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Study on the Pathogenic Fungi Threatening Pepper Cultivation in the Northern Guinea Savannah Ecological Zone of Nigeria

B.G. Zakari[1]*, Isma'ila Muhammad[2], A.S. Kiri[1] and A. Idi[3]

[1]Department of Plant Science, Faculty of Life Sciences, Modibbo Adama University, Yola, P.M.B. 2076, Yola Adamawa State, Nigeria.
[2]Department of Botany, Faculty of Science, Gombe State University, P.M.B 127, Tudun wada, Gombe, Nigeria.
[3]Department of Biotechnology, School of Life Science, Modibbo Adama University, Yola, P.M.B. 2076, Yola Adamawa State, Nigeria.

*Corresponding author:
B.G. Zakari,
Department of Plant Science,
Faculty of Life Sciences,
Modibbo Adama University,
Yola, P.M.B. 2076,
Yola Adamawa State,
Nigeria.
Email: bgzakari@mau.edu.ng

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ABSTRACT

The Northern Guinea Savannah ecological zone of Nigeria, with its rich history of pepper production, faces challenges like diseases, pests, and weed management issues, resulting in lower yields compared to Western Europe. This investigation explores the prevalence and virulence of fungal pathogens affecting pepper cultivation in this region, specifically in Jalingo and Yola, characterized by distinct wet and dry seasons. The study employed a complete randomized design for laboratory investigations and split plots for screenhouse pathogenicity tests, taking into account different pepper cultivars. It identified five primary fungal pathogens responsible for fungal diseases: *Fusarium oxysporum*, *Colletotrichum capsici, Fusarium solani, Phoma* species, and *Aspergillus niger. Fusarium oxysporum* was the most frequently isolated fungus, comprising 91.7% of occurrences, particularly notable during seedling and maturity stages. *Colletotrichum capsici*, *Fusarium solani, Phoma* spp., and *Aspergillus niger* followed in frequency. These pathogens exhibit varying levels of virulence on pepper tissues, with fruits being more susceptible than leaves. *Fusarium solani*, notably, induces severe rot on *Capsicum annuum* fruits, with a pathogenicity level of 68.8%. This research offers valuable insights into the prevalence, virulence, and diversity of fungal pathogens affecting pepper crops in the Northern Guinea Savannah. The suggested recommendations for integrated disease management and cultivar improvement provide essential guidance for promoting sustainable pepper production in the zone.

INTRODUCTION

Pepper, recognized as the earliest spice utilized by humans, boasts archaeological evidence dating back 6000 years [1]. It is a natural source of colors and antioxidants, containing essential vitamins A, C, and E, with exceptional antiflu properties in vitamin C [2]. Besides its nutritional and medicinal benefits, pepper contributes essential flavor to enhance otherwise bland diets and serves as a crucial raw material for cosmetics and ornamental gardens [3]. Nigeria and Ghana lead West Africa in pepper production, ranking eighth and thirteenth globally [4]. Despite possessing favorable conditions, Nigeria's reported yield of 8.4 t/ha lags behind the estimated 15 t/ha in Western Europe. Production challenges, including diseases, pests, and inadequate weed management, contribute to these lower yields, particularly in northern states such as Kaduna, Kano, Katsina, Kogi, Kwara, Yobe, and Zamfara [5-7].

Globally, diseases significantly threaten pepper production, impacting the supply chain and endangering farmers' livelihoods [8]. Its pest include phytopathogenic fungi, bacteria, and viruses, and are major limiting factors for peppers worldwide [9]. Fungal diseases, including Anthracnose, Cercospora leaf spot, velvet spot,

Phytophthora blight, damping off, wilting by white rot, powdery mildew, and bacterial wilt, contribute to substantial losses [5]. Bacterial canker, bacterial soft rot, and nematodes like *Meloidogyne Incognita, Meloidogyne hapla*, and others further exacerbate issues such as root knot in pepper crops [10]. To address these challenges and identify the fungi responsible for pepper diseases in Nigeria's Northern Guinea Savannah ecological zone, this research aims to isolate and categorize the pathogens affecting pepper cultivation in this significant region.

MATERIALS AND METHODS

The Study Area

The research was conducted in Jalingo, Taraba State (**Fig. 1**), and Yola, Adamawa State (**Fig. 2**), Nigeria, covering the period from May 2019 to October 2020. These locations are situated in the Northern Guinea savannah ecological zones, known for their distinct wet and dry seasons. Geographically, they range from latitudes 8º47' to 9°19'N and longitudes 11º09' to 12°30'E. According to data sourced from the Upper Benue River Basin Development Authority [11], the wet season typically spans from late April to October, while the dry season extends from November to March. Both areas experience an annual mean rainfall of around 1,200 mm, with an average temperature of approximately 29ºC. Relative humidity varies, ranging from 60–70% in the wet season to 35–45% in the dry season. The predominant soil composition in these regions is sandy and loamy.

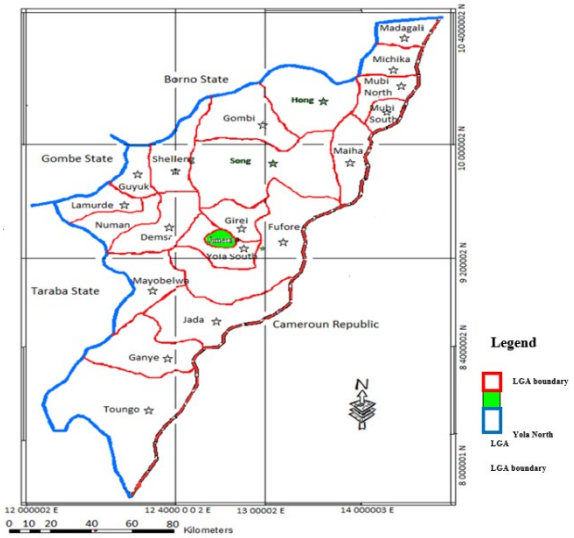

Fig. 1. Map of the Adamawa State showing study area.

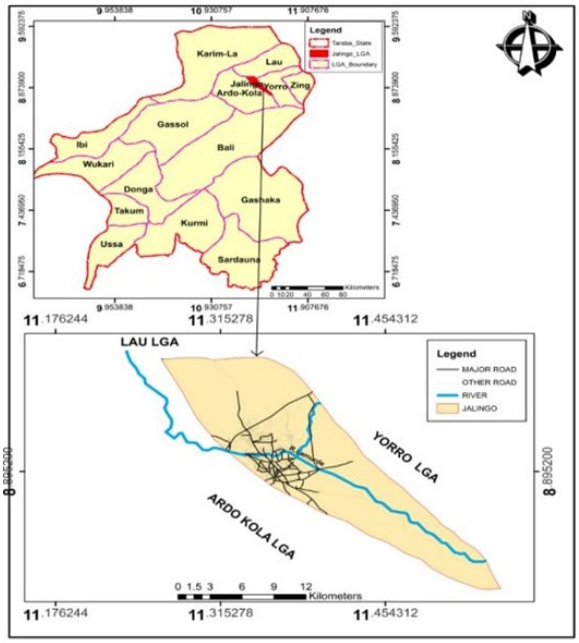

Fig. 2. Map of Jalingo showing the study area.

Experimental Design

The laboratory experimental setup utilized a complete randomized design (CRD) with three replications. Two distinct experimental designs were employed for screenhouse experiments. The first involved a Complete Randomized Design (CRD) to assess the phytotoxic activity of fungal isolates on pepper seedlings, with three replications. The second design employed split plots for conducting pathogenicity tests. This design designated main plots for fungal pathogens, while subplots were allocated for different pepper cultivars.

Table 1. Spilt-plot layout and randomization of screen house treatments for pathogenicity test.

A_1B_1	A_2B_2	A_3B_1	A_4B_2	$R15_3B_1$	A_6B_2
A_1B_3	A_2B_3	A_3B_2	A_4B_1	$R1A_5B_3$	A_6B_3
A_1B_2	A_2B_1	A_3B_3	A_4B_3	$R1A_5B_2$	A_6B_1
A_1B_3	A_2B_3	A_3B_3	A_4B_1	A_5B_3	R_6B_3
A_1B_2	A_2B_1	A_3B_2	A_4B_2	A_5B_1	R_6B_2
A_1B_1	A_2B_2	A_3B_1	A_4B_3	A_5B_2	R_6B_1
A_1B_2	A_2B_3	A_3B_2	A_4B_1	R_5B_3	A_6B_2
A_1B_1	A_2B_1	A_3B_3	A_4B_3	R_5B_2	A_6B_1
A_1B_3	A_2B_2	A_3B_1	A_4B_2	R_5B_1	A_6B_3

Main Treatments (Fungal Pathogens and Control)
A_1: *Aspergillus niger*
A_2: *Colletotrichum capsici*
A_3: *Fusarium oxysporium*
A_4: *Fusarium solani*
A_5 *Phoma spp,*
A_6 Control (Distilled water)

Sub Treatments (Pepper Cultivars)
B_1: Pepper cultivar-Atarugu (*Capsicum chinense*)
B_2: Pepper cultivar-Shambo (*Capsicum frutescense*)
B_3: Pepper cultivar-Tattaste (*Capsicum annum*)

Laboratory Investigations

Sterilization process

Petri dishes underwent sterilization in a hot air oven at a temperature of 160°C for a duration of one hour. The sterilization process for the Potato Dextrose Agar (PDA) medium, water agar medium, and water involved subjecting them to 15 pounds per square inch (psi) at a temperature of 121.6°C for 15 minutes in an autoclave. Inoculation needles and other metallic instruments were sterilized by immersing them in alcohol and then heating them over an open flame. A procedure was followed to surface sterilize plant parts and diseased materials, which included immersing them in a 0.1 percent mercuric chloride solution for 30 seconds, followed by three subsequent washes in sterilized water. The work **Table** was sterilized using 70% alcohol for 30 minutes.

Preparation of culture media

Potato Dextrose Agar (PDA) and Water Agar (WA) were employed to isolate and identify fungal pathogens. The preparation of media followed the manufacturer's guidelines, which included combining Commercial Media Powder with distilled water, autoclaving the mixture, and adding Chloramphenicol to prevent bacterial contamination.

Isolation of fungal pathogens

Pepper fruits, leaves, roots, and stems obtained from Tattase, Atarugu, and Shambo cultivars underwent surface sterilization.

Small tissue fragments were excised, treated with a mercuric chloride solution for surface sterilization, dried, and then placed onto Petri dishes containing a sterile culture medium. Soil samples were appropriately diluted and the resulting.

The solution was spread onto agar plate. The inoculated plates were incubated, and the frequency of fungal isolations was determined using the formula:

$$\% \text{ Frequency} = \frac{\text{Number of times a fungus encountered}}{\text{Total fungal isolated}} \text{x } 100$$

The maintenance of fungal isolates was carried out through the single hyphal tip method. Isolated hyphal tips were transferred to potato dextrose agar slants and preserved in the refrigerator at 4°C.

Identification of pathogens

Identification of isolated fungi relied on the evaluation of cultural and morphological characteristics, with comparisons made to standard atlases. Criteria such as colony color, growth pattern, and the formation of acervuli on Potato Dextrose Agar (PDA) were employed for the identification process.

Pathogenicity test on leaves and fruits

The pathogenicity of fungal isolates on pepper fruits and leaves was assessed following Koch's postulates, utilizing a suspension concentration of 10^6. Inoculated fruits and leaves underwent incubation, and the severity of fungal growth and pathogenicity were categorized as low, medium, high, or very high based on the degree of surface coverage. Control groups consisted of fruits and leaves inoculated with pure Potato Dextrose Agar (PDA) and distilled water. The experiment was conducted in triplicate.

In this study, the fungus was considered pathogenic on the fruit if new mycelia emerged, spreading radially and upwards from the initial inoculated disc, becoming visible beyond the original wound hole and resulting in fruit rot. For leaves, pathogenicity was identified if brown or yellow spots or lesions appeared. The assessment of growth and pathogenicity was classified as follows: low (mycelia and lesions covering less than 25% of the fruit surface), medium (26-50% coverage), high (51-75% coverage), and very high (75% and above coverage).

Frequency of Isolation of the Fungal Pathogens

In the research conducted in Jalingo and Yola, diseased pepper plants were gathered from diverse fields spanning sixteen locations. Utilizing Potato Dextrose Agar (PDA) and Water Agar (WA) media, five distinct fungi, namely *Aspergillus niger, Colletotrichum capsici, Fusarium oxysporum, Fusarium solani*, and *Phoma* species, were isolated from these plants. Identification of the fungal isolates relied on their observable traits on culture media and when examined under a light microscope.

Virulence of Pathogens

The pathogenicity of the five fungal isolates was evaluated on pepper plant tissues in both laboratory and screen house environments. The research sought to assess the harmfulness of these samples by examining how they impact the pepper plants, in controlled and semi natural environments. Works incolve sterile procedures to prevent any contamination issues arising. Pepper plant parts like leaves stems and roots were cleaned with a 1 percent solution of sodium hypochlorite followed by several washes using sterile distilled water. These parts were then placed on filter papers, in Petri dishes that had been sterilized. Each type of fungus was grown on Potato Dextrose Agar (PDA). Kept at 25 degrees Celsius for 5 to 7 days to ensure the best possible growth. Each sample of mycelium was carefully transferred to the pepper tissues using an inoculation loop, for each isolate. The tissues that received the treatment were placed in a growth chamber at 25°C with 80% humidity to replicate the conditions for fungal development. During a span of 7 to 14 days following the inoculation process the tissues were checked daily for any signs of infection like color changes, wilting or tissue death. The intensity of disease symptoms was. Ranked on a scale, from no symptoms (0) to severe symptoms (5) providing a way to measure the pathogenic nature of each strain.

For the assessment of the screen house conditions, pepper plants at the 4 5 leaf stage were chosen and planted in pots containing clean potting soil. We allowed the plants to adapt for a week to minimize any stress from transplantation. Next each type of fungus was turned into a solution by collecting spores from PDA cultures and adjusting their density to 1 x 10^6 spores, per milliliter using a hemocytometer. The spore suspensions were gently sprayed onto the pepper plants using a sprayer to make sure that the leaves, stems and the soil surface were evenly covered. Another group of plants was sprayed with water as a control measure. The plants were looked after in a protected area with temperatures that varied between 20°C and 30°C and humidity levels of 70% to 80%. The soil was watered regularly to maintain moisture levels similar to those found in natural field conditions. Signs of disease progression was closely monitored. The intensity of symptoms like leaf discoloration,wilting and stem damage was assessed using the 0 5 rating system employed in our lab trials.

Statistical Analysis

All data collected were subjected to analysis of variance (ANOVA) using Paleontological Statistics (PAST) package version 4.07 and means were separated using Fischer's Least Significant Difference (FLSD) at 5 % probability level.

RESULTS

Frequency of Isolation of the Fungal Pathogens

A total of five fungi were isolated from different parts of diseased pepper plants collected across various pepper fields in the sixteen study sites in Jalingo and Yola using Potato Dextrose Agar (PDA) and Water Agar (WA) media (**Table 2** and **Figs. 4** to **8**). The identification of fungal isolates was based on their characteristics and appearance on culture media and under a light microscope, resulting in the identification of *Aspergillus niger*, *Colletotrichum capsici*, *Fusarium oxysporum, Fusarium solani,* and *Phoma* species. The frequency of fungal isolation was presented in **Table 3**.

Fusarium oxysporum was the most frequently isolated fungus (91.7%), appearing in all examined plant parts during seedling and maturity stages, and absent only in fruits of the plants examined at the flowering stage, occurring 11 times out of a possible 12 times. *Colletotrichum* spp. were the second most frequently isolated (58.3%), with a total of 7 out of 12 isolations, followed by *Fusarium solani* (50.0%) with 6 out of 12 isolations. *Phoma* spp. (25.0%) and *A. niger* (16.7%) appeared as the least frequently isolated with 3 and 2 out of 12 isolations, respectively.

Virulence of Pathogens

The pathogenicity of the five fungal isolates was assessed on pepper plant tissues in both laboratory and screen house settings. Each isolate demonstrated varying degrees of virulence on the examined pepper tissues, exhibiting the ability to grow on the tissues and induce rot and damage, indicating their virulence. In

laboratory conditions, fruits were generally more susceptible to the fungal pathogens than the examined leaves (**Table 3**). Among the five pathogens, *Phoma* species exhibited the lowest level (3.9%) of tissue damage, indicating a low virulence effect. Mycelial growth and rots were observed primarily around the slit on the leaves of *Capsicum chinense* after 7 days of inoculation, maintaining a consistently low level across all three pepper types, except in cases of *Aspergillus niger*, where some leaves and fruits showed higher levels of damage.

The highest severity of rot (68.8%) was noted on the fruits of *Capsicum annuum* inoculated with *Fusarium solani*, indicating a high level of pathogenicity. Other fungal pathogens exhibiting high virulence levels were *Colletotrichum capsici* on fruits of *Capsicum annuum* (63.7%) and *Capsicum chinense* (59.4%) pepper types, and *Fusarium oxysporum* on *Capsicum annuum* (58.9%) pepper type only. *Capsicum frutescens* was rated as *oxysporum* on *Capsicum annuum* (58.9%) pepper type only.

Table 2. Characteristics of fungi isolated from pepper in Jalingo and Yola during 2019 rainy season.

Fungal pathogen	Cultural characteristics	Morphological characteristics
Aspergilus niger	Colonies with loose white to yellow mycelium rapidly becoming dark brown to black on the development of conidia	Conidiophores hyaline or pale brown, erect, simple, thick-walled, with foot cells,inflated at the apex forming globose vesicles, Conidia phialosporous, brown, black, globose, minutely echinulate.
Colletotrichum capsici	Initial white colonies turned to brown and grey colour with dark centre. Grey in colour with dark concentric rings Oval shape colonies, fluffy mycelium	Hyaline with both ends curved, pointed and gradually tapering towards the both ends.
Fusarium oxysporium	Colony on PDA initially with white aerial mycelium, becoming salmon, with a tendency towards violet, and a purple back.	Microconidia produced on short monophialides as a false head, mostly unicellular, oval–ellipsoid to cylindrical, from straight to curve. Macroconidia are also formed in abundance, with an attenuated apical cell and a pedicellate basal cell, with 3–5 septate, produced in short branched or unbranched monophialides or sporodochia. constant presence of chlamydospores, with a smooth wall, the most formed singly, with intercalated or terminal location.
Fusarium solani	Colony on PDA has abundant aerial mycelium, cream surface or purple–coloured with undersurface showing a dark violet color or colorless.	Identification was based on microconidia formed from lateral long monophialides, narrowing at the apex, unicellular, oval or kidney–shaped. Macroconidia were generally cylindrical almost the entire length, with 3–5 septate. Chlamydospores are formed singly or in pairs, globular or oval, with a smooth or wrinkled wall.
Phoma species	Hyphae flat; velvety with white coloration on the upper surface of the colony while on the reverse side was grayish. Measured 7cm in diameter at 5 days of incubation PDA.	The mycelium produced aseptate hyphae phialides producing pycnidia which was small in size. Round pyriform with fruiting bodies.

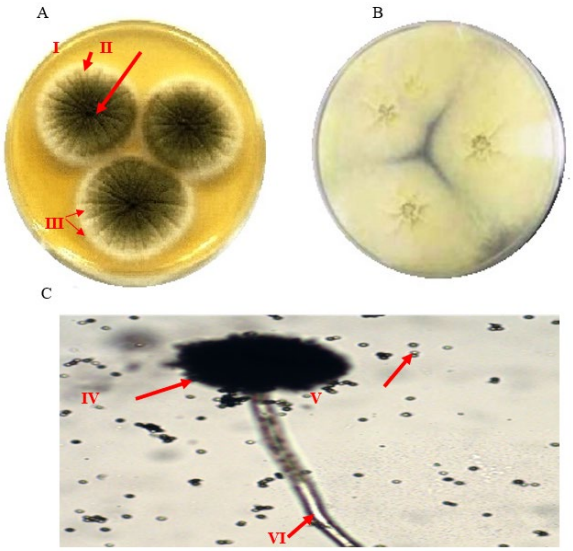

Fig. 4. Cultural and morphological characteristics of a seven-day-old *Aspergillus niger* (A-front **Fig.**, B-reverse **Fig.**, C-Conidia at x10 objective, I and II- black old and white advancing mycelia, III- typical spiral zonation, IV, V and VI- ascocarp, ascus and septate hyphae).

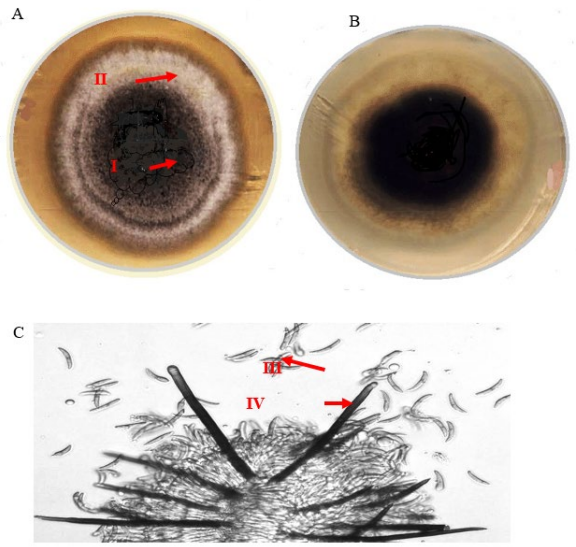

Fig. 5. Cultural and morphological characteristics of a seven-day-old *Colletotrichum capsici* (A-front **Fig.**, B-reverse **Fig.**, C-Conidia at x10 objective, I and II- grey old and white advancing mycelia, IIIandIV-Micro and macro conidia).

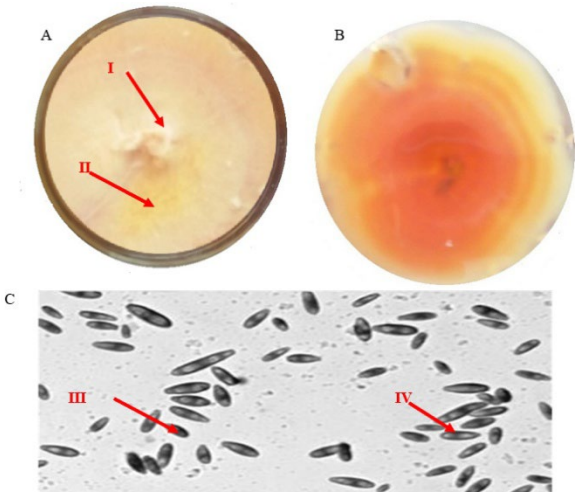

Fig. 6. Cultural and morphological characteristics of a seven-day-old *Fusarium oxysporum* (A-front **Fig.**, B-reverse **Fig.**, C-Conidia at x10 objective, I andII- Salmon old and white advancing mycelia, IIIandIV-micro and macro conidia).

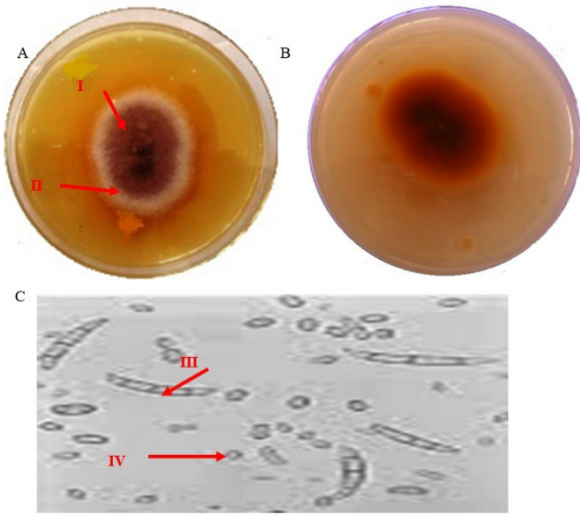

Fig. 7. Cultural and morphological characteristics of a seven-day-old *Fusarium solani* (A-front **Fig.**, B-reverse **Fig.**, C-Conidia at x10 objective, I and II- pink old and white advancing mycelia, III and IV-micro and macro conidia).

Fusarium oxysporum emerged as the most commonly isolated fungus, accounting for 91.7% of occurrences. It was present in all examined plant parts during seedling and maturity stages but was absent in fruits during flowering (**Table 3**). *Colletotrichum* spp. ranked as the second most frequently isolated (58.3%), with a total of 7 out of 12 isolations, followed by *Fusarium solani* at 50.0%, with 6 out of 12 isolations. *Phoma* spp. and A. niger had lower frequencies of isolation, accounting for 25.0% and 16.7%, respectively, with 3 and 2 out of 12 isolations. Each isolate displayed varying degrees of virulence on the tested pepper tissues, demonstrating the capability to grow on and cause damage to the tissues.

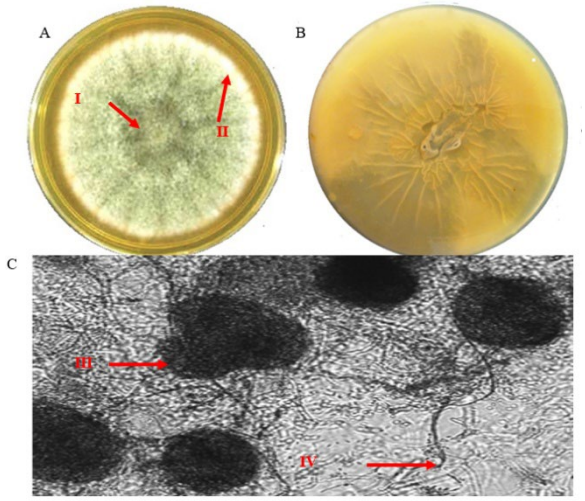

Fig. 8. Cultural and morphological characteristics of a seven-day-old *Phoma* species (A-front **Fig.**, B-reverse **Fig.**, C-Conidia at x10 objective, I and II- light green velvety old and white advancing mycelia, III andIV-Micro and macro conidia).

Table 3. Percentage frequency of fungi isolated from pepper plants at different stages of growth in Jalingo and Yola During the 2019 rainy season.

Growth stage	Seedling stage				Flowering stage				Maturity stage				Occurrence	
Isolates	PR	PS	PL	RS	PR	PS	PL	RS	PR	PS	PL	PF	Freq-uency	Perce-ntage
A. niger	×	×	×	√	×	×	×	√	×	×	×	×	2	16.7
Colletotrichum spp.	×	×	√	√	×	×	√	√	×	√	√	√	7	58.3
F. oxysporum	√	√	√	√	√	√	√	×	√	√	√	√	11	91.7
F. solani	√	√	×	√	√	×	×	×	√	√	×	×	6	50.0
Phoma spp.	√	×	×	×	×	×	×	×	√	×	×	√	3	25.0

Key: PR-Plant root, PS-Plant stem, PL-Plant leaf, PF-Plant fruit, RS-Root soil, √ = Detected, × = not detected

Capsicum frutescens was rated as having only medium tissue damage on fruits and leaves, with growth and rot covering less than 50% of the fruits and leaves surfaces.

There was no significant difference ($p < 0.05$) in the virulence of the five fungal pathogens on different pepper types, indicating a certain level of resistance. The pathogenicity test of the fungal isolates on pepper seedlings under screen house conditions revealed that all tested isolates could infect various parts of pepper plants, inducing typical symptoms of foliar and root rot in growth chamber conditions using the root dip and soil drench infestation inoculation methods. Each pathogen was evaluated based on its typical disease symptoms. Among the five pathogens, *Aspergillus niger* exhibited the least disease symptoms on the seedlings of *Capsicum chinense* pepper type (**Table 4**).

In laboratory conditions, fruits were generally more susceptible to fungal pathogens than the examined leaves. Among the five pathogens, *Phoma* species exhibited the lowest level (3.9%) of tissue damage, signifying a low virulence effect. Mycelial growth and rots were predominantly observed around the slit on the leaves of *C. chinense* after 7 days of inoculation, maintaining a consistently low level across all three pepper types, except in cases of *Aspergillus niger,* where some leaves and fruits exhibited higher levels of damage.

The highest severity of rot (68.8%) was observed on the fruits of *C. annuum* inoculated with *Fusarium solani*, indicating a high level of pathogenicity. Other fungal pathogens also exhibited high virulence. The rot symptoms appeared in less than fifty percent (49.1%) of the entire plant parts, and the pathogenic effect was rated as medium. Rots were observed only around the leaves of *Capsicum chinense* at four weeks after inoculation. Other fungal pathogens exhibited a high level of pathogenicity on this pepper variety, with symptoms covering more than fifty percent of the entire plant parts, with the highest disease severity index at 69.0% caused by *Fusarium solani*.

The most severe rot symptom (64.0%) observed on seedlings of *Capsicum annuum* varieties was in those inoculated with the spore suspensions of *Fusarium oxysporum*. The highest disease severity index was observed on the seedlings *of Capsicum annuum* inoculated with *Fusarium oxysporum*. All the pepper seedlings of the pepper variety of *Capsicum frutescens* exhibited medium pathogenicity, with the least disease severity index of 26.2% caused by spores of *Fusarium oxysporum* (**Table 5**). Again, two-way analysis of variance showed no significant difference ($p < 0.05$) in the effect of the five fungal pathogens on this pepper type, confirming the level of resistance exhibited by this variety's tissues under laboratory conditions.

Table 4. Virulence of the fungal pathogens on pepper fruits and leaves,

Fungal pathogens	Severity of fungal rot (%)					
	C. annum		*C. chinense*		*C. frutescens*	
	Fruit	Leaf	Fruit	Leaf	Fruit	Leaf
Aspergillus niger	30.3^{++}	14.4^{+}	55.1^{+++}	16.9^{+}	26.2^{++}	25.5^{++}
*Colletotricum capsici**	63.7^{+++}	18.3^{+}	59.4^{+++}	29.1^{++}	44.9^{++}	22.3^{++}
*Fusarium oxysporium**	38.7^{++}	30.8^{++}	68.8^{+++}	31.0^{++}	36.9^{++}	31.4^{++}
*Fusarium solani**	39.4^{++}	18.5^{+}	58.9^{+++}	30.9^{++}	40.7^{++}	27.3^{++}
Phoma sp	49.9^{++}	16.5^{+}	49.1^{++}	3.9^{+}	33.9^{++}	17.4^{++}
Mean	44.44	19.7	58.26	22.36	36.52	24.78
p-value	0.0619	0.3060	0.6045	0.1158	0.0318	0.4235
LSD	ns	ns	ns	Ns	16.32	Ns

Key

–	0 %	Non pathogenic
+	1– 25 %	Low
++	26 – 50 %	Medium
+++	51 – 75 %	High
++++	> 75 %	Very high

* Selected for screening experiments due to high pathogenicity.

Table 5. Virulence of the fungal pathogens on pepper seedlings.

Fungal pathogens	Mean disease severity index (%)			
	C. annum	*C. chinense*	*C. frutescens*	Mean
Aspergillus niger	38.7^{++}	49.1^{++}	36.9^{++}	41.6^{++}
*Colletotricum capsici**	30.3^{++}	51.8^{+++}	34.6^{++}	38.9^{++}
Fusarium oxysporium *	49.9^{++}	69.0^{+++}	33.9^{++}	50.9^{+++}
*Fusarium solani**	64.0^{+++}	55.1^{+++}	26.2^{++}	48.3^{++}
Phoma sp	39.4^{++}	58.9^{+++}	40.7^{++}	46.3
Mean	44.4	56.7	34.5	45.2
p-value	0.119			
LSD	ns			

Key

_	0 %	Non pathogenic
+	< 25 %	Low
++	26 – 50 %	Medium
+++	51 – 75 %	High
++++	> 75 %	Very high

* Selected for screening experiments due to high pathogenicity

DISCUSSION

Aspergillus niger, Colletotrichum capsici, Fusarium oxysporum, Fusarium solani, and *Phoma* species were common fungi isolated from diseased pepper samples collected from pepper fields across sixteen study sites in Jalingo and Yola. These fungi have been reported in various studies globally, making them important pathogens of pepper plants [5,12-15]. Among the isolates, *Fusarium oxysporum* and *Colletotrichum capsici* were the most frequently isolated fungi from diseased samples collected in the study areas, appearing in all examined plant parts. Similar studies conducted in Benue State found *Colletotrichum capsici*, *Aspergillus niger*, and *A. flavus* as the most frequently isolated fungi [16]. *Phoma* spp. were also reported on pepper seeds in that study. [12] reported the isolation of *Aspergillus niger*, *Aspergillus flavus, Colletotrichum capsici*, and *Phytophthora capsici*, with differences in frequency compared to our study. The discrepancies could be due to different plant parts used in the studies, with [12] focusing on postharvest fungal rot disease on pepper fruits, while our study investigated pre-harvest diseases of pepper.

The study confirmed the pathogenicity of the five fungal isolates on pepper plant tissues under laboratory and scree house conditions. The response to these fungal pathogens showed no significant difference among pepper types. *Fusarium solani, Colletotrichum capsici,* and *Fusarium oxysporium*, identified in the study, are economically important in causing damping off, root rot, vascular wilt, anthracnose, and fruit rots in various plants, including Solanaceae [5,12-16]. Future studies include the identification of *Fusarium* up to the species level via molecular phylogenetics [17]. Chilli crops are susceptible to several soil-borne pathogenic fungi, resulting in significant plant mortality and high losses in yield and quality globally.

CONCLUSION

The fungal pathogens identified as significant contributors to major pepper diseases in the Northern Guinea Savannah ecological zone of Nigeria include *Aspergillus niger, Colletotrichum capsici, Fusarium oxysporum, Fusarium solani*, and *Phoma* species. *Fusarium oxysporum* emerged as the most prevalent and virulent fungus isolated from various pepper plant samples collected. The study also revealed a complex of diseases at each growth stage of pepper, with variable occurrences across districts. Consequently, an integrated approach is deemed necessary for managing the diverse diseases in the region. Additionally, the selection, testing, and genetic improvement of pepper cultivars for controlling the disease-causing pathogen are recommended.

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