

Full Length Research Paper

Plant disease forecast and modern dynamism in black pod disease management in Nigeria

Peter M. Etaware

Department of Botany, Faculty of Science, University of Ibadan, Ibadan, Nigeria.

Received 16 June, 2019; Accepted 21 August, 2019

Black pod disease (BPD) is reputed for its regular occurrence in Africa and around the world with high propensity for massive destruction of cocoa pods in the field and total yield loss per season if proper management strategies are not applied. This research was designed to provide useful and timely information on BPD outbreak, its intensity and specific areas expected to be massively affected by the disease in Nigeria. Twelve (12) research locations were mapped out from four important cocoa producing states in Southwest, Nigeria for BPD assessment and forecast. The BPD forecast system “ETAPOD” accurately predicted BPD outbreak in Ondo (Ọwenà and Wáàsimi) and Osun (Adaàgbà, Iyánfowọ̀rọ̀gi, and Owódé-Igàngán), but it failed to give accurate predictions for Ogun (Ọbáfémi-Owódé) and Oyo (Mòyè village, Dáagi-Lógbà and Olórò village) states. The performance of ETAPOD was greatly affected by the credibility of the data fed into the system, this can be improved on. ETAPOD predicted BPD outbreak closely within the range of natural BPD occurrences.

Key words: Disease forecast, black pod disease (BPD) outbreak, total yield loss, ETAPOD, data credibility.

INTRODUCTION

Black pod disease (BPD) associated with symptoms like leaf blight, pod rot, stem canker and death of the entire *Theobroma cacao* plant was reported by Opoku et al. (2000) as one of the most influential diseases of cocoa. Akrofi (2015) reported that the disease occurred annually with high propensity for massive cocoa pod destruction and total yield loss if proper management strategies were not applied. Oluyole and Lawal (2008) reported an estimated average occurrence of the disease in several parts of West Africa as 40% and up to 90% in certain places in Nigeria. The extent of damage caused by BPD infections had been reported by Kudjordjie (2015) to be more in West Africa than in any other cocoa growing regions of the world.

This research was designed to provide useful and timely information on BPD outbreak, its intensity and specific areas expected to be greatly affected by the disease in Nigeria. This will eradicate doubts and uncertainty in the minds of investors on their choice of investment(s) made in cocoa production nationwide, eradicate fungicide misuse, increase cocoa production, reduce the risk of chemical poisoning by discouraging indiscriminate use of fungicide which will further ensure the availability of disease-free and non-toxic raw materials for cocoa processing industries; increasing farmers' profit, foreign exchange values and internally generated revenue (IGR) from the sales of cocoa beans. The forecast system “ETAPOD” is user friendly, easy to interpret, highly

E-mail: peterparkers007@gmail.com. Tel: +2348032229349.

Author(s) agree that this article remain permanently open access under the terms of the [Creative Commons Attribution License 4.0 International License](https://creativecommons.org/licenses/by/4.0/)

Table 1. The description of the research locations.

Post	Location	LGA	State	Latitude	Longitude	Altitude (m)	Farm size (m ²)
1	Qbáfémi-Owódé	Qbáfémi-Owódé	Ogun	7°08'30.37" N	3°25'56.71" E	187	10,000
2	Qbáfémi-Owódé	Qbáfémi-Owódé	Ogun	7°08'30.32" N	3°25'56.73" E	192	10,000
3	Adaàgbà	Ife South	Osun	7°22'13.80" N	4°33'34.42" E	262	40,000
4	Owódé-Igàngán	Atàkunmosá East	Osun	7°29'59.99" N	4°48'59.99" E	276	50,000
5	Iyánfowórogì	Ife South	Osun	7°21'55.22" N	4°34'16.54" E	259	20,000
6	Owódé-Igàngán	Atàkunmosá East	Osun	7°29'53.45" N	4°48'59.01" E	282	50,000
7	Òwenà	Ondo East	Ondo	7°12'11.52" N	5°00'55.76" E	289	10,000
8	Òwenà	Ondo East	Ondo	7°12'11.50" N	5°00'55.76" E	291	10,000
9	Wáàsìmi	Ondo East	Ondo	7°10'42.78" N	4°59'31.34" E	249	30,000
10	Mòyè village	Qnà-Arà	Oyo	7°18'54.54" N	4°01'09.34" E	205	20,000
11	Dáagi-Lógbà	Iddo	Oyo	7°20'47.58" N	3°44'30.59" E	174	20,000
12	Olórò village	Qnà-Arà	Oyo	7°20'44.00" N	3°59'34.00" E	179	10,000

Source: BPD assessment (2015/2016) © Etaware and Adedeji (2018).

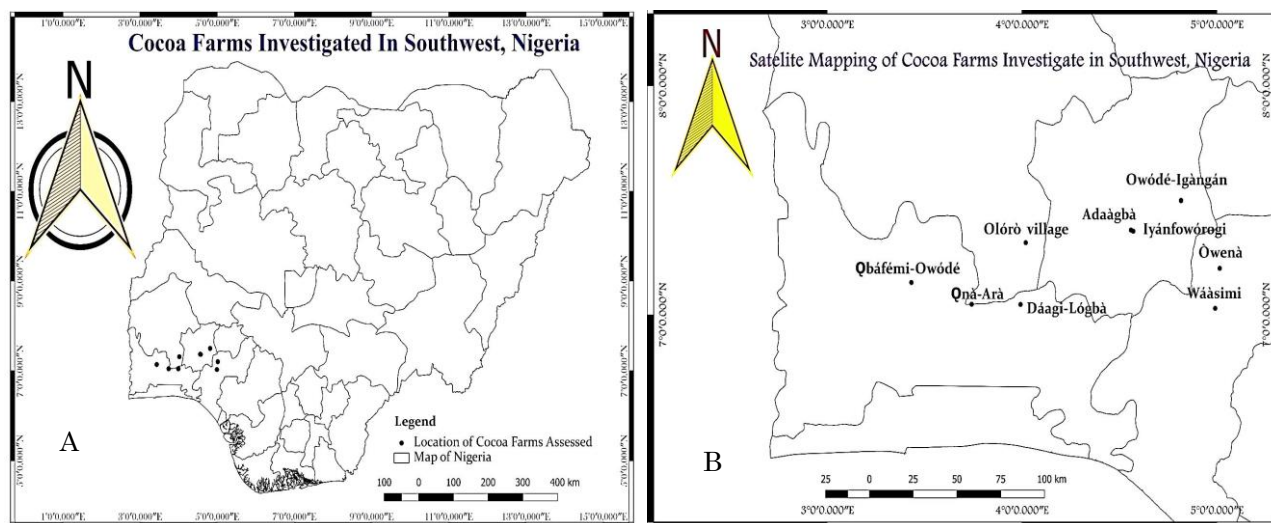


Figure 1. The research locations: (A) an overview; (B) a cross section view.

proficient, reliable, and cost efficient, designed for monthly and annual BPD predictions. The installation and implementation of ETAPOD will help promote a disease free, clean and healthy environment.

MATERIALS AND METHODS

Research locations

Twelve (12) research locations were mapped out from four important cocoa producing states in Southwest, Nigeria. The research locations are shown in Table 1 and their geographical positions shown in Figure 1.

Epidemiological data

The disease status (BPD incidence and severity) from the

earmarked research locations were obtained from Etaware and Adedeji (2018).

Weather data

Weather data used for BPD prediction was collected from the National Bureau of Statistics (NBS) Ibadan and Nigerian Meteorological Station (Nimet).

BPD Prediction

The forecast system used for BPD prediction (ETAPOD) was developed by Etaware et al. (2018).

Data analysis

The geospatial data collected using Garmin eTrex® 10 GPS tracker

ETAPOD									
Black pod disease warning system for the Southwest of Nigeria									
2015/2016			Rainfall (mm)		Rel. Humidity (%)		Temperature (°C)	Black Pod Occurrence (%)	
9	January	20.4	0.004	6.50	0.27	35.8	0.51	18.4	-1.3964
10	February	20.4	0.004	35.6	0.27	35.4	0.51	21.5	-0.03971999999999991
11	March	20.4	0.004	84.5	0.27	49.8	0.51	22.8	4.31544
12	April	20.4	0.004	173	0.27	59.2	0.51	22.7	6.4792
13	May	20.4	0.004	168	0.27	67.2	0.51	22.6	8.5776
14	June	20.4	0.004	199	0.27	70.4	0.51	22.0	9.0524
15	July	20.4	0.004	313	0.27	82.6	0.51	21.2	11.4824
16	August	20.4	0.004	208	0.27	75.8	0.51	21.6	10.2602
17	September	20.4	0.004	255	0.27	75.0	0.51	22.1	10.0908
18	October	20.4	0.004	125	0.27	67.2	0.51	21.4	8.1682
19	November	20.4	0.004	25.7	0.27	52.4	0.51	21.3	4.49784
20	December	20.4	0.004	2.08	0.27	40.2	0.51	20.2	0.75788
Total Annual Occurrence (>PPT)									72.24584
Average Annual Black pod Disease Occurrence									6.0 %

Figure 2. Simulated BPD outbreak values for Ondo (2015/2016).

ETAPOD									
Black pod disease warning system for the Southwest of Nigeria									
2015/2016			Rainfall (mm)		Rel. Humidity (%)		Temperature (°C)	Black Pod Occurrence (%)	
9	January	20.4	0.004	0.42	0.27	35.2	0.51	21.46	0.04692000000000001
10	February	20.4	0.004	41.4	0.27	36.2	0.51	23.62	1.25452
11	March	20.4	0.004	63.2	0.27	48.6	0.51	23.96	4.68864
12	April	20.4	0.004	101	0.27	57.8	0.51	23.68	6.87888
13	May	20.4	0.004	159	0.27	66.2	0.51	23.14	8.6394
14	June	20.4	0.004	168	0.27	69.8	0.51	22.86	9.4326
15	July	20.4	0.004	210	0.27	80.8	0.51	22.04	11.8164
16	August	20.4	0.004	136	0.27	74.4	0.51	21.96	10.3436
17	September	20.4	0.004	149	0.27	73.0	0.51	22.64	10.2588
18	October	20.4	0.004	163	0.27	65.0	0.51	22.16	7.79856
19	November	20.4	0.004	30.7	0.27	52.0	0.51	22.40	4.94104
20	December	20.4	0.004	14.9	0.27	41.2	0.51	21.58	1.67004
Total Annual Occurrence (>PPT)									77.7694
Average Annual Black pod Disease Occurrence									6.5 %

Figure 3. Simulated BPD outbreak values for Osun (2015/2016).

were analysed and positioned on the map using the quantum geographic information system (QGIS 2.18.3) incorporated with GRASS 7.2.0 functions for optimization. The analysis of variance was carried out using COSTAT 6.451 software and homogeneity of means determined using Duncan Multiple Range Test (DMRT).

RESULTS

ETAPOD simulated BPD outbreak (ESBO) versus real life BPD outbreak (RLBO)

ETAPOD simulated BPD outbreak was 9.05% in Ondo (RLBO: 9.5%), 9.43% in Osun (RLBO: 9.0%), 11.5% in Ogun (RLBO: 0.0%), and 9.43% in Oyo (RLBO: 0.0%) in June 2015. In July, ESBO was 11.5% in Ondo (RLBO: 18.0%), 11.8% in Osun (RLBO: 13.5%), 12.2% in Ogun (RLBO: 0.0%), and 11.8% in Oyo (RLBO: 6.0%). In August, ESBO was 10.3% in Ondo (RLBO: 26.5%), 10.3% in Osun (RLBO: 8.0%), 11.2% in Ogun (RLBO: 3.0%), and 10.4% in Oyo (RLBO: 16.0%). In September, ESBO was 10.1% in Ondo (RLO: 11.0%), 10.3% in Osun (RLBO: 11.5%), 9.86% in Ogun (RLBO: 15.0%), and

9.98% in Oyo (RLBO: 14.0%). In October, ESBO was 8.17% in Ondo (RLBO: 5.0%), 7.8% in Osun (RLBO: 10.0%), 9.23% in Ogun (RLBO: 22.0%), and 7.80% in Oyo (RLBO: 0.0%), respectively (Figures 2, 3, 4 and 5 and Table 2). The comparison was based on the optimum cocoa production period (July-August) to October where most of the pods are harvested from the field.

The difference between ESBO and RLBO values in Ogun, Ondo, Osun and Oyo

It was also shown that the difference between real life BPD occurrences and predicted values was $-8.58\% \leq \text{Ondo} \leq 16.2\%$, $-7.14\% \leq \text{Osun} \leq 2.20\%$, $-11.5\% \leq \text{Ogun} \leq 12.8\%$ and $-9.43\% \leq \text{Oyo} \leq 5.60\%$, respectively (Table 3).

The level of accuracy of ETAPOD

ETAPOD accurately predicted BPD outbreak for Ondo and Osun for the period of June 2015 to March 2016

Ogun		ETAPOD							
LGA									
Town									
		<i>Black pod disease warning system for the Southwest of Nigeria</i>							
2015/2016		Rainfall (mm)		Rel. Humidity (%)		Temperature (°C)	Black Pod Occurrence (%)		
9	January	20.4	0.004	2.92	0.27	37.6	0.51	22.14	1.03172
10	February	20.4	0.004	13.1	0.27	39.4	0.51	24.76	2.81312
11	March	20.4	0.004	72.0	0.27	47.6	0.51	24.66	4.74076
12	April	20.4	0.004	120	0.27	59.2	0.51	24.16	7.4256
13	May	20.4	0.004	139	0.27	69.2	0.51	24.00	9.968
14	June	20.4	0.004	162	0.27	73.6	0.51	24.94	11.5434
15	July	20.4	0.004	199	0.27	81.4	0.51	22.48	12.2468
16	August	20.4	0.004	88	0.27	75.6	0.51	22.70	11.237
17	September	20.4	0.004	206	0.27	74.4	0.51	21.56	9.8596
18	October	20.4	0.004	135	0.27	68.2	0.51	23.06	9.23452
19	November	20.4	0.004	22.5	0.27	54.4	0.51	23.04	5.94856
20	December	20.4	0.004	0.8	0.27	42.6	0.51	21.86	2.2474
Total Annual Occurrence (>PPT)								88.29648	
Average Annual Black pod Disease Occurrence								7.4 %	

Figure 4. Simulated BPD outbreak values for Ogun (2015/2016).

Oyo		ETAPOD							
LGA									
Town									
		<i>Black pod disease warning system for the Southwest of Nigeria</i>							
2015/2016		Rainfall (mm)		Rel. Humidity (%)		Temperature (°C)	Black Pod Occurrence (%)		
9	January	20.4	0.004	0.42	0.27	35.8	0.51	21.46	0.208920000000003
10	February	20.4	0.004	41.4	0.27	36.4	0.51	23.58	1.28812
11	March	20.4	0.004	63.2	0.27	48.2	0.51	23.94	4.57044
12	April	20.4	0.004	101	0.27	57.8	0.51	23.66	6.86868
13	May	20.4	0.004	159	0.27	66.4	0.51	23.14	8.69356
14	June	20.4	0.004	168	0.27	69.8	0.51	22.86	9.43428
15	July	20.4	0.004	210	0.27	80.6	0.51	22.06	11.7722
16	August	20.4	0.004	138	0.27	74.8	0.51	21.86	10.39252
17	September	20.4	0.004	149	0.27	73	0.51	22.10	9.9834
18	October	20.4	0.004	163	0.27	65	0.51	22.16	7.79856
19	November	20.4	0.004	29.6	0.27	52	0.51	22.40	4.9456
20	December	20.4	0.004	14.9	0.27	41.2	0.51	21.58	1.67004
Total Annual Occurrence (>PPT)								77.62632	
Average Annual Black pod Disease Occurrence								6.5 %	

Figure 5. Simulated BPD values for Oyo (2015/2016).

Table 2. ETAPOD Simulated BPD Outbreak (SBO) versus Real Life BPD Occurrence (RLO).

Period	BPD Outbreak (%)							
	Ondo		Osun		Ogun		Oyo	
	RLBO	ESBO	RLBO	ESBO	RLBO	ESBO	RLBO	ESBO
05/2015	0.0	8.58	1.5	8.64	0.0	9.97	0.0	8.69
06/2015	9.5	9.05	9.0	9.43	0.0	11.5	0.0	9.43
07/2015	18.0	11.5	13.5	11.8	0.0	12.2	6.0	11.8
08/2015	26.5	10.3	8.0	10.3	3.0	11.2	16.0	10.4
09/2015	11.0	10.1	11.5	10.3	15.0	9.86	14.0	9.98
10/2015	5.0	8.17	10.0	7.80	22.0	9.23	0.0	7.80
11/2015	0.0	4.50	0.0	4.94	0.0	5.95	0.0	4.95
12/2015	0.0	0.76	0.0	1.67	0.0	2.25	0.0	1.67
01/2016	0.0	-1.40	0.0	0.05	0.0	1.03	0.0	0.21
02/2016	0.0	-0.04	0.0	1.25	0.0	2.81	0.0	1.29
03/2016	0.0	4.32	0.0	4.69	0.0	4.74	0.0	4.57
04/2016	0.0	6.48	0.0	6.88	0.0	7.43	0.0	6.87
05/2016	0.0	8.58	0.0	8.64	0.0	9.97	0.0	8.69

RLBO: Real Life BPD Occurrences; ESBO: ETAPOD simulated BPD outbreaks; BPD: black pod disease.

Table 3. The difference between ESBO and RLBO values in Ogun, Ondo, Osun and Oyo.

Period	Estimated difference (%)			
	Ondo	Osun	Ogun	Oyo
05/2015	-8.58	-7.14	-9.97	-8.69
06/2015	0.45	-0.43	-11.5	-9.43
07/2015	6.50	1.70	-12.2	-5.80
08/2015	16.2	-2.30	-8.20	5.60
09/2015	0.90	1.20	5.14	4.02
10/2015	-3.17	2.20	12.8	-7.80
11/2015	-4.50	-4.94	-5.95	-4.95
12/2015	-0.76	-1.67	-2.25	-1.67
01/2016	1.40	-0.05	-1.03	-0.21
02/2016	0.04	-1.25	-2.81	-1.29
03/2016	-4.32	-4.69	-4.74	-4.57
04/2016	-6.48	-6.88	-7.43	-6.87
05/2016	-8.58	-8.64	-9.97	-8.69

Table 4. The level of accuracy of ETAPOD.

Period	Ondo	Osun	Ogun	Oyo
05/2015	-	-	-	-
06/2015	+	-/+	-	-
07/2015	+	+	-	-
08/2015	+	-/+	-	+
09/2015	+	+	+	+
10/2015	-/+	+	+	-
11/2015	-/+	-/+	-	-/+
12/2015	-/+	-/+	-/+	-/+
01/2016	+	+	-/+	-/+
02/2016	+	-/+	-/+	-/+
03/2016	-/+	-/+	-/+	-/+
04/2016	-	-	-	-
05/2016	-	-	-	-

+ = Accurate Disease Prediction. -/+ = Error in disease prediction less than 5%. - = Error in disease prediction more than 5%

(Table 4). Although, the simulated BPD outbreak values from the forecast system was not 100% accurate for Ogun and Oyo, BPD predictions for August 2015 to March 2016 (Table 4) was within the range of real life occurrences for 2015/2016 cocoa production season in Nigeria.

The error of prediction for the developed BPD forecast model

The error in the predicted result from ETAPOD was estimated as follows: 0.20 (Ondo), 0.18 (Osun), 132.3 (Ogun), and 88.92 (Oyo) in June 2015. 42.25 (Ondo), 2.89 (Osun), 148.8 (Ogun), and 33.64 (Oyo) in July;

262.4 (Ondo), 5.29 (Osun), 67.24 (Ogun), and 31.36 (Oyo) in August; 0.81 (Ondo), 1.44 (Osun), 26.42 (Ogun), and 16.16 (Oyo) in September; and 10.05 (Ondo), 4.84 (Osun), 163.8 (Ogun), and 60.84 (Oyo) in October 2015, respectively (Table 5).

DISCUSSION

ETAPOD was able to forecast BPD outbreak for the 2015/2016 cocoa production season in Ogun, Ondo, Osun and Oyo states. ETAPOD accurately quantified BPD outbreaks in Ondo and Osun during the optimum season of cocoa production in Nigeria, but it failed to accurately predict the disease level for Ogun and Oyo.

Table 5. The error of prediction for the developed BPD forecast model.

Period	Error in prediction of black pod disease occurrence			
	[E= (Y-Ŷ) ²]			
	Ondo	Osun	Ogun	Oyo
05/2015	73.62	50.98	99.4	75.52
06/2015	0.20	0.18	132.3	88.92
07/2015	42.25	2.89	148.8	33.64
08/2015	262.4	5.29	67.24	31.36
09/2015	0.81	1.44	26.42	16.16
10/2015	10.05	4.84	163.8	60.84
11/2015	20.25	24.4	35.40	24.5
12/2015	0.58	2.79	5.06	2.79
01/2016	1.96	0.00	1.06	0.04
02/2016	0.00	1.56	7.90	1.66
03/2016	18.66	22.00	22.47	20.88
04/2016	41.99	47.33	55.20	47.20
05/2016	73.62	74.65	99.40	75.52

This was in agreement with the research of Luo (2008) who stated that no forecast system can be 100% accurate at all times and that the accuracy level of any forecast system depends on several factors such as the credibility of the weather data fed into the system, the user proficiency of the forecast system, program errors, etc., which can be improved with time. The study was solely concerned with the maximum (March – October) and optimum (July – August) season of cocoa production and as such BPD information generated from ETAPOD was solely validated for those periods. It is known in Ghana that primary infection of cocoa pods in the field usually occur around June, but the peak of BPD infection generally occurred between August and October (Opoku et al., 2000, 2007). Information on the period for possible BPD infection in the field is useful in determining the pattern of disease development. Such information could be an important tool for disease management. The environmental conditions immediately preceding the infection period must be favourable for BPD development to occur and this period can be targeted for disease management.

Conclusion

ETAPOD is a warning system developed to ameliorate the devastating effects of black pod disease pestilence in Nigeria, within Africa and around the world, by providing useful information on the occurrence and spread of the disease with a clear coverage on the areas under severe attack. ETAPOD is unique as it is not geographically bound and thus, can be manipulated to provide optimum results wherever it is needed. A qualitative and quantitative description of the disease pressure was the

key factor to determining the prevalence and spread of black pod disease in this study.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Akrofi AY (2015). *Phytophthora megakarya*: a review on its status as a pathogen on cacao in West Africa. African Crop Science Journal 23(1):67-87.
- Etaware PM, Adedeji AR (2018). Black pod disease profile: Monitoring its outbreak in Southwest, Nigeria. BioRxiv 32 p.
- Etaware PM, Adedeji AR, Osowole OI, Odebode AC (2018). ETAPOD: A forecast model for prediction of black pod disease outbreak in Nigeria. BioRxiv 32 p.
- Kudjordjie EN (2015). *Phytophthora megakarya* and *P. palmivora* on *Theobroma cacao*: Aspects of virulence and the effects of temperature on growth and resistance to fungicides. Master's thesis submitted to the Faculty of Science, University of Copenhagen, Denmark 81 p.
- Luo W (2008). Spatial/Temporal modelling of crop disease data using high-dimensional regression. Department of Statistics, University of Leeds 223 p.
- Oluyole KA, Lawal JO (2008). Determinants of the occurrence of black pod disease of cocoa in Edo state, Nigeria: a multivariate probit analysis approach. Economics and Statistics Division, Cocoa Research Institute of Nigeria, Ibadan Nigeria, Journal of Innovative Development Strategy 2(2):1-4.
- Opoku IY, Appiah AA, Akrofi AY (2000). *Phytophthora megakarya*: A potential threat to the cocoa industry in Ghana. Ghana Journal Agricultural Science 33:135-142.
- Opoku IY, Assuah MK, Aneani F (2007). Management of black pod disease of cocoa with reduced number of fungicide application and crop sanitation. African Journal of Agricultural Research 2:601-604.