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Assessment of black pod disease outbreak in Southwest, Nigeria

Peter Mudiaga Etaware[1]* and Adegboyega Rasheed Adedeji[2]
[1]Department of Botany, Faculty of Science, University of Ibadan, Ibadan, Nigeria
[2]Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Nigeria

Corresponding author: peterparkers007@gmail.com

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ABSTRACT

Aim: The aim of this study is to evaluate Black pod disease (BPD) infection and Cocoa farming in Nigeria.

Method and Materials: 12 Stations were mapped out for research from 4 important cocoa-producing States in Southwest, Nigeria. The Stations were monitored periodically for BPD outbreak. Infected cocoa pods and topsoil samples were collected for laboratory analysis. BPD outbreak was recurrent in all the stations (100%)..

Results: It was immense in August in Station 1 (30.0%), Station 3 (23.0%), Station 11 (16.0%), Station 4 (9.0%), Station 5 (7.0%), and Station 8 (3.0%). Massive cocoa pod destruction was noticed in September in Station 1 (100.0%), Station 3 (96.7%), Station 5 (85.7%), Station 11 (84.3%), and Station 4 (70.0%) with the exception of Station 8 (100% in October).

Conclusion: The present study was able to show that BPD outbreak occurred massively between July-September while cocoa pods infection was massive between August-September. Therefore, farmers in Nigeria are advised to apply treatment at the beginning (March) and middle (June) of the raining season to avoid crop lose and minimize fungicide misuse.

Keywords: BPD outbreak, Cocoa farming and Fungicide misuse.

Introduction

Theobroma cacao (Cocoa) is native to South America but widely cultivated in Africa, Europe, Asia and Australia. Cocoa cultivation has been a major source of income for most 3rd world countries [1]. The largest proportion of global cocoa beans (59%) is from West Africa, with Côte d'Ivoire and Ghana producing 1,472,313 and 858,720 tonnes respectively. Cocoa is highly susceptible to pests and diseases among which is BPD infection [2] which occurs seasonally, affecting cocoa pods at different developmental stages in the field. BPD is highly destructive, fast spreading and most consistent among other cocoa diseases [3]. It is more established in West Africa than in other cocoa-growing regions around the world. In Nigeria, Cameroon and Togo, BPD constitutes the greatest set-back to cocoa production with losses of up to 90% [3]. In the early 1980s, BPD in Ghana was only known to be caused by *P. Palmivora*. However, in 1985, a severe outbreak, which appeared different from that previously known, was reported in the Akomadan area of the Ashanti region. Investigations conducted by [4] showed that *P. megakarya* was the causal agent, and this was subsequently confirmed by several researchers [5,6].

P. megakarya produces lesions of BPD with irregular edges on the pod surface whereas lesions caused by *P. palmivora* have regular borders and are generally smaller [7]. The first symptom is a brown to black spot on the pod, which spreads rapidly in all directions and eventually covers the whole pod. The beans become infected internally about 15 days after the initial infection and are soon of no commercial value [8]. Generally, cocoa pods closest to the ground are first affected by the disease which spreads rapidly around the entire tree. *P. megakarya* can also cause seedling blight and trunk cankers [9], ensuring a slow and steady death of the affected tree(s). The disease now poses serious threat to cocoa survival, cocoa farms are gradually abandoned and none established in areas massively blighted by BPD [3]. The disease is not only responsible for immense pod losses, but also infliction of severe stem canker resulting in the death of many cocoa trees [5]. Unless concerted efforts are made to effectively monitor and manage the disease, BPD will greatly reduce cocoa production in Nigeria and around the world [3,10] and will eventually result in extinction of cocoa in the nearest future.

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Methods and Materials

Research Stations

The research Stations were described in Table 1, while cocoa producing States and the region that makes up Southwestern Nigeria was described in Fig 1 alongside the areas under serious attack by BPD.

BPD outbreak evaluation in the research stations

BPD evaluation was carried out for 13months within each research station. The evaluation was spread across 3 cocoa production seasons in Nigeria i.e. the major (March to October), the minor (November to April) and the optimum (July to August) cocoa production seasons in Nigeria. Seasonal variation and farm altitude were also considered in other to determine the possible ways of BPD development and spread.

Evaluation of BPD incidence

The method adapted for evaluation of BPD incidence was that of [11]. Cocoa trees were assessed in a transverse and diagonal mode as described in Fig 2 within each research station. Green and ripe Cocoa pods from each tree were inspected for the symptoms of BPD; the rain splash zone described in Fig 3 was of interest. If an infected pod was detected on the tree, the stand (tree) was noted as being infected. The assessment was repeated for 100 trees and the observations noted.

$$BPD\ Incidence\ (\%) = \frac{No.of\ infected\ trees}{100\ trees\ Assessed} \times 100$$

Black Pod Disease Severity

Infected cocoa pods were assessed and the extent of damage inflicted by the disease described by scores from 0 to 5 according to [12] (Table 2).

- BPD evaluation based on observations made during raining and dry Seasons**:**

$$\mathbf{SI}\ (\%) = \frac{\mathbf{SOS_i}}{\mathbf{SL_{total}}}$$

- BPD evaluation based on the altitude of the research stations:

$$AI\ (\%) = \frac{SOA_i}{SL_{total}}$$

- BPD Status determination in Southwest Nigeria:

$$BSS\ (\%) = \frac{SO_i}{SL_{total}}$$

- BPD Status determination in Ogun, Ondo, Osun and Oyo:

$$BST\ (\%) = \frac{ST_i}{SL_{total}}$$

Where,

SI = Seasonal Influence on BPD Status, $\mathbf{SOS_i}$ = Sum of all observations made per Season (per month), **AI** = Altitudinal influence on BPD Status, $\mathbf{SOA_i}$ = Sum of all observations made per altitudinal Level (per month), **BSS** = BPD Status in Southwest, Nigeria, $\mathbf{SO_i}$ = Sum of all observations (per month) from the stations, **BST** = BPD Status in each State, $\mathbf{ST_i}$ = the sum of BPD Status from all the sampled stations within a State (per month) and $\mathbf{SL_{total}}$ = The Total No. of study locations assessed.

BPD profile from 1985 to 2014

BPD profile was obtained from Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan, Oyo State, Nigeria and the report of [13].The data collected spanned from 1985 to 2014.

Data Analysis

Qualitative data were represented as graphs plotted using Microsoft Office (Excel) 2007 and SPSS v20.0 for 32 bits resolution. Analysis of variance was carried out using COSTAT 6.451 statistical software and the homogeneity of means was determined using Duncan Multiple Range Test (DMRT).

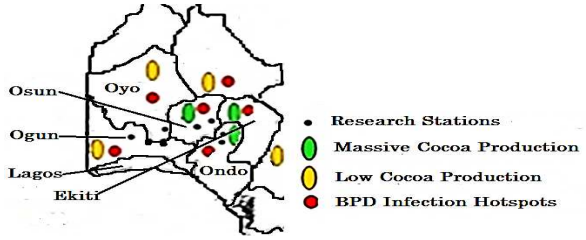

Fig 1: Cocoa production and areas under spotlight for BPD outbreak in Southwest, Nigeria

Table 1: Research Stations, their locations with GPS co-ordinates and sizes

Station	Location	Latitude N	Longitude E	Altitude (m)	Size (m²)
1	Òwẹ̀nà (Down-Stream)	7° 12' 11.52"	5° 00' 55.76"	289	10,000
2	Òwẹ̀nà (Up-Stream)	7° 12' 11.50"	5° 00' 55.76"	291	10,000
3	Wáàsimi	7° 10' 42.78"	4° 59'31.34"	249	30,000
4	Adaàgbà	7° 22' 13.80"	4° 33' 34.42"	262	40,000
5	Iyánfọwọrọgi	7° 21' 55.22"	4° 34' 16.54"	259	20,000
6	Owódé-Igàngán (Inland)	7° 29' 59.99"	4° 48' 59.99"	276	50,000
7	Owódé-Igàngán (Outskirt)	7° 29' 53.45"	4° 48' 59.01"	282	50,000
8	Ọbáfẹmi-Owódé (Post 1)	7° 08' 30.37"	3° 25' 56.71"	187	10,000
9	Ọbáfẹmi-Owódé (Post 2)	7° 08' 30.32'	3° 25' 56.73"	192	10,000
10	Mòyè	7° 18' 54.54"	4° 01' 09.34"	205	20,000
11	Ọmi-Adió	7° 20' 47.58"	3° 44' 30.59"	174	20,000
12	Olórò	7° 20' 44.00"	3° 59' 34.00"	179	10,000

Criteria for selection: Farm size, Consistency in cocoa production, Cropping system and Locality.

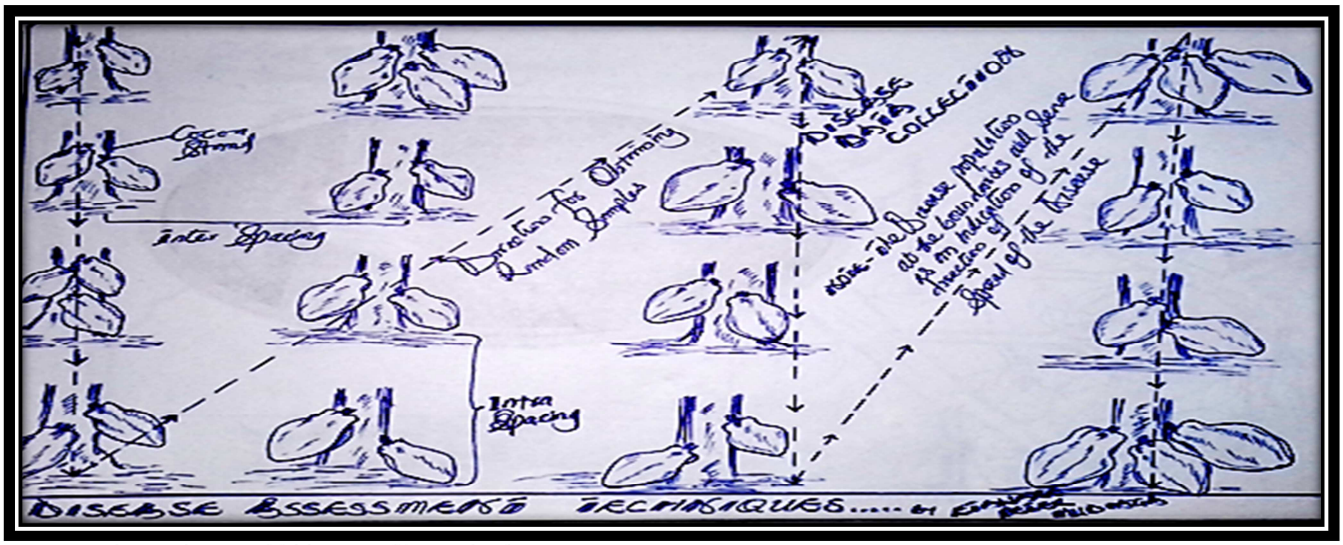

Fig 2: Sampling techniques (a) blueprint (b) sample plan

Table 2: Evaluation of BPD severity on cocoa pod

Score	Infected Pod Portion	BPD Severity (%)	Inference
0	None	00	Healthy
1	(1/5)	20	Not Severe
2	(2/5)	40	Mildly Severe
3	(3/5)	60	Averagely Severe
4	(4/5)	80	Severe
5	All	100	Extremely Severe

© Akrofi (2015). **BPD** – Black pod disease

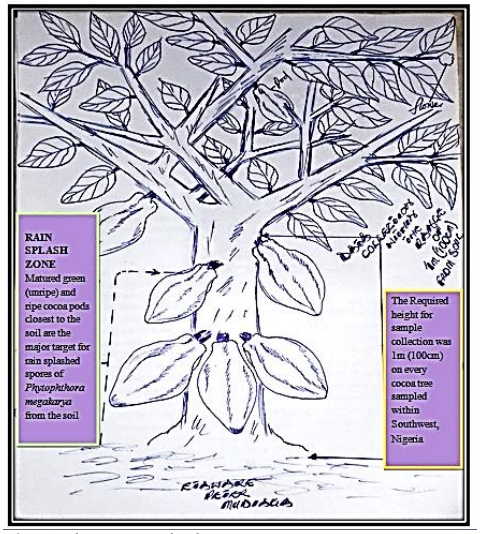

Fig 3: The rain-splash zone

Results

Description of BPD causal pathogen

Morphological Description: Cotton white appearance of mycelia on PDA at the early stages which turns pale creamy-yellow in older cultures (Fig 4a).

Cytological Description: The hyphae appeared hyaline, septate and heterogeneously branched, double walled with thin layers. Zoospores were produced on sporangiophores. The zoospores had double layers, ellipsoidal in shape, with a pointed node each. Each zoospore had a single flagellum located at the posterior part of the spore (Fig 4b).

A projection of the possible trend of survival of the pathogen

A brief study of the pathogen in the laboratory was described in (Fig 5). Spores of the pathogen germinated into motile zoospores (Fig 5b). The motile spores shed-off their flagella, germinate, and gain entrance into the host tissue (Fig 5c).The pathogen developed cell structures, hyphae and mycelia (Fig 5d). At maturity, the pathogen produced sporangiophores with spores apically located at its end (Fig 5e).The spores are attached to the sporangiophore aided by the peduncle (Fig 5e). Mature flagellated zoospores are then released into the environment when there is distress or limitation in food supply (Fig 5a).

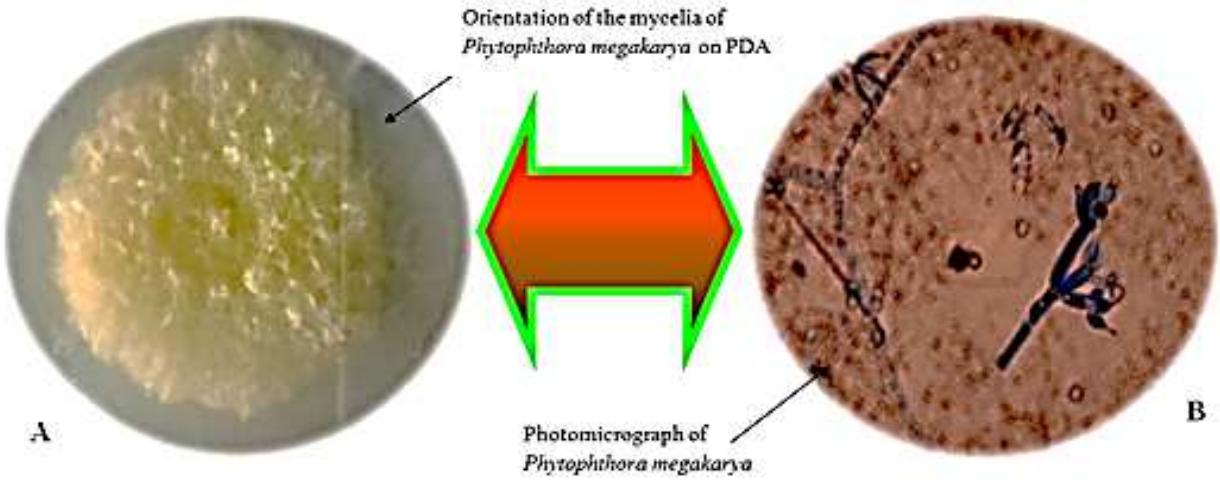

Fig 4: *Phytophthora megakarya*

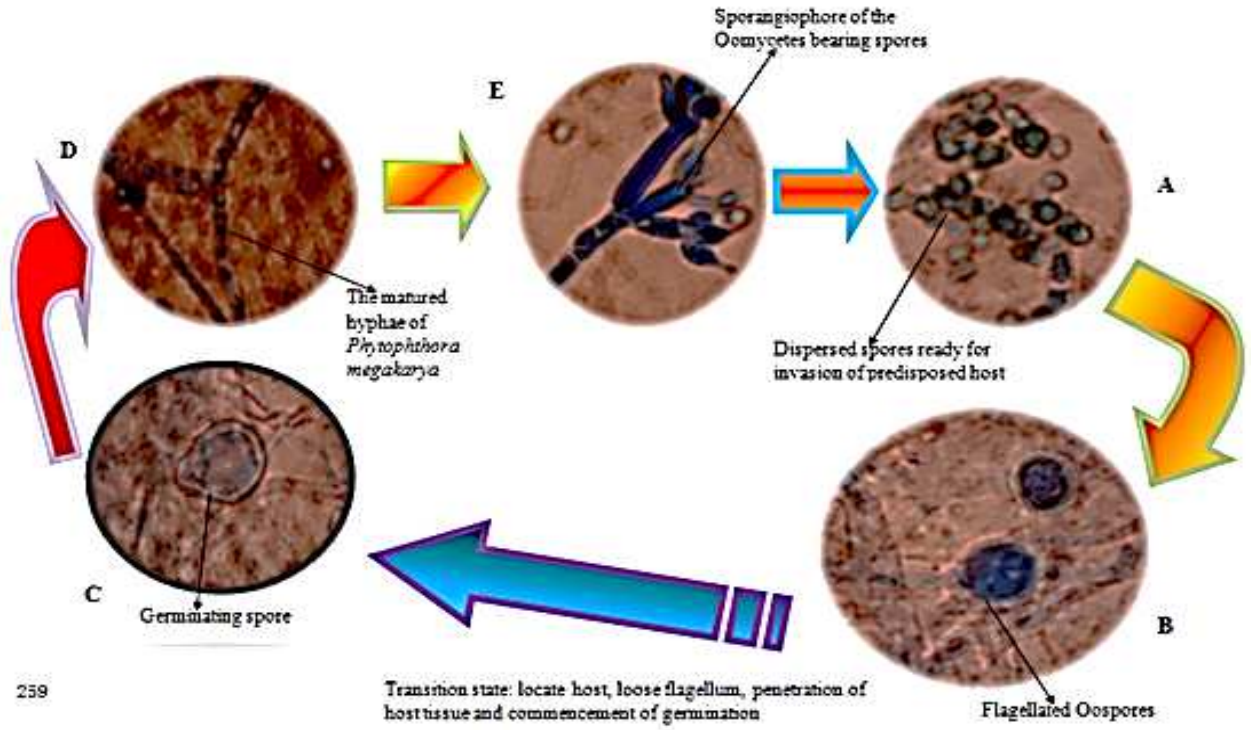

Fig 5: A possible transmission pattern for *Phytophthora megakarya*

Disease and pest evaluation in the research stations

Cherelle wilt, Insect and rodents attack occurred only in the dry season (50%) while BPD outbreak occurred in the rainy season (50%). BPD and Cherelle wilt appeared in all the research stations (100%), whereas, Insect and Pest outbreak was observed in 10 out of the 12 stations (81.9%). Stem canker was absent in all the research stations (Table 3).

Evaluation of BPD incidence in the research stations

There was early BPD incidence in Stations 5 and 6 (3.0 and 9.0%, respectively) in May 2015. In June 2015, the number of research stations with BPD infection increased i.e. Stations 3 (12.0%), 5 (11.0%), 1 (8.0%), 2 (7.0%) and 4 (7.0%). In July, the level of BPD incidence increased in all the Station i.e. Stations 1 (20.0%), Stations 3, 5, 4, and 11 (16.0, 15.0, 12.0 and 6.0% respectively). BPD incidence was highest in August 2015 i.e. Station 1 (30.0%), Stations 3, 11, 4, 5, and 8 (23.0, 16.0, 9.0, 7.0, and 3.0%, respectively). There was decline in BPD incidence in September 2015 through the dry season but research Station 8 showed progressive increase in BPD outbreak (22.0%) till October (Fig 6).

A projection of BPD incidence in Ogun, Ondo, Osun and Oyo (2015/2016)

In May 2015, Osun was the only State with BPD incidence (1.5%). June-July 2015, Ondo and Osun had 9.5-18.0% and 9.0-13.5% BPD incidence, respectively. In August 2015, BPD incidence increased in all the States [Ondo (26.5%), Oyo (16.0%), Osun (8.0%) and Ogun (3.0%)]. An increase in BPD incidence was further experienced in Ogun from September (15.0%) through October (22.0%) in 2015, whereas the reverse was the case in other States (Table 4).

Land height of research station and BPD incidence

Research stations situated 200m above sea level (>200m) had early BPD outbreak, beginning from May (0.8%) through August (17.3%) 2015 followed by a decline in September (11.3%) through October (7.5%) and 0% in the dry season. Research stations below 200m from sea level (≤200m) had a slow start to BPD outbreak (Fig 7).

A projection of BPD status in Southwest, Nigeria (2015/2016)

The project BPD outbreak for Southwest, Nigeria in May 2015 was 0.4%, June 2015 (4.6%), July 2015 (9.4%), August 2015 (13.4%), September

2015 (12.9%), October 2015 (9.3%), November to the end of the dry season (0.0%). Massive cocoa pod loss in Southwest, Nigeria was recorded in September 2015 (86.8%). The safest periods for cocoa pods in the field falls between November and April (Table 5).

Evaluation of BPD severity in the research stations

BPD infection on cocoa pods were severe in Stations 5 and 6 (60.0 and71.1%) only very early in the month of May, 2015. The level of pod destruction rose from 0 to 95.1% (Station 4), 93.9% (Station 3), 62.5% (Station 2), and 60.0% (Station 1), while Station 5 also had appreciable increase (90.9%) in June 2015 (Fig 8). In July, the intensity of cocoa pod infection was 87.5% (Station 1), 78.1% (Station 4), 76.7% (Station 11), 62.2% (Station 5), and 60.0% (Station 3), respectively. In August, Station 3 had 93.0% cocoa pod infections, Station 1 (92.7%), Station 5 (89.2%), Station 4 (80.0%), Station 11 (75.0%), and Station 8 (66.7%). In September 2015, Station 1 had 100.0% cocoa pod infections, Station 3 had 96.7%, Station 8 had 86.7%, Station 5 had 85.7%, Station 11 had 84.3%, and Station 4 was the least with 70.0%. There was a massive decline in cocoa pod infected by BPD in some Stations in the month of October e.g. Station 11 (0.0%), Station 3 (55.0%), Station 1 (0.0%), Stations 4 and 5 (64.6 and 74.3%, respectively); whereas, Station 8 experience 100.0% BPD infection on all the cocoa pods in the farm (Fig 8).

Projected level of BPD Severity in Ondo, Ogun, Osun and Oyo States

The estimated level of cocoa pods infected by BPD infection in Osun was 30.0% (May 2015). In June, it was estimated as 93.0% (Osun), and 76.7% (Ondo). In July, the level of cocoa pod infection in Ondo was 73.8%, Osun (70.1%), Oyo (76.7%) and Ogun (0.0%). In August, Ondo recorded 92.9% cocoa pod infections; Osun had 84.6%, Ogun State (66.7%) and Oyo (75.0%). In September, pod loss aggravated to 98.3% (Ondo), 86.7% (Ogun), 84.3% (Oyo) and 77.9% (Osun). Ogun had 100.0% cocoa pod spoilage in October 2015 (contrary to the observed BPD trend) as shown in Table 6.

Altitude of research stations and BPD severity

BPD infection on cocoa pods in research stations above 200m height from sea level was 15.0% (May 2015). The level of cocoa pods infected by BPD was 84.8% in June, 2015, 71.9% (July 2015), 88.7% (August 2015), and 88.1% in to September 2015. A decline in the level of cocoa pod destroyed by BPD was observed in October (48.5%). Research Stations located below 200m altitude had no BPD infections in May and June (2015). In July, the magnitude of cocoa pod destroyed was 38.4%, 70.9% in August, 85.5% in September and 50.0% in October, 2015 (Table 7).

Table 3: Evaluation of disease occurrence and pest attack in the research stations

			Occurrence	
Disease	**No. of Stations**	**Prob./Season**	**Rainy Season (%)**	**Dry Season (%)**
BPD	12 (100%)	0.5	100	0.0
Cherelle Wilt	12 (100%)	0.5	0.0	100
Pests	10 (81.9%)	0.5	0.0	100
Canker	0 (0.0%)	0.0	0.0	0.0

Table 4: Projected BPD incidence in Ogun, Ondo, Osun and Oyo States

	BPD incidence (%)			
Period	**Ondo**	**Osun**	**Ogun**	**Oyo**
05/2015	0.0^{b}	1.5^{a}	0.0^{b}	0.0^{b}
06/2015	9.5^{a}	9.0^{a}	0.0^{b}	0.0^{b}
07/2015	18.0^{a}	13.5^{b}	0.0^{d}	6.0^{c}
08/2015	26.5^{a}	8.0^{c}	3.0^{d}	16.0^{b}
09/2015	11.0^{a}	11.5^{a}	15.0^{a}	14.0^{a}
10/2015	5.0^{c}	10.0^{b}	22.0^{a}	0.0^{d}
11/2015	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
12/2015	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
01/2016	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
02/2016	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
03/2016	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
04/2016	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}
05/2016	0.0^{a}	0.0^{a}	0.0^{a}	0.0^{a}

Means with the same alphabets across the row are not significantly different at P<0.05.Homogeneity of mean was done using Duncan Multiple Range Test (DMRT).

Table 5: Projected BPD status in Southwest, Nigeria (2015/2016)

Period	BPD status in Southwest Nigeria	
	Incidence (%)	**Severity (%)**
05/2015	0.4[d]	10.0[f]
06/2015	4.6[c]	56.6[c]
07/2015	9.4[b]	55.2[d]
08/2015	13.4[a]	79.8[b]
09/2015	12.9[a]	86.8[a]
10/2015	9.3[b]	49.3[e]
11/2015	0.0[d]	0.0[g]
12/2015	0.0[d]	0.0[g]
01/2016	0.0[d]	0.0[g]
02/2016	0.0[d]	0.0[g]
03/2016	0.0[d]	0.0[g]
04/2016	0.0[d]	0.0[g]
05/2016	0.0[d]	0.0[g]

Means with the same alphabets across the row are not significantly different at P<0.05 Homogeneity of mean was done using Duncan Multiple Range Test (DMRT).

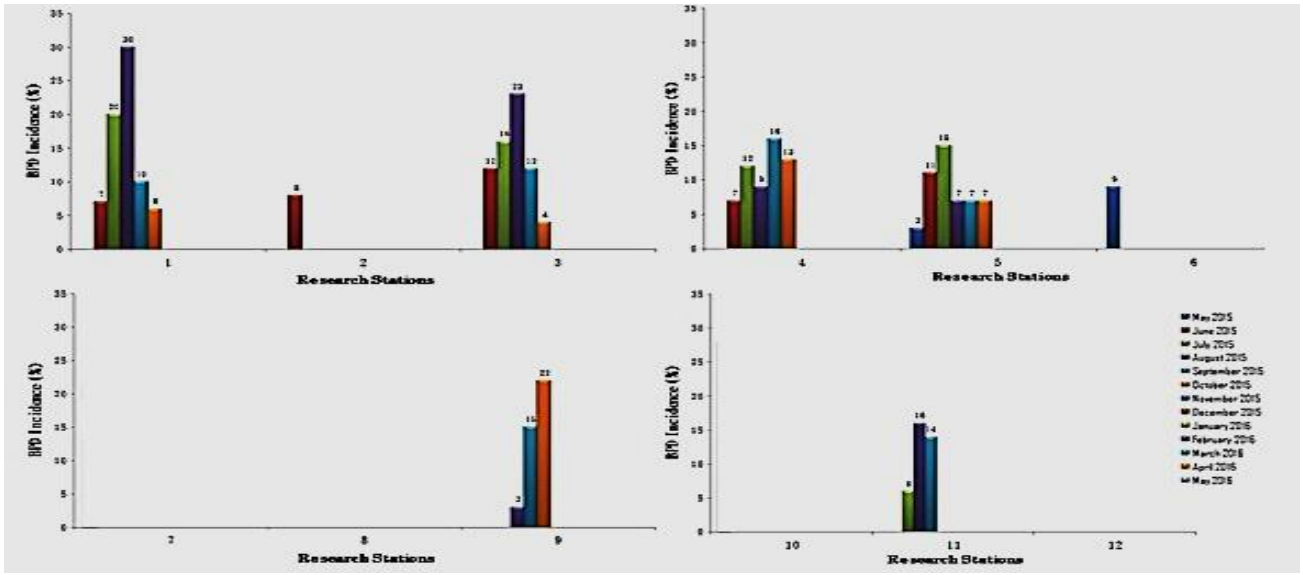

Fig 6: Determination of BPD incidence in the research stations

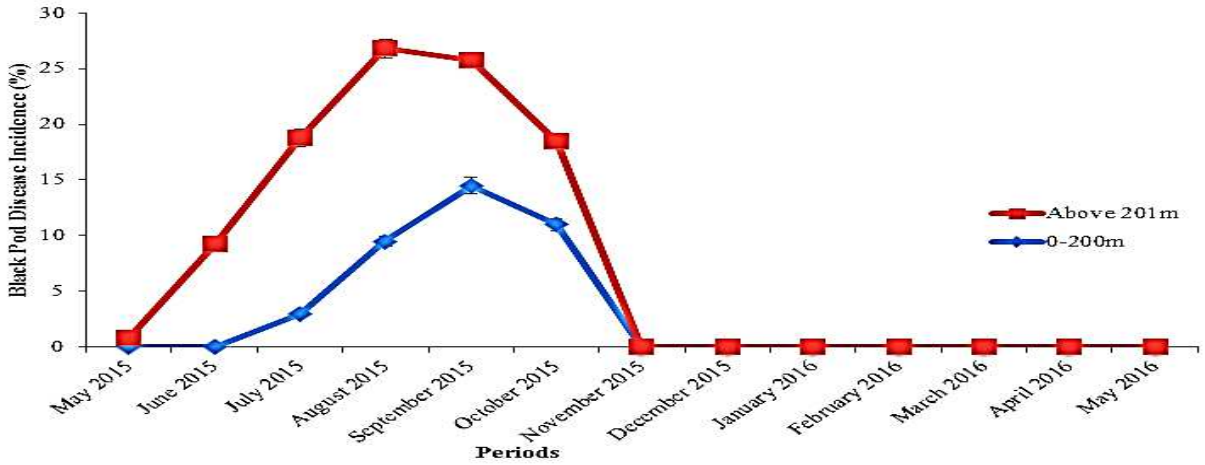

Fig 7: The altitudes of the research stations and BPD incidence

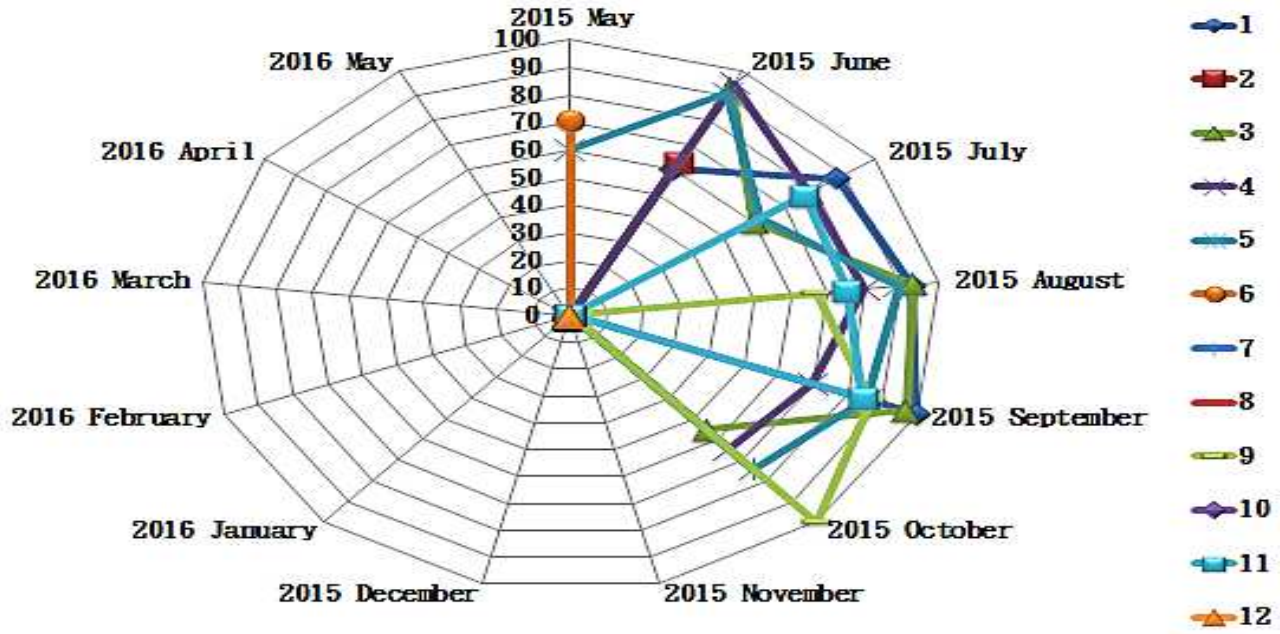

Fig 8: The intensity of BPD infection on cocoa pods in each research stations (2015/2016).

Table 6: A projection of BPD infection on cocoa pods in Ogun, Ondo, Osun and Oyo (2015/2016)

	BPD Severity (%)			
Period	**Ondo**	**Osun**	**Ogun**	**Oyo**
05/2015	00.0[b]	30.0[a]	00.0[b]	na
06/2015	76.7[b]	93.0[a]	00.0[c]	na
07/2015	73.8[b]	70.1[c]	00.0[d]	76.7[a]
08/2015	92.9[a]	84.6[b]	66.7[d]	75.0[c]
09/2015	98.3[a]	77.9[d]	86.7[b]	84.3[c]
10/2015	27.5[c]	69.5[b]	100.0[a]	00.0[d]
11/2015	00.0[a]	00.0[a]	00.0[a]	00.0[a]
12/2015	00.0[a]	00.0[a]	00.0[a]	00.0[a]
01/2016	00.0[a]	00.0[a]	00.0[a]	00.0[a]
02/2016	00.0[a]	00.0[a]	00.0[a]	00.0[a]
03/2016	00.0[a]	00.0[a]	00.0[a]	00.0[a]
04/2016	00.0[a]	00.0[a]	00.0[a]	00.0[a]
05/2016	00.0[a]	00.0[a]	00.0[a]	00.0[a]

Means with the same alphabets across the row are not significantly different at P<0.05 using Duncan Multiple Range Test (DMRT) for separation of statistically significant means. **na** – not available

Table 7: The influence of altitude on black pod disease severity in Southwest Nigeria

	Height Above Sea Level	
Duration	**0-200m**	**Above 200m**
05/2015	0.0[b]	15.0[a]
06/2015	0.0[b]	84.8[a]
07/2015	38.4[b]	71.9[a]
08/2015	70.9[b]	88.7[a]
09/2015	85.5[a]	88.1[b]
10/2015	50.0[a]	48.5[a]
11/2015	0.0[a]	0.0[a]
12/2015	0.0[a]	0.0[a]
01/2016	0.0[a]	0.0[a]
02/2016	0.0[a]	0.0[a]
03/2016	0.0[a]	0.0[a]
04/2016	0.0[a]	0.0[a]
05/2016	0.0[a]	0.0[a]

Means with the same alphabets across the row are not significantly different at P<0.05 using Duncan Multiple Range Test (DMRT) for separation of statistically significant means.

Discussion

Diseases and pests attack on cocoa were noticed to have a link with seasonal changes from the assessment conducted in 2015/2016. [14,15] suggested that cocoa is highly sensitive to changes in weather pattern which can greatly influence its yield and productivity, and predispose it to a greater extent to BPD infection. BPD outbreak and Cherelle wilt were the most common diseases recorded in 2015/2016, while insects and pests invasion were less prominent in Southwest, Nigeria. This was a consolidation of the report of [16] who stated that some areas in Southwest, Nigeria have been identified as hotspots for black pod disease invasion and modern disease management strategies are urgently needed.

There was early upsurge of BPD outbreak in some Stations and the period of massive disease outbreak was in August. The same pattern of BPD outbreak was described by [5] in the tropical regions of Ghana, who stated that primary infections usually occur around June, but massive BPD outbreak occur between August and October. A decline in BPD outbreak was recorded in the dryer periods of the research year. This was in agreement with the reports of [17], they affirmed that black pod disease is prevalent only in the wet season. In 2015, Osun State had the first reported incidence of BPD outbreak. In June 2015, there was a wide spread of BPD outbreak from Osun to Ondo, subsequently to Oyo and lastly, to Ogun State; suggesting the possible origin and mode of spread of BPD in Southwest, Nigeria. This was a confirmation of the report given by [16] that identified Osun State as one of the nation's reservoir for the infectious pathogen responsible for BPD outbreak.

A comparison between the two sets of farm altitudes suggest that the activity of the pathogen was closely affected by the altitude of the sample Stations. It was learned in connection with this research that the sample Stations situated at high altitudes had early start to BPD outbreak and the magnitude of the disease on the average was enormous compared to those sample Stations located at lower altitudes. The altitude and topography of the farm played a pertinent role in BPD establishment. It was observed that the trend of black pod disease outbreak in Southwest, Nigeria was logarithmic with a very slow start in May and a steady increase till August followed by a decline in BPD outbreak from September to the end of the dry Season. The number of cocoa pods destroyed by the disease was more in September and least in the dryer parts of the season. [13] also determined the trend of cocoa pod loss to BPD and the factors responsible for BPD outbreak in Nigeria. The level of cocoa pod infected rose from June to September. This was in line with the research work of [18,19]. They noted that losses can reach up to 100% of the cocoa production in smallholders' plantations when no control measures are taken.

Massive destruction of cocoa pods was observed very early in cocoa farmlands located only in Osun state (May, 2015) during the rainy season. The focal point for BPD appears to be Osun, spreading through Ondo, Oyo and Ogun States. This same sequence was earlier noticed by [16] who identified Osun State as a potential BPD terrain. There was massive cocoa pod infection recorded early within the research period for cocoa farmlands in higher altitude (above 200m) and none in areas located in lower altitude[20]. Although, the rate of cocoa pod destroyed monthly increased in both areas with time, research Stations on higher altitude were more affected by the disease. Although, no research work was available to affirm this report, [5] suggested a similar possibility.

Conclusion

It was established by the research conducted that BPD was and still is a major threat to cocoa farmers in Southwest, Nigeria. The areas under severe BPD attack were noted and the possible periods of BPD infection determined. Farmers in Nigeria are indeed tired of the huge loss incurred by the ravaging disease on annual basis, cocoa farming is fast becoming a myth in Nigeria; unless concerted efforts towards black pod disease management is put in place, cocoa farming will go into extinction in the nearest future.

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