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Modeling the impact of some weather factors on the prevalence of fruit rot and premature nut fall diseases of coconut

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ABSTRACT

Coconut (*Cocos nucifera* L.) provides a staple food and serves as a cash crop in many developing countries. Also, it provides a tremendous foreign exchange to producer countries across the world. Its production is mainly affected by climate, soil, and diseases. Climate change threatens crop production, both directly through changes in crop growth and yield, and indirectly through the development of diseases, pests, and weeds in crops. The aim of the study was to determine the impact of some weather factor on the prevalence of fruit rot and premature nut fall diseases of coconut. In the study, data on fruit rot and premature nut fall diseases of coconut (classified as dependent variables), and some weather factor data (temperature, rainfall, and relative humidity: Classified as independent variables) were collected daily from two locations across two growing seasons in four varieties of coconut. Regression analysis was used to study the impact of temperature, rainfall and relative humidity on the percentage of disease incidence (PDI) of fruit rot and premature nut fall diseases of coconut. The results from the regression analysis on the impact of the independent variables on the dependent variables (PDI of fruit rot and premature nut fall diseases of coconut) show that, when the R2 (coefficient of variation) value is equal to or above 0.5, it suggests that the independent variables were highly regressive on the dependent variables. When the R2 value is below 0.5, it suggests that the independent variables were not regressive on the dependent variables. More so, the findings from the study reveals that weather factors like temperature, rainfall, and humidity significantly influence the PDI of fruit rot and premature nut fall diseases in coconut varieties.

Keywords: Weather factors, variables, varieties, percentage of disease incidence, regression analysis.

1. INTRODUCTION

Farmers worldwide combat an endless war against several pathogens, pests, and weeds. The spread of these organisms are promoted by international trade and transport, but there is growing concern that climate change could also enhance disease risk (Chaloner et al., 2021). Because coconut (*Cocos nucifera* L.) provides a staple food and serves as a cash crop in many developing countries, providing a tremendous foreign exchange to producer countries across the world Bourke and Harwood, (2009), its production, is mainly affected by climate, soil, and diseases (Ekhorutomwen et al., 2019). Climate change threatens crop both directly through changes in plant growth and production, and indirectly through impacts on crop diseases, pests, and weeds (Balasubramanian, 2018; Velásquez et al., 2018; Newbery et al., 2016). Climate change impacts will differ between crops, diseases and geographic locations, with disease severity increasing in crop-producing areas or decreasing in others (Newbery et al., 2016).

Climate change at the global level has resulted in increased temperature, rainfall, and other climatic extremes such as drought, floods, and storms (Piñeiro et al., 2010; Galant et al., 2012). More so, little effort has made to ascertain the impact that these forecasted weather conditions, specifically increased temperature, rainfall and relative humidity will have on plant pathogen-host interactions (Gallana et al., 2013; Eastburn et al., 2011). A plant disease can result from the interaction between a susceptible host plant, a virulent pathogen, and the environment (Elad and Pertot, 2014). Because the environment significantly, directly or indirectly, influences plants, pathogens, and their antagonists, changes in environmental conditions are strongly associated with differences in the level of losses caused by a disease, and environmental changes result in the emergence of new diseases (Elad and Pertot, 2014).

For these reasons, the changes associated with global warming (that is, increased temperatures, rainfall, and humidity, increased CO2 and ozone levels, drought, etc.) may affect the incidence and severity of plant disease and influence the further coevolution of plants and their pathogens (Eastburn et al., 2011; Crowl et al., 2008; Burdon et al., 2006; Garrett et al., 2006; Chakraborty, 2005). Furthermore, plant diseases are affected by weather conditions and each disease has specific weather requirements for infection to occur (Hardwick, 2002). Weather factors, therefore, play a significant part in the initiation of disease, and for each pathogen to cause a disease, hence, needs optimum weather requirements for infection (Velásquez et al., 2018; Hardwick, 2002). Pathogens are mostly spread by wind and rain but those that are transmitted by vectors would be dependent on conditions suitable for them.

Some spores are released under drying conditions or in films of water arising from rain or dew on the leaf surface. High humidity, or the presence of free water on a leaf surface, is required to initiate the infection process in plant pathogen (Hardwick, 2002). Temperature will speed or slow the infection process and disease development in plants (Hardwick, 2002). An understanding of weather and the pathogen allows pathologists to produce forecasts of potential disease epidemics. Because observational data on pathogen impacts on crops are scarce, leaving researchers to infer climate change effects from biased and incomplete data sets, which have often been collected for other purposes (Bebber et al., 2019).

Hence, the study was carried out to correct such anomaly, by providing sufficient data from the fruit rot and premature nut fall diseases of coconut, and correlate it with some weather factor data (in coconut-producing areas). More so, in coconut production, less than one-third of the button nuts produced in an inflorescence eventually develop into mature nuts, that is, as a result of fruit rot and premature nut fall diseases caused by *Botryodiplodia theobromae* (Dheepa et al., 2018; Rajapakse et al., 1995). This manuscript provides information on impact of some weather factors on fruit rot and premature nut fall diseases of coconut in two major coconut-producing areas in Ovia North East Local Government Area, Edo State, Nigeria.

2. MATERIALS AND METHODS

Study Location

Two locations in Ovia North East Local Government Area, Edo State, Nigeria were used to collect data during the course of the study. The locations include: (1) Nigerian Institute for Oil Palm Research (NIFOR) Main Station, and (2) Coconut Garden, Isihor.

Weather Conditions of the Chosen Locations

Geographic coordinates of each location/field were ascertained using a hand-held global positioning system (GPS). NIFOR Main Station has latitude (06.33ºN) and longitude (05.37ºE), while Coconut Garden, Isihor has latitude (06.39ºN) and longitude (5.61ºE) respectively. Both location climate is subtropical humid and the entire year is classified into two distinct seasons viz., (1) dry (summer) season, which starts around October and extends up to March, (2) rainy (wet) season, which starts around April and extends up to September. However, there is slight variability in both seasons.

Collection of Data on Fruit Rot and Premature Nut Fall Diseases of Coconut

Diseased coconut fruits showing signs of rot and freshly fallen nuts were recorded from coconut plantations in the 2 study locations. Preference was given to palms showing signs and symptoms of fruit rot and premature nut fall (and were classified as dependent variables in this study). The coconut varieties used in this study include: Green dwarf (GD), orange dwarf (OD), yellow dwarf (YD), and red dwarf (RD), also called Sri Lanka brown. The mean value of each of the variables were used in the study.

Collection Data on Some Weather Factors

Temperature, rainfall, and relative humidity data were recorded with the aid of thermometer, rain gauge and hygrometer respectively. These data were classified as independent variables. The mean value of each of the variables were used in the study.

Isolation and Identification of *Botryodiplodia theobromae*

Mature and immature coconut fruit samples showing signs of rot and freshly fallen nuts were taken to the laboratory to isolate the causal organism. Infected tissues were cut into pieces with a sterile knife from the edge of the lesion. The pieces were surface-sterilized with 0.5% sodium hypochlorite (NaOCl) solution for 2 minutes and washed in three changes of sterile distilled water. The surface sterilized pieces were air-dried in sterile lamina flow with the flame of a spirit lamp. After that, it was plated on sterilized PDA in a 9 cm Petri dish, and incubated at 28±2ºC for 7 days. Stock cultures of *B. theobromae* were obtained using the hyphal tip transfer procedure Rangaswami et al., (1975) and maintained in tube slants of PDA at 10ºC. In addition, isolates were sub-cultured into appropriate growth medium for identification as described by the Commonwealth Mycological Institute (CMI) (Venugopal and Chandra-Mohanan, 2006; Dheepa et al., 2018).

Statistical Analysis

Regression analysis (in SPSS version 26) was used to determine the relationship between the value of temperature, rainfall, and relative humidity data (independent variables) against the percentage disease incidence (PDI) of fruit rot and premature nut fall data (dependent variables).

3. RESULTS

Botryodiplodia theobromae was identified to be the pathogen responsible for fruit rot and premature nut fall diseases of coconut (Dheepa et al., 2018; Venugopal and Chandra-Mohanan, 2006). Table 1 shows the results of the mean values of the PDI of dependent variables of fruit rot and independent variables (temperature, rainfall, and relative humidity). In contrast, Table 2 shows the model summary of independent variables against dependent variables. Table 3 shows the mean values of the PDI of dependent variables (premature nut fall) and independent variables (temperature, rainfall, and relative humidity). In contrast, Table 4 shows the model summary of independent variables vs dependent variables.

Table 1 Mean Values of Percentage of Disease Incidence of Fruit Rot and Independent Variables.

Locations	Growing seasons	GD PDI FR	OD PDI FR	YD PDI FR	RD PDI FR	TEMP.	RAINFALL	RH
		Σ value						
NIFOR Main Station	2021 – 2022	81.6	50.1	33.3	329.1	329.1	1849.8	911.3
Coconut Garden, Isihor		80.6	59.2	48.7	53			
		$\bar{x}$ value						
NIFOR Main Station		6.8	4.2	2.8	3.5	27.4	154.2	75.9
Coconut Garden, Isihor		6.7	4.9	4.1	4.4			

		Σ value						
NIFOR Main Station	2022 – 2023	81.1	65.6	81	64.5	328.9	2476.3	898.8
Coconut Garden, Isihor		80.8	61.1	76.6	70.7			
		x̄ value						
NIFOR Main Station		6.8	5.5	6.8	5.4	27.4	206.4	74.9
Coconut Garden, Isihor		6.7	5.1	6.4	5.9			

Key: Independent variables {tempt. (temperature), rainfall, RH (relative humidity)}, Dependent variables {FR (fruit rot)}, GD (green dwarf), OD (orange dwarf), YD (yellow dwarf), RD (red dwarf), PDI (percentage of disease incidence).

Table 2 Model Summary of Independent Variables against the Percentage of Disease Incidence of Fruit Rot.

Location	**Growing seasons**	**Variables**	**R2**	**Independent variables sig.**	**ANOVA sig.**
NIFOR Main Station	2021 – 2022	Independent variables vs GD PDI FR	0.863	T=0.022, R=0.347, RH=0.136	0.022
		Independent variables vs OD PDI FR	0.564	T=0.032, R=0.409, RH=0.267	0.072
		Independent variables vs YD PDI FR	0.557	T=0.703, R=0.052, RH=0.014	0.076
		Independent variables vs RD PDI FR	0.604	T=0.084, R=0.109, RH=0.274	0.050
Coconut Garden, Isihor		Independent variables vs GD PDI FR	0.49	T=0.310, R=0.644, RH=0.489	0.128
		Independent variables vs OD PDI FR	0.704	T=0.080, R=0.043, RH=0.222	0.016
		Independent variables vs YD PDI FR	0.499	T=0.437, R=0.508, RH=0.278	0.120
		Independent variables vs RD PDI FR	0.064	T=0.528, R=0.710, RH=0.642	0.906
NIFOR Main Station	2022 – 2023	Independent variables vs GD PDI FR	0.349	T=0.926, R=0.683, RH=0.535	0.304
		Independent variables vs OD PDI FR	0.499	T=0.107, R=0.602, RH=0.357	0.119
		Independent variables vs YD PDI FR	0.864	T=0.041, R=0.046, RH=0.513	0.001
		Independent variables vs RD PDI FR	0.511	T=0.528, R=0.421, RH=0.403	0.150
Coconut Garden, Isihor		Independent variables vs GD PDI FR	0.860	T=0.296, R=0.060, RH=0.003	0.001
		Independent variables vs OD PDI FR	0.719	T=0.645, R=0.998, RH=0.258	0.013
		Independent variables vs YD PDI FR	0.696	T=0.905, R=0.460, RH=0.298	0.018

		Independent variables vs RD PDI FR	0.391	T=0.514, R=0.544, RH=0.695	0.242

Key: Dependent variables (T: temperature, R: rainfall, RH: relative humidity), independent variables {FR (fruit rot)}, GD (green dwarf), OD (orange dwarf), YD (yellow dwarf), RD (red dwarf), PDI (percentage of disease incidence), R2 (coefficient of variation); Sig (Significant): 5% probability level.

Table 3 Mean Values of Percentage of Disease Incidence of Premature Nut Fall and Independent Variables.

Location	**Growing seasons**	**GD PDI PNF**	**OD PDI PNF**	**YD PDI PNF**	**RD PDI PNF**	**TEMP.**	**RAINFALL**	**RH**
		Σ value						
NIFOR Main Station	2021 – 2022	108.7	65.6	49.3	62.1	329.1	1849.8	911.3
Coconut Garden, Isihor		63.7	69.5	50.8	66.9			
		x̄ value						
NIFOR Main Station		9.1	5.5	4.1	5.2	27.4	154.2	76.0
Coconut Garden, Isihor		5.3	5.8	4.2	5.6			
		Σ value						
NIFOR Main Station	2022 – 2023	105.7	94.5	73.5	77.7	328.9	2476.3	898.8
Coconut Garden, Isihor		89	65.4	47.5	48.4			
		x̄ value						
NIFOR Main Station		8.8	7.9	6.1	6.5	27.4	206.4	74.9
Coconut Garden, Isihor		7.4	5.5	4.0	4.0			

Key: Independent variables {tempt. (temperature), rainfall, RH (relative humidity)}, dependent variables {PNF (premature nut fall)}, GD (green dwarf), OD (orange dwarf), YD (yellow dwarf), RD (red dwarf), PDI (percentage of disease incidence).

Table 4 Model Summary of Independent Variables against Percentage of Disease Incidence of Premature Nut Fall.

Locations	**Growing seasons**	**Variables**	**R2**	**Independent variables sig.**	**ANOVA sig.**
NIFOR Main Station	2021 – 2022	Independent variables vs GD PDI PNF	0.829	T=0.440, R=0.641, RH=0.050	0.002
		Independent variables vs OD PDI PNF	0.519	T=0.430, R=0.514, RH=0.318	0.103
		Independent variables vs YD PDI PNF	0.301	T=0.195, R=0.786, RH=0.235	0.388
		Independent variables vs RD PDI PNF	0.526	T=0.599, R=0.991, RH=0.205	0.097
Coconut Garden, Isihor		Independent variables vs GD PDI PNF	0.707	T=0.298, R=0.405, RH=0.590	0.016
		Independent variables vs	0.769	T=0.098, R=0.814, RH=0.428	0.006

		OD PDI PNF			
		Independent variables vs YD PDI PNF	0.789	T=0.249, R=0.774, RH=0.229	0.004
		Independent variables vs RD PDI PNF	0.278	T=0.711, R=0.946, RH=0.710	0.430
NIFOR Main Station	2022 – 2023	Independent variables vs GD PDI PNF	0.509	T=0.490, R=0.498, RH=0.929	0.111
		Independent variables vs OD PDI PNF	0.812	T=0.002, R=0.813, RH=0.023	0.003
		Independent variables vs YD PDI PNF	0.752	T=0.104, R=0.997, RH=0.924	0.008
		Independent variables vs RD PDI PNF	0.650	T=0.058, R=0.940, RH=0.503	0.031
Coconut Garden, Isihor		Independent variables vs GD PDI PNF	0.779	T=0.418, R=0.193, RH=0.141	0.005
		Independent variables vs OD PDI PNF	0.838	T=0.026, R=0.086, RH=0.691	0.002
		Independent variables vs YD PDI PNF	0.795	T=0.048, R=0.114, RH=0.692	0.004
		Independent variables vs RD PDI PNF	0.793	T=0.030, R=0.052, RH=0.848	0.004

Key: Dependent variables (T: temperature, R: rainfall, RH: relative humidity), independent variables {PNF (premature nut fall)}, GD (green dwarf), OD (orange dwarf), YD (yellow dwarf), RD (red dwarf), PDI (percentage of disease incidence), R2 (coefficient variation); Sig (Significant): 5% probability level.

4. DISCUSSION

Necrotrophic fungi that are pathogenic to plants obtain nutrients from dead plant tissues and are affected by the active metabolism of host plant cells Kumar et al., (2017), while biotrophic fungi derive their nutrients from living plant cells and have deep and prolonged physiological interactions with their host plant. Therefore, extreme weather events such as high or low temperatures that promote death of the plant tissues, may favour infection by necrotrophic pathogens. Also, weather factors that affect the growth of plants, such as increased temperature or drought, may cause changes in the physiology of a host plant species that will profoundly alter the colonization of the host tissues by biotrophic pathogens (Kumar et al., 2017).

Climate change (results in extreme weather conditions such as high or low temperatures, solar radiation, drought, wind, rainfall, flood, relative humidity, etc.) may directly affect several aspects of the biology of host plants, including their phenology (senescence), sugar and starch contents, nitrogen and phenolic contents, root and shoot biomass, number and size of leaves, amount and composition of wax on leaves, changes in stomatal densities, conductance, and root exudation (Asselbergh et al., 2008). Any change of these areas may influence infection and colonization by pathogens. For example, after infection, host plant water potentials and nutritional content may affect the rate of colonization of host tissues, the production of new inoculums and the expression of symptoms in the host (Asselbergh et al., 2008).

Drought and temperature stress been shown to negatively affect a plant's ability to respond to biotic stresses through changes in endogenous abscisic acid levels that affect defense responses involving salicylic acid, jasmonic acid, or ethylene (Asselbergh et al., 2008). Rainfall and relative humidity have shown to either resuscitate (spores) or initiate the infection process of the pathogen (Hardwick, 2002). As mentioned earlier, weather factors play a significant role in initiating disease, and each pathogen has its optimum weather requirements for infection (Hardwick, 2002). In this study, regression analysis is used to determine the impact of some weather factors (temperature, rainfall, and relative humidity) on the prevalence of fruit rot and premature nut fall diseases of coconut.

As earlier mentioned, in the study, temperature, rainfall, and relative humidity data were classified as independent variables. In contrast, the fruit rot and premature nut fall diseases data were classified as dependent variables. In addition, when the R2 (coefficient of variation) value is equal to or above 0.5, it suggests that the independent variables were highly regressive on the dependent variables. When the R2 value is below 0.5, it suggests that the independent variables were not regressive on the dependent variables. Also, when the level of significance of each of the independent variables is equal to or above 0.05, it suggests that the independent variable immensely contributed to the variation observed on the effect of independent variables on the dependent variables. In contrast, when the level of significance of each of the independent variables is less than 0.05, it suggests that the independent variable did not contributed to the variation observed on the effect of independent variables on the dependent variables.

For fruit rot disease of coconut during the 2021 – 2022 growing season in NIFOR Main Station, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of fruit rot in GD, OD, YD, and RD coconuts were significant. It suggest that the three independent variables (temperature, rainfall, and relative humidity) were highly regressive on the PDI of fruit rot in GD, OD, YD, and RD coconuts. Furthermore, rainfall and relative humidity immensely contributed to the variation observed in the PDI of fruit rot in GD and OD coconuts, temperature and rainfall immensely contributed to the variation observed in the PDI of fruit rot in YD coconut. In contrast, the three independent variables (temperature, rainfall, and relative humidity) immensely contributed to the variation observed in the PDI of fruit rot in RD coconut (Table 2).

During the 2021 – 2022 growing season in the Coconut Garden, Isihor, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of fruit rot in OD coconut were highly regressive (but the R2 value was not regressive on the PDI of fruit rot in GD, YD, and RD coconuts), as the three independent variables (temperature, rainfall and relative humidity) immensely contributed to the variation observed in the PDI of fruit rot in OD coconut (Table 2). During the 2022 – 2023 growing season in NIFOR Main Station, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of fruit rot in YD and RD coconuts were highly regressive (but R2 value was not regressive on the PDI of fruit rot in GD and OD coconuts). Relative humidity immensely contributed to the variation observed in the PDI of fruit rot in YD coconut.

In contrast, the three independent variables (temperature, rainfall, and relative humidity) immensely contributed to the variation observed in the PDI of fruit rot in RD (Table 2). During the 2022 – 2023 growing season in the Coconut Garden, Isihor, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of fruit rot in GD, OD, and YD coconuts, showed that the three independent variables were highly regressive on the PDI of fruit rot in GD, OD, and YD coconuts (but the R2 value was not regressive on the PDI of fruit rot in RD coconut). More so, temperature and rainfall immensely contributed to the variation observed in the PDI of fruit rot in GD coconut, while the three independent variables immensely contributed to the variation observed in the PDI of fruit rot in OD and YD coconuts (Table 2).

For the premature nut fall disease of coconut during the 2021 – 2022 growing season in NIFOR Main Station, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of premature nut fall in GD, OD, and RD coconuts were significant. This infers that the three independent variables were highly regressive on the PDI of premature nut fall in GD, OD, and RD coconuts (but the R2 value was not regressive on the PDI of premature nut fall in YD coconut). Furthermore, the three independent variables immensely contributed to the variation observed in the PDI of premature nut fall in GD, OD, and RD coconuts (Table 4).

During the 2021 – 2022 growing season in the Coconut Garden, Isihor, the R2 value on the role of the independent variables (temperature, rainfall, and relative humidity) on the PDI of premature nut fall in GD, OD, YD, and RD coconuts were highly regressive, as the three independent variables (temperature, rainfall, and relative humidity) immensely contributed to the variation observed in the PDI of premature nut fall in GD, OD, YD, and RD coconuts (Table 4). During the 2022 – 2023 growing season in NIFOR Main Station, the R2 value on the role of the independent variables on the PDI of premature nut fall in GD, OD, YD, and RD coconuts were highly regressive. But the three independent variables (temperature, rainfall, and relative humidity) immensely contributed to the variation observed in the PDI of premature nut fall in GD, YD, and RD coconuts.

In contrast, only relative humidity immensely contributed to the variation observed in the PDI of premature nut fall in OD coconut (Table 4). During the 2022 – 2023 growing season in the Coconut Garden, Isihor, the R2 value on the role of the independent variables on the PDI of premature nut fall in GD, OD, YD, and RD coconuts were highly regressive. The three independent variables (temperature, rainfall, and relative humidity) immensely contributed to the variation observed in the PDI of premature nut fall in GD coconut. In contrast, rainfall and relative humidity immensely contributed to the variation observed in the PDI of premature nut fall in

OD, YD, and RD coconuts (Table 4). The findings from this study also agree with the work of Romero et al., (2022) and Netam et al., (2014), which shows that some weather factors promote the incidence and severity of plant diseases.

5. CONCLUSION

The regression analysis used in this study showed that some weather factors (temperature, rainfall, and relative humidity) immensely contributed to the variations observed in the PDI of fruit rot and premature nut fall diseases of coconut in the two locations and growing seasons across coconut varieties.

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Author Contributions to Manuscripts

Osayomore Endurance Ekhorutomwen: Conceptualization, Methodology, Experimental Design, Writing of Manuscript. Osarugiagbon Stanley Uyi: Experimental Design and Data Analysis. Nnamdi Ifechukwude Chidi: Conceptualization, Review and Editing of Manuscript. Olalekan Hakeem Shittu: Conceptualization, Review and Editing of Manuscript.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study for collection & identification.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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Data and materials availability

All data associated with this study are present in the paper.

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