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Influence of varieties and growing seasons on the distribution of *Botryodiplodia theobromae* causing fruit rot disease of coconut

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ABSTRACT

This study examines an intensive field survey on the fruit rot disease of coconut that was conducted between April 2021 and March 2023 to observe the distribution of *Botryodiplodia theobromae* causing the coconut fruit rot disease across varieties and growing seasons in 2 major coconut-growing areas in Ovia North-East Local Government Area, Edo State, Nigeria. Coconut (*Cocos nucifera* L.) is an important economic crop. Its production is affected by several factors; among them, diseases play a major role. The fruit rot disease of coconut is a disease frequently encountered by coconut farmers. Fruit rot disease incidence was recorded daily from coconut fields cultivated with four different coconut varieties. The study examined a total of 8764 coconut fruits from 32 coconut palms. The causal agent of fruit rot was isolated from the internal tissues of infected fruits using the direct plating technique in potato dextrose agar. The causal agent of the disease was identified as *B. theobromae*. The study found that the relative distribution of *B. theobromae* in the study area significantly explained the proportion of the disease distribution in coconut varieties across the growing seasons. The study reveals a high level of variability in the percentage of disease incidence (PDI) between coconut varieties and fruit rot. The distribution and/or relative abundance of *B. theobromae* causing the fruit rot disease of coconut is influenced by coconut varieties and growing seasons in the two coconut-growing areas examined in the study.

Contribution/ Originality: Before now, data on fruit rot disease of coconuts was very scarce. The disease was not thought to cause significant losses to coconut growers. Therefore, the study provides intensive data on fruit rot disease of coconuts and the loss coconut growers encounter in their plantations.

1. INTRODUCTION

Globally, people cultivate the perennial coconut palm (Cocos nucifera L.) (James, 1983). Its widespread cultivation is due to the influence of humans, having been carried from place to place by explorers and immigrants (Ekhorutomwen, Udoh, & Esiegbuya, 2017). An estimated 11 million farmers grow coconut palm across 12 million hectares in 90 countries around the world (Adkins, Foale, & Samosir, 2006; FAO, 2014; Gurr et al., 2016). In Nigeria, the crop is mainly grown in southern Nigeria, and the highest concentration is found in the Badagry Local Government Area of Lagos State along the Atlantic coastline (Ojomo, Osaigie, & Udoh, 2010). Coconut serves as a

cash crop in many developing countries (Bourdeix, Konan, & N'Cho, 2005; Bourke & Harwood, 2009). Also, it is an important component in the global agricultural industry, supporting commerce and consumers worldwide (Bourke & Harwood, 2009). In Nigeria, coconut is grown mainly for food and wholly eaten raw, until recently, when it was processed on a small scale into candles, chips, flakes, etc. (Asiedu, 1989). Although coconut has been processed into so many food products, some of which, like coconut milk, are indispensable ingredients in many of the traditional cuisines of Southeast Asian countries, in South America, coconut water is mainly consumed.

Several factors, including diseases, significantly impact coconut production. Fruit rot disease of coconut is a field and storage disease of coconut (Ekhorutomwen et al., 2017). Taylor and Hyde (2003) established *Botryodiplodia theobromae* as the causal agent of the fruit rot disease of coconut. *B. theobromae* is a cosmopolitan soil-borne fungus that causes field and storage diseases of major economic and important crops (coconuts included), resulting in consequential yield losses of up to 60% (Marques et al., 2013; Punithalingam, 1980; Viana et al., 2007). The fungus has a wide host range, including gymnosperms and angiosperms, and can occur in nature as a parasite, saprophyte, or endophyte (Alves, Crous, Correia, & Phillips, 2008; Machado, Pinho, & Pereira, 2014; Slippers & Wingfield, 2007). The fungus is a threat to crops because it can live endophytically in asymptomatic plant material and avoid detection during quarantine procedures. As mentioned earlier, coconut is among those crops highly threatened by *B. theobromae*, among other pathogens. Factors that contribute to the distribution of *B. theobromae* causing fruit rot disease of coconut include host plant range determined by transmission from infected palm to susceptible healthy palm, *B. theobromae* preference for host palm, variation in transmission or infection rate, virulence of the *B. theobromae*, time of sampling, and poor agronomic practice. Information on the distribution of *B. theobromae* causing the fruit rot disease of coconut and, more importantly, the impact of the disease on the coconut value chain is very scarce. Therefore, the study aimed to determine the distribution of *B. theobromae* causing the coconut fruit rot disease across varieties and growing seasons in two major coconut-growing areas.

2. MATERIALS AND METHODS

2.1. Sampling

Sampling was done (using simple random sampling) in four quarters during the dry and rainy seasons (for twenty-four months) in two locations, namely Nigerian Institute for Oil Palm Research (NIFOR) Main Station and Coconut Garden, Isihor, in Ovia North East Local Government Area, Edo State, Nigeria.

2.2. Weather Conditions of the Study Locations

The geographic coordinates of each location or field were recorded using a hand-held global positioning system (GPS). NIFOR Main Station, Benin City, has latitude (06.33°N) and longitude (05.37°E), while Coconut Garden, Isihor, and Benin City have latitude (06.39°N) and longitude (5.61°E), respectively. The weather at both locations is subtropical and humid, with two distinct seasons: (1) the dry season, which starts around the month of October and extends up to March, and (2) the rainy season, which starts around April and extends up to September. Both seasons exhibit minor fluctuations.

2.3. Source of Coconut Fruits

Diseased coconut fruits (fruit on a bunch) showing signs of rot were collected (and recorded daily) from coconut plantations cultivated with different coconut varieties {viz., green dwarf (GD), orange dwarf (OD), yellow dwarf (YD), and red dwarf (RD), also called Sri Lanka brown) from the selected locations (preference was given to palms showing signs of fruit rot). The coconut samples collected were preserved in transparent screw-cap plastic containers for the isolation of the causal agent.

2.4. Isolation and Identification of Botryodiplodia Theobromae

Samples of diseased coconut fruit were cut into pieces using a sterile knife. Thereafter, the pieces were surface sterilized for two minutes using a 0.5% sodium hypochlorite solution and then were rinsed three times using sterile distilled water. The surface-sterilized pieces were air-dried in sterile lamina flow with the flame of a spirit lamp. Thereafter, potato dextrose agar (PDA) was prepared, sterilized with an autoclave (at 121°C for 15 minutes), and later dispensed into Petri dishes. A sterile inoculating needle was used to inoculate the dissected samples into Petri plates with PDA, and the plates were incubated at room temperature for 7 days (Phipps & Porter, 1998). The hyphal tip transfer procedure (Rangaswami, Kandasamy, & Ramasamy, 1975) yielded stock cultures of *B. theobromae*, which we maintained in tube slants of PDA at 10°C. Thereafter, isolates were subcultured in PDA medium for identification as described by the Commonwealth Mycological Institute (CMI) (Venugopal & ChandraMohanan, 2006).

2.5. Data Analysis

Data obtained from coconut fruit showing signs and symptoms of fruit rot were calculated using the percentage of disease incidence (PDI) in a Microsoft Excel worksheet.

3. RESULTS

3.1. Coconut Fruit Population in the 2021 – 2023 Growing Season

During the growing season (April 2021-March 2022), a total of 1922 coconut fruits in the coconut field at NIFOR Main Station were examined for coconut fruit rot disease, while 2238 coconut fruits in the Coconut Garden in Isihor were examined for coconut fruit rot disease. During the growing season (April 2022-March 2023), a total of 2536 coconut fruits in the coconut field at NIFOR Main Station were examined for coconut fruit rot disease, while 2068 coconut fruits in the Coconut Garden in Isihor were examined for coconut fruit rot disease (Table 1).

3.2. Coconut Fruit Rot Incidence in the 2021 – 2023 Growing Season

During the growing season (Apr 2021-Mar 2022); the percentage disease incidence (PDI) of fruit rot for both NIFOR Main Station and Coconut Garden, Isihor, was 5.7% each (Table 1). While, during the growing season (Apr 2022-Mar 2023); in NIFOR Main Station, PDI was 7.7%, while PDI was 7.2% in Coconut Garden, Isihor (Table 1).

Table 1. Coconut fruit population and fruit rot incidence in both locations and growing seasons.

Location	Growing seasons	Coconut varieties	No of coconut fruit sampled	No of fruit rot	PDI
NIFOR main station	2021-2022	GD, OD, YD, RD	1922	110	5.7
	2022-2023	GD, OD, YD, RD	2536	195	7.7
Coconut garden, Isihor	2021-2022	GD, OD, YD, RD	2238	128	5.7
	2022-2023	GD, OD, YD, RD	2068	148	7.2

Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage of disease incidence).

3.3. Coconut Varietal Fruit Population in the 2021 – 2023 Growing Seasons

During the growing season (April 2021-March 2022), at the NIFOR Main Station, a total of 638 GD, 487 OD, 422 YD, and 375 RD coconut fruits were examined for fruit rot disease, while in Coconut Garden, Isihor, 627 GD, 545 OD, 500 YD, and 566 RD coconut fruits were examined for fruit rot disease (Table 2). During the growing season (April 2022–March 2023), at the NIFOR Main Station, a total of 921 GD, 561 OD, 498 YD, and 556 RD coconut fruits were examined for fruit rot disease, while in Coconut Garden, Isihor, 547 GD, 498 OD, 529 OD, and 494 RD coconut fruits were examined for fruit rot disease (Table 2).

3.4. Incidence of Fruit Rot Across Coconut Varieties in the 2021 – 2023 Growing Seasons

During the growing season (Apr 2021-Mar 2022), at the NIFOR Main Station, the PDI of fruit rot was 7.5% GD, 5.3% OD, 4.3% YD, and 4.8% RD, while in the Coconut Garden, Isihor, the PDI of fruit rot was 7.7% GD, 5.3% OD, 4.8% YD, and 4.8% RD (Table 2). During the growing season (April 2022-March 2023), in NIFOR Main Station, the PDI of fruit rot was 7.6% GD, 8.6% OD, 8.8% YD, and 5.9% RD, while in the Coconut Garden, the PDI of fruit rot was 7.5% GD, 6.4% OD, 7.8% YD, and 6.9% RD (Table 2).

Table 2. Fruit rot incidence across coconut varieties in both locations and growing seasons.

Location	Growing seasons	Coconut varieties	No of coconut fruits sampled	No of fruit rot	PDI
NIFOR main station	2021-2022	GD	638	48	7.5
		OD	487	26	5.3
		YD	422	18	4.3
		RD	375	18	4.8
	2022-2023	GD	921	70	7.6
		OD	561	48	8.6
		YD	498	44	8.8
		RD	556	33	5.9
Coconut garden, Isihor	2021-2022	GD	627	48	7.7
		OD	545	29	5.3
		YD	500	24	4.8
		RD	566	27	4.8
	2022-2023	GD	547	41	7.5
		OD	498	32	6.4
		YD	529	41	7.8
		RD	494	34	6.9

Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage Disease Incidence).

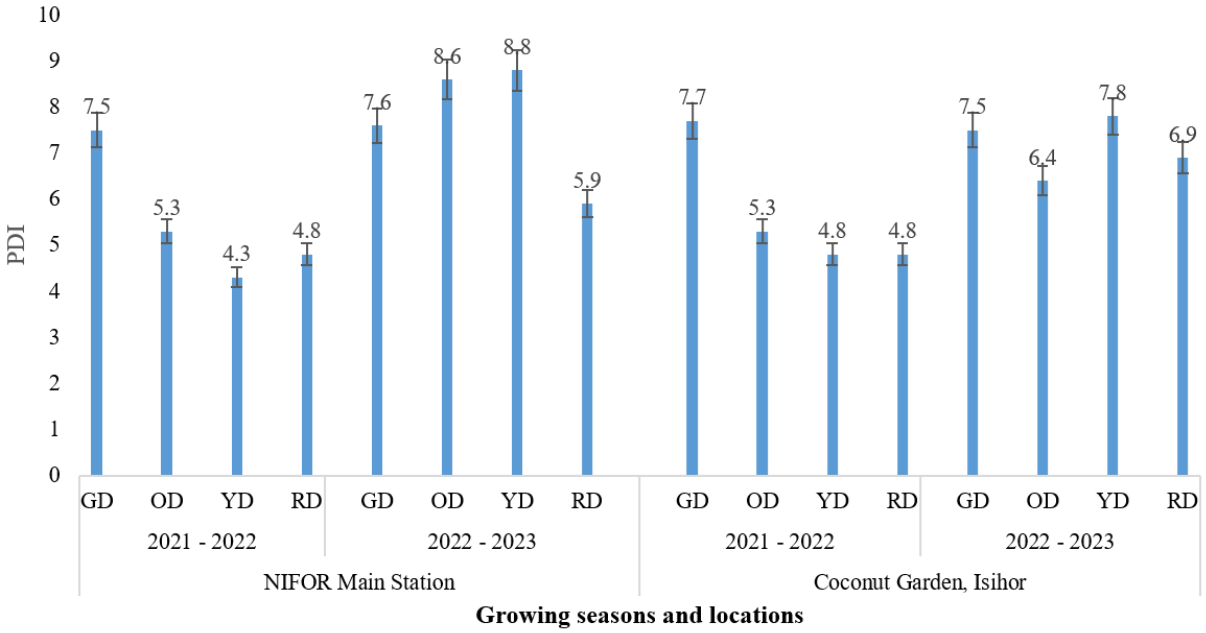

Figure 1. Percentage of disease incidence of fruit rot across coconut varieties in both locations and growing seasons.
Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf).

3.5. Fruit Rot Incidence across Coconut Varieties, with Sampling Periods (Quarters) in both Locations and Growing Seasons

During the growing season (April 2021-March 2022), in NIFOR Main Station, GD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 26.7%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 13.9%; OD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 18.4%, while the 1st quarter (Jan–Mar) also had a low PDI of

fruit rot of 2.4%; YD: the 4th quarter (Oct–Dec) had a high PDI of fruit rot of 18.3%, while in the 1st quarter (Jan–Mar) no disease incidence was recorded for fruit rot; RD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 20.7%, while in the 1st quarter (Jan–Mar) no disease incidence was recorded for fruit rot (Figure 2A). In the Coconut Garden, Isihor, GD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 31.2%, while the 1st quarter (Jan-Mar) had a low PDI of fruit rot of 7.1%; OD: the 4th quarter (Oct–Dec) had a high PDI of fruit rot of 24.9%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 6.0%; YD: the 2nd quarter (Apr-Jun) had a high PDI of fruit rot of 16.6%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 2.9%; RD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 17.8%, while the 4th quarter (Oct–Dec) had a low PDI of fruit rot of 5.0% (Figure 2B).

During the growing season (April 2022-March 2023), in NIFOR Main Station, GD: the 2nd quarter (Apr–Jun) had a high PDI of fruit rot of 33.5%, while the 4th quarter (Oct–Dec) had a low PDI of fruit rot of 9.8%; OD: the 3rd quarter (Jul–Sep) had a high PDI of fruit rot of 32.3%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 5.9%; YD: the 3rd quarter (Jul–Sep) also had a high PDI of fruit rot of 35.2%, while the 4th quarter (Oct–Dec) had a low PDI of fruit rot of 5.6%; RD: the 2nd quarter (Apr–Jun) had a high PDI of fruit rot of 28.6%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 2.4% (Figure 2A). In the Coconut Garden, Isihor, GD: the 3rd quarter (Jul-Sep) had a high PDI of fruit rot of 30.3%, while the 1st quarter (Jan-Mar) had a low PDI of fruit rot of 2.2%; OD: the 3rd quarter (Jul–Sep) also had a high PDI of fruit rot of 28.4%, while the 1st quarter (Jan–Mar) had no disease incidence recorded for fruit rot; YD: the 3rd quarter (Jul–Sep) also had a high PDI of fruit rot of 33.0%, while the 1st quarter (Jan–Mar) had a low PDI of fruit rot of 2.0%; RD: the 3rd quarter (Jul–Sep) also had a high PDI of fruit rot of 23.8%, while the 1st quarter (Jan-Mar) had a low PDI of fruit rot of 7.5% (Figure 2B).

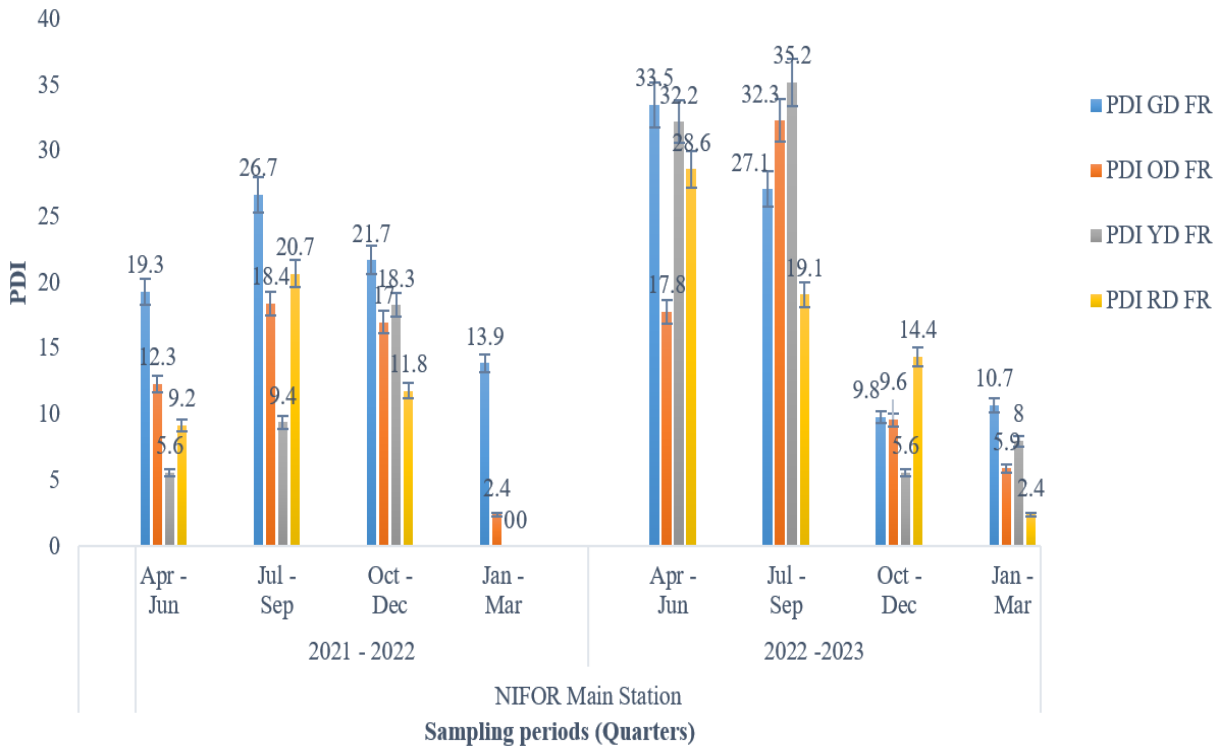

Figure 2A. Percentage of disease incidence of coconut fruit rot across varieties, growing seasons and sampling periods (quarters) in NIFOR Main Station.

Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage disease incidence).

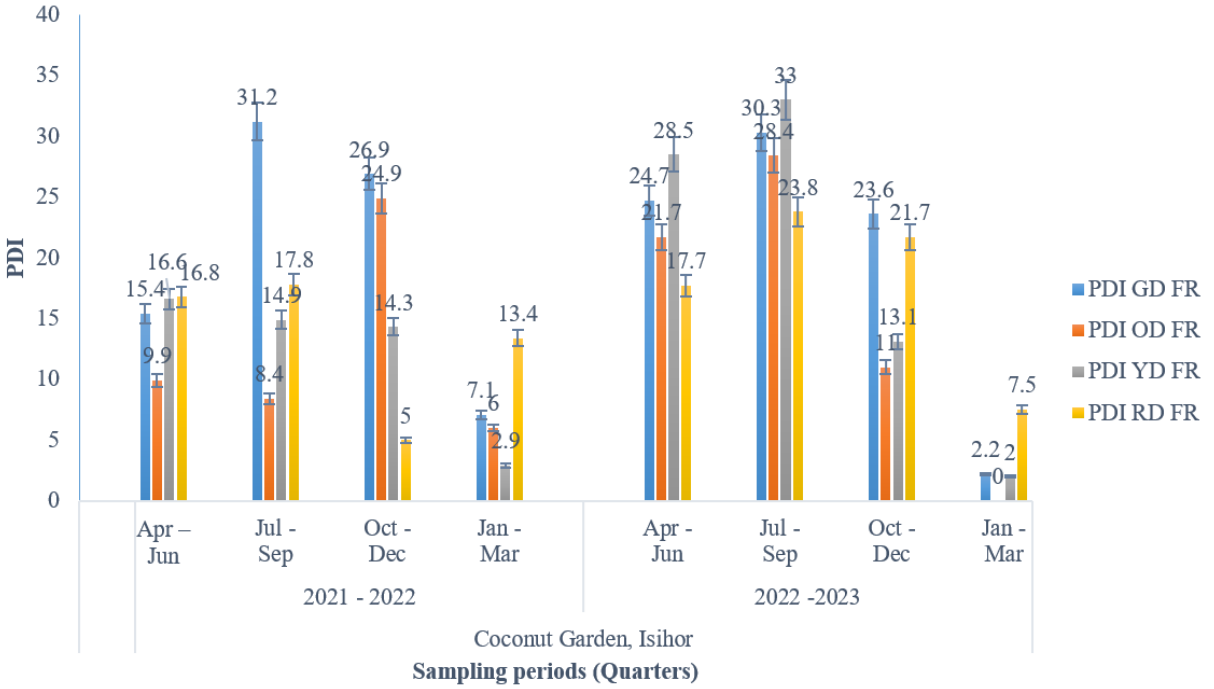

Figure 2B. Percentage of disease incidence of coconut fruit rot across varieties, growing seasons and sampling periods (quarters) in coconut Garden, Isihor.
Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage disease incidence).

3.6. Fruit Rot Incidence across Coconut Varieties with Sampling Periods (Months) in both Growing Seasons and Locations

During the growing season (April 2021-March 2022), at the NIFOR Main Station, GD: Jul had a high PDI of fruit rot of 12.5%, while in Mar, no disease incidence was recorded for fruit rot; OD: Oct had a high PDI of fruit rot of 8.3%, while in Apr, Feb, and Mar, no disease incidence was recorded for fruit rot; YD: Dec had a high PDI of fruit rot of 8.5%, while in Apr, May, Jan, Feb and Mar, no disease incidence was recorded for fruit rot; RD: Jul had a high PDI of fruit rot of 7.5%, while in May, Jan, Feb, and Mar, no disease incidence was recorded for fruit rot (Figure 3a). In the Coconut Garden, Isihor, GD: Aug had a high PDI of fruit rot of 12.2%, while in Apr and Feb no disease incidence was recorded for fruit rot; OD: Oct had a high PDI of fruit rot of 11.6%, while in Mar, no disease incidence was recorded for fruit rot; YD: Oct also had a high PDI of fruit rot of 8.9%, while in Feb and Mar, no disease incidence was recorded for fruit rot; RD: Jul had a high PDI of fruit rot of 8.3%, while in Nov, no disease incidence was recorded for fruit rot (Figure 3b).

During the growing season (April 2022-March 2022), in NIFOR Main Station, GD: May had a high PDI of fruit rot of 13.4%, while in Dec and Jan, no disease incidence was recorded for fruit rot; OD: Jul had a high PDI of fruit rot of 14.7%, while in Apr and Jan, no disease incidence was recorded for fruit rot; YD: Aug had a high PDI of FR of 13.9%, while in Nov, Dec, Jan, and Feb, no disease incidence was recorded for fruit rot; RD: May had a high PDI of fruit rot of 15.2%, while in Jan and Feb, no disease incidence was recorded for fruit rot (Figure 3a). In Coconut Garden, Isihor, GD: Sep had a high PDI of fruit rot of 11.1%, while in Jan and Mar, no disease incidence was recorded for fruit rot; OD: Jul had a high PDI of fruit rot of 12.9%, while in Jan, Feb, and Mar no disease incidence was recorded for fruit rot; YD: Jul also had a high PDI of fruit rot of 13.9%, while in Nov, Feb, and Mar, no disease incidence was recorded for fruit rot; RD: Jun also had a high PDI of fruit rot of 10.4%, while in Apr and Feb, no disease incidence was recorded for fruit rot (Figure 3b).

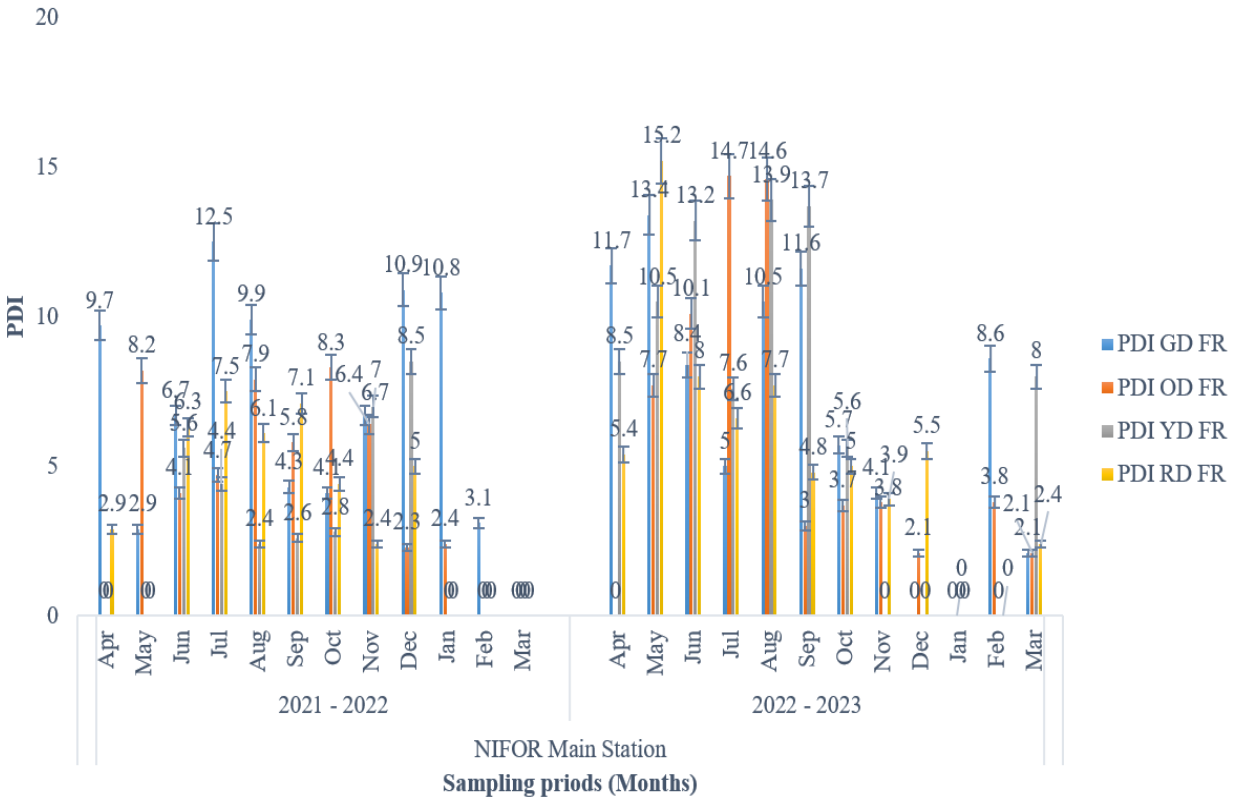

Figure 3A. Percentage of disease incidence of coconut fruit rot across varieties, growing seasons and sampling periods (months) in NIFOR Main Station.

Note: 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage disease incidence).

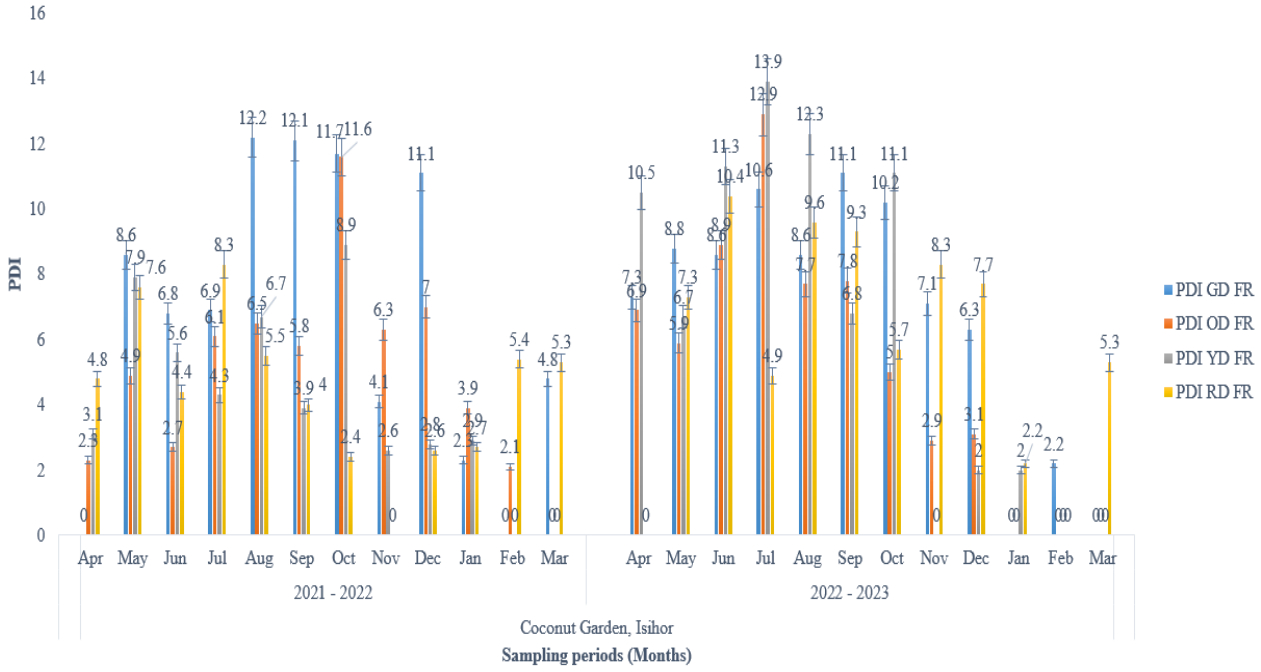

Figure 3B. Percentage of disease incidence of coconut fruit rot across varieties, growing seasons and sampling periods (months) in Coconut Garden, Isihor.

Note 1GD (Green Dwarf), OD (Orange Dwarf), YD (Yellow Dwarf), RD (Red Dwarf), PDI (Percentage Disease Incidence).

Table 3. Coconut fruit rot of different ages (sizes) in the two study locations.

Location	Fruit ages (Sizes)	No of fruit rot samples	FR yielding fungi		FR not yielding fungi	
			No	%	No	%
NIFOR main station	1 month-old (Button nut)	76	76	100.00	0	0.00
	2-3 month-old (Fistula nut)	192	192	100.00	0	0.00
	4-7 month-old (Tender nut)	31	31	100.00	0	0.00
	8-12 month-old (Mature nut)	6	6	100.00	0	0.00
	Total	305	305	100.00	0	0.00
Coconut Garden, Isihor	1 month-old (Button nut)	41	41	100.00	0	0.00
	2-3 month-old (Fistula nut)	202	202	100.00	0	0.00
	4-7 month-old (Tender nut)	25	25	100.00	0	0.00
	8-12 month-old (Mature nut)	8	8	100.00	0	0.00
	Total	276	276	100.00	0	0.00
	Grand total	581	581	100.00	0	0.00

Note: Key: FR (Fruit rot).

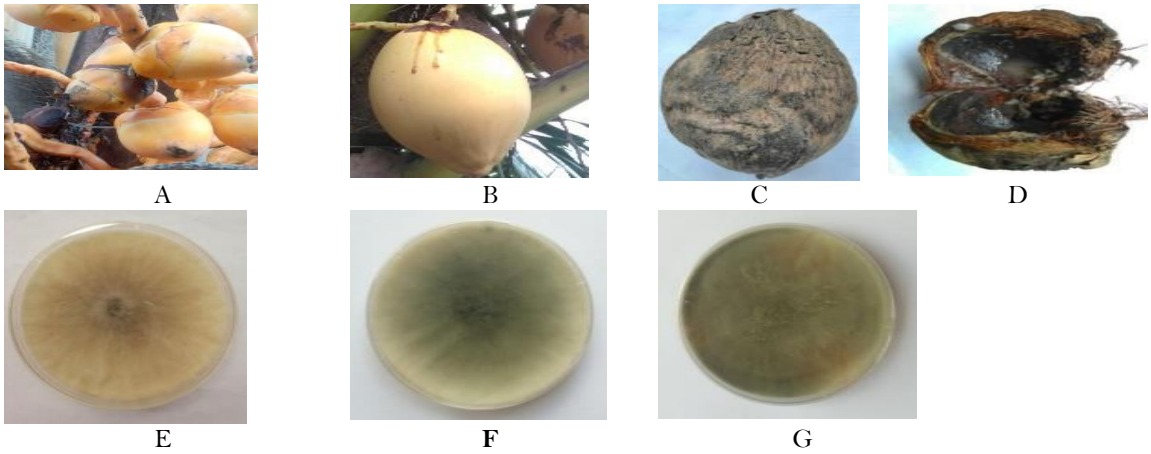

Figure 4. A. Bottom nuts ODC with rot disease, B: Tender nut ODC with liquid exudates (water oozing), C: Mature nut ODC affected with rot disease (100% severity), D: Dissection of mature ODC showing rot covering the entire endosperm, E: A 3-day-old *B. theobromae* isolated from ODC after first-fold subculture with dull white color, F: 5-day-old *B. theobromae* isolated from ODC after first-fold subculture with greyish-white color, G: 7-day-old *B. theobromae* isolated from ODC after first-fold subculture with greyish-color.

Note: ODC: Orange dwarf coconut.

4. DISCUSSION

Previous studies on the fruit rot disease of coconut were based on post-harvest disease (Dasgupta & Mandal, 1989; Dheepa et al., 2018; EI -Ghaouth & Wilson, 1995; Venugopal & ChandraMohanan, 2006). In Nigeria, to the best of my knowledge, the study provides the first report on the pre-harvest (field) disease of coconut fruit, as well as the distribution of B. theobromae responsible for the fruit rot disease of coconut. In the study, field data of fruit rot was documented in 2 locations (namely, NIFOR main Station and Coconut Garden, Isihor) in Ovia North East Local Government Area, Edo State, Nigeria. The study was necessary to determine if the distribution of *B. theobromae* responsible for the coconut fruit rot disease varies over time in the two coconut-growing areas. The pathogen responsible for this disease was isolated from the internal tissues of the diseased samples collected during the study and was identified as *B. theobromae*. *B. theobromae* enters into the coconut fruit through a crack on the surface of the fruit or through the spikelet or from point of attachment of the fruit to the spikelet and spreads through the endocarp and endosperm and gradually spreads outwardly towards the mesocarp, causing severe damage to the fruit (Ekhorutomwen, Udoh, & Omoregie, 2019). Early signs and symptoms of the disease appear as light or dark brown lesions turning into whitish-grey color with a shriveled appearance (Dheepa et al., 2018; Venugopal & ChandraMohanan, 2006). The infected fruit later turns blackish with cracks at the basal part of the fruit (Figure A-E) causing the fruit to fall off from the bunch before maturity or harvesting, called premature nut fall (Venugopal & ChandraMohanan, 2006). Liquid exudates (water oozing) might appear on the affected fruit

(Figure 4: D). As mentioned earlier, the study reveals the distribution of *B. theobromae* causing the coconut fruit rot disease across coconut varieties and growing seasons in two locations (Table 1). The percentage disease incidence (PDI) of coconut fruit rot in the growing seasons varies from 5.7 to 7.7% in both locations (Table 1). The PDI in the 2021-2022 growing season was the same for both location, while the PDI in the 2022-2023 growing season was higher in NIFOR Main Station (7.7%) than in Coconut Garden, Isihor (7.2%). In both locations, the PDI was higher in the 2022-2023 growing season than in the 2021-2022 growing season, respectively (Table 1). In addition, in NIFOR Main Station, the result reveals that as the coconut fruit population increases from 1922 (2021-2022 growing season) to 2536 (2022-2023 growing season), coconut fruit rot increases from 110 to 195 (representing a 2% increase); in Coconut Garden, Isihor, the coconut fruit population decreases from 2238 (2021-2022 growing season) to 2068 (2022-2023 growing season) while the coconut fruit rot increases (representing a 1.5% increase). This indicates that the spread of *B. theobromae*, which causes coconut fruit rot, was affected by an increase in the population of coconut fruit at NIFOR Main Station. In Coconut Garden, Isihor, a slight decrease in the population of coconut fruits contributed to the incidence of *B. theobromae*, which causes coconut fruit rot. The PDI of fruit rot disease in coconut indicates significant variability both within and between two locations throughout the growing seasons. The findings of Venugopal and ChandraMohanan (2006) and Dheepa et al. (2018) are in line with this current study, where *B. theobromae* causes the fruit rot disease of coconuts to spread across different locations.

The PDI of coconut varieties to the fruit rot in the 2021-2023 growing season and in both locations varies from 4.3 to 8.8% (Table 2). In both locations, the GD coconut has a high PDI of 7.5 and 7.7%, while the RD and YD coconut has a low PDI of 4.8 and 4.3% in the 2021-2022 growing, respectively (Table 2). But during the 2022-2023 growing season, the OD and YD coconuts have a high PDI of 8.6 and 8.8%, while the RD and OD coconuts have low PDIs of 5.9 and 6.4%, respectively (Table 2). The PDI of coconut varieties to the fruit rot reveals that there is a high level of variability of the disease across the coconut varieties in both growing seasons and locations. In addition, the distribution of *B. theobromae* causing the coconut fruit rot across the sampling period (quarter) in both growing seasons and locations varies from 2.0 to 35.2%. During the 2021-2022 growing season, in both locations, the GD coconut has the highest PDI of 26.7 and 31.2%, respectively, in the 3rd quarter (Jul–Sep), while in the 1st quarter (Jan–Mar), no disease incidence was recorded in NIFOR Main Station for both YD and RD. But during the growing season 2022-2023, in both locations, the YD coconut has a high PDI of 33.0 and 35.2% in the 3rd quarter (Jul-Sep), while no disease incidence was recorded for OD coconut in the 1st quarter (Jan–Mar) in Coconut Garden, Isihor) (Figures 2A and B). This study also reveals that there is a high level of variability in the disease distribution across the growing seasons and sampling periods (quarters) within and between the locations.

More so, the distribution of *B. theobromae* responsible for the coconut fruit rot across the sampling period (month) in both locations and growing seasons varies from 2.0 to 15.2%. In NIFOR Main Station, the GD has a high PDI of 12.5% in July during the 2021-2022 growing season, while the RD coconut has a high PDI of 15.2% in May during the 2022-2023 growing season (Figure 3A). In Coconut Garden, Isihor, the GD coconut has a high PDI of 12.2% in August during the 2021-2022 growing season, while the YD coconut has a high PDI of 13.9% in July during the 2022-2023 growing season (Figure 3B). The result from the study also reveals that there is a high level of variability of the disease across the growing seasons and sampling periods (months) in both locations. In addition, in both locations, among the fruit ages (sizes), the fistula size (2–3 month-old nuts) is most affected by rot, while the mature size (10–12 month-old nuts) is less affected by rot (Table 3). Furthermore, in both locations, fungi were isolated from all coconut fruits showing signs and symptoms of fruit rot, and the fungus was identified through cultural and molecular means as *B. theobromae*. This suggests that *B. theobromae* is the cause of the coconut fruit rot disease.

5. CONCLUSION

The distribution and/or relative abundance of *B. theobromae* causing the fruit rot disease of coconut was influenced by coconut varieties and growing seasons in the coconut-growing areas examined in this study. This study revealed a high level of variability in the PDI of both within and between both locations, growing seasons, sampling periods, and coconut varieties. The results of this study will help provide a guide for proper control of the fruit rot disease of coconut.

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