this study. These included *Botryodiplodia* sp., *Aspergillus* sp., *Colletotrichum* sp., and *Fusarium* sp.. These fungi are generally associated with yam rot during storage. Previous studies have shown that these fungal genera are linked to yam rots during storage (Ogunleye *et al*. 2014; Nweke, 2015). These authors demonstrated that fungi isolated from yam rots usually include *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium oxalicum*, and *Rhizopus nodosus*. Our results are consistent with those of these authors, with the absence of *Colletotrichum* sp. possibly due to differences in storage locations and associated rot symptoms. Our study also

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revealed that *Botryodiplodia* sp. was the most isolated fungus, while *Fusarium* sp. was the least isolated. Bua *et al*. (2012), who found that *Botryodiplodia theobromae* was the most frequently isolated fungus from yam rot in Uganda during storage, made similar observations.

3.4 Rot Volume of Fungal Isolates Based on Varieties

All the inoculated fungal genera caused rot symptoms on yam tubers. These symptoms varied between dry and soft rots of different colorations. Statistical analysis of rot volume data based on fungal genera showed a significant difference (p=0.000) compared to varieties (p=0.001). The probability associated with the fungi*variety interaction (p=0.011) indicated no significant difference (Table 1).

Table 1: Effect of fungal isolates based on varieties

	F	p
Fungi	12,3446	0,000001
Varieties	3,9318	0,015022
Fungi*variety	1,6443	0,117974

The Tukey test grouped the fungal genera and varieties into seven (7) homogeneous groups. The most severe rots were caused by *Aspergillus* sp. 2 (182 cm^3), while *Colletotrichum* sp. induced the smallest rot volume (0.23 cm^3). The most severe rots were observed in the Ma01 variety, while the smallest rot volumes were observed in the improved variety TDr10/00006. Regardless of the variety used, fungal isolates caused rot. In other words, no variety resisted the inoculation of fungal isolates (Table 2). The Aspergillus sp. genus induced the most severe rot in the Ma01 variety, while *Colletotrichum* sp. caused the smallest rot volumes in the TDr10/00006 clone. The pathogenicity test performed during this study revealed that all fungal and bacterial isolates were responsible for yam rot and material loss during storage. The observed rots varied between dry and wet rot. All isolated microorganisms caused rot symptoms.

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Table 2: Rot volume of fungal isolates based on varieties

Fungi	Varieties	Mean ± Standard deviation
Colletotrichum sp	TDr10/00006	0,23 ± 0,10 d
Fusarium sp	TDr10/00006	0,35 ± 0,07 cd
Colletotrichum sp	Krenglè	0,35 ± 0,07 cd
Aspergillus sp 1	TDa01/00002	0,39 ± 0,21 cd
Colletotrichum sp	Ma01	0,51 ± 0,24 cd
Brotryodiplodia sp	TDr10/00006	0,56 ± 0,48 cd
Fusarium sp	TDa01/00002	0,58 ± 0,29 bcd
Colletotrichum sp	TDa01/00002	0,60 ± 0,31 bcd
Fusarium sp	Ma01	0,60 ± 0,16 bcd
Aspergillus sp 1	Ma01	0,67 ± 0,31 bcd
Brotryodiplodia sp	Ma01	0,72 ± 0,28 abcd
Aspergillus sp 2	TDr10/00006	0,72 ± 0,46 abcd
Brotryodiplodia sp	Krengle	0,84 ± 0,07 abcd
Brotryodiplodia sp	TDa01/00002	0,88 ± 0,14 abcd
Aspergillus sp 1	TDr10/00006	0,93 ± 0,04 abcd
Fusarium sp	Krengle	1,00 ± 0,08 abcd
Aspergillus sp 1	Krengle	1,12 ± 0,38 abcd
Aspergillus sp 2	TDa01/00002	1,4 ± 0,25 abc
Aspergillus sp 2	Krengle	1,70 ± 1,02 ab
Aspergillus sp 2	Ma01	1,82 ± 0,61 a

Average volume bearing the same letter are statitically identicalat the threshold of 5% according to Turkey test.

This could be due to the pathogens' ability to use carbohydrate reserves as substrates for their growth and development. These results are like reports on fungi associated with yam in Nigeria (Okigbo & Ikediugwu 2000). The *Aspergillus sp.* genus induced the most severe rot, followed by *Fusarium sp.* and *Botryodiplodia sp.*. The *Colletotrichum sp.* genus induced the smallest rot volumes. These results are consistent with studies by Assiri *et al*. (2017), who observed that *Aspergillus sp.* and *Botryodiplodia sp.* are among the most important fungi, while *Colletotrichum sp.* is the least responsible for yam rot during post-harvest storage. The hybrid variety TDr10/00006 showed the highest resistance to fungal genera during the test. This clone could possess resistant genes to these microorganisms during storage.

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4. CONCLUSION

The study conducted in the national yam genetic resources collection allowed for the identification of the main pathogens and pests associated with tuber rot in two yam species (*Dioscorea rotundata* and *Dioscorea alata*) during storage. These organisms caused rot of various aspects and coloration, leading to significant losses. Four fungal genera (*Botryodiplodia* sp., *Aspergillus* sp., *Colletotrichum* sp., and *Fusarium* sp.) and one pest insect (*Euzopherodes vapidella*) were identified during this study. Pathogenicity tests showed that the *Aspergillus* sp. genus was the most virulent. The hybrid variety TDr10/00006 exhibited the highest resistance to these microorganisms. It is recommended that producers to use biofungicides rich in oxygenated monoterpenes (Astoun 50 EC) and in Thymol, Gamma-Terpinene and Eugenol (NECO 50 EC) registered in Côte d'Ivoire as treatments which have shown their effectiveness against the causal agents of rot as soon as the yam tubers are harvested or arrive in the storage area. To store yam tubers in a cool, dry place such as a ventilated cellar with a central chimney, a raised straw hut, a structure mounted on stilts fitted with rat-proof protection and a cellar straw hut pit 4m by 2m by 1.80m deep.

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