T3 Pests and Diseases

IMPACT OF CLIMATE CHANGE ON TIMING AND FREQUENCY OF FUNGICIDE APPLICATION FOR THE CONTROL OF *PHYTOPHTHORA* POD ROT OF *CACAO* IN NIGERIA

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ABSTRACT

Cocoa production is an important economic activity in growing ecologies of Nigeria. the tree *Theobroma cacao* is prone to many diseases, among which pod rot caused by *Phytophthora* species is major and resulted into economic losses if not managed. Hence, an effective crop protection strategy is a main factor in cacao production in Nigeria. A regular application of copper- based fungicides during cropping season is being practice by farmers, but impact of climate change on the efficacy of these fungicides in management of *Phytophthora* pod rot is of majr concern. Field trials were conducted in 2014, 2015 and 2016 in Ibadan, Oyo State (Lat. 7.216ºN, Long. 3.852ºE) Nigeria. The study was conducted by application of copper-1-oxide 60% + metalaxyl 12% WP between May and October each year with three spray regime (fortnight monthly-spray, monthly-spray and no spray application). The regression statistics of the three weather parameters and black pod disease incidence indicates strong relationship and high R-square value; weather parameters significantly affect the black pod incidence in cocoa season in the trial location. Generally, there was a positive correlation between black pod incidence and relative humidity (r= 0.19, 0.53) except in year 2016 which recorded a negative linear correlation (r= -0.19). Negative correlation (r= -0.54) was recorded between black pod incidence and temperature in year 2014 and 2015, while it was positive (r=0.53) in 2016. The linear relationship between black pod disease and rainfall shows a negative correlation (-0.42). Effect of weather vis-à-vis relative humidity, temperature and rainfall was established both in temporal and spatial distribution of pod rot incidence in cocoa production, The effect of fungicide application on cocoa production was not significant and environmental factors influencing development of *Phytophthora* pod rot were both positively and negatively correlated in the trial location.

Keywords: *Cacao, Phytophthora pod rot, fungicide application, timing, climate change*

INTRODUCTION

Climate is a very important factor in agriculture as it sets the limit for the agricultural activity in any area or ecological zone of the world. The temperature, rainfall, humidity, photo-period and altitude are the major components of climate which interact to produce the local weather. Adverse effects of climate change continue to be a major threat to rural livelihoods (Pouliott *et.al*, 2009). The sensitivity of cocoa production to change from length and intensity of sunshine, rainfall and water application, soil condition and temperature due to evapo-transpiration effects is very high. Climate change also plays a major role in altering the development of cocoa pests and pathogens and shifting their interactions (Oyekale *et al,* 2009) which implies reduction in crop yields and out-turns and negative impact on income and livelihood of farmers. Climate change imposes constraints to development especially among smallholder farmers whose livelihoods mostly depend on rain-fed agriculture (IPCC, 2007; Tanner and Mitchell, 2008). Cocoa black pod disease is one of the major diseases affecting the cocoa production in Nigeria and in other producing nations worldwide. Black pod diseases account for quite a lot of cocoa production losses by attacking the ripened or very young pods (Opoku *et al*, 1999) and the diseases are closely related to the pattern of rainfall distribution. It is more prevalent in damp situations with utmost pod infection in years when the short dry period from July to August is very wet. The climate variables influenced the cocoa black pod disease incidence and it is important to quantify the black pod disease variation due to the effect of climate variables Chang *et al.,* (2016). Changing climate can also alter the development of pests and diseases and modify the host's resistance and more importantly, the black pod disease is a major threat to cocoa production when the relative humidity is very high (Anim-Kwapong and Frimpong, 2005).

This paper however, is a preliminary investigation of the effect of climate variables on the cocoa black pod disease incidence in selected growing ecologies of Nigeria.

MATERIALS AND METHODS

A mature and optimally bearing cocoa plots were selected in Ibadan, Oyo State (Lat. 7.216^{o}N, Long. 3.852^{o}E) Nigeria for the field trials of effect of climate change on *Phytophthora* pod rot incidence on cacao during the fruiting season of 2014, 2015 and 2016. The copper-1-oxide 60% + metalaxyl 12% WP – based fungicide was applied to control *Phytophthora* pod rot disease on cacao between May and October each year and black pod incidence records were taken. The selected cacao plots were subjected to three spray application strategies: Alternate monthly-spray, monthly-spray and no spray application.

Information collected on incidence of *Phytophthora* pod rot, weather parameters in the study locations and subjected to correlation and regression analysis to determine effect of weather situation on disease prevalence and management strategy

RESULTS

Analysis of Variance (ANOVA)

Regressing the three parameters on incidence of black pod disease, the result shows a significant effect on pod rot incidence at $\alpha = 0.05$ (Table 1). The regression statistics of the three weather parameters on black pod disease incidence show 0.9785 as strength of relationship and R^2 as 95.7%. The weather parameter significantly affect black pod incidence in 2014 crop season.

Also the effect of weather parameters on black pod disease incidence (Table 2) shows a correlation coefficient of 0.8766 and R^2 of 76.84% showing significant effect of the weather on black pod incidence in 2015 crop season.

In the 2016 crop season, the effect of weather parameters were also significant on the incidence of black pod disease also at $\alpha = 0.05$ (Table 3). The regression statistics of the three weather parameters on black pod disease incidence show 0.6648 as strength of relationship and R^2 as 44.20%. The weather parameter significantly affect black pod incidence, however the level of significant was low compare to the effect recorded in 2014 and 2015 crop seasons.

Table 1: Regression and ANOVA summary output (2014)

Regression Statistics	
Multiple R	0.978491043
R Square	0.957444722
Adjusted R Square	0.893611805
Standard Error	6.965128624
Observations	6

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	3	2182.973966	727.657989	14.99923	0.063148915
Residual	2	97.02603351	48.5130168		
Total	5	2280			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-524.2533949	118.7990586	-4.4129423	0.047706	-1035.404489	-13.10230099	-1035.4	-13.1023
Relative humidity	6.096633819	1.467714595	4.15382789	0.05336	-0.218432389	12.41170003	-0.21843	12.4117
Temperature	-0.059691184	0.404287887	-0.1476452	0.896163	-1.799201563	1.679819194	-1.7992	1.679819
Rainfall	0.215775057	0.03427323	6.29573157	0.024313	0.06830925	0.363240864	0.068309	0.363241

$Y = -524.25+6.09X_1-0.06X_2+0.22X_3+e$, Where Y is the estimated black pod incidence, X_1 is relative humidity, X_2 is temperature, X_3 is rainfall and e is the error terms

Table 2: Regression and ANOVA summary output (2015)

Regression Statistics	
Multiple R	0.876581402
R Square	0.768394954
Adjusted R Square	0.073579815
Standard Error	15.49606763
Observations	5

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	3	796.6719	265.5573	1.105898	0.588199903
Residual	1	240.1281	240.1281		
Total	4	1036.8			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-62.49106701	468.9392	-0.13326	0.915661	-6020.928266	5895.94613	-6020.93	5895.946132
Relative humidity	1.277165443	1.848472	0.690931	0.615091	-22.20989235	24.7642232	-22.2099	24.76422324
Temperature	-0.749431469	15.0634	-0.04975	0.968353	-192.1480895	190.649227	-192.148	190.6492266
Rainfall	-0.122877479	0.088531	-1.38796	0.397468	-1.247772859	1.0020179	-1.24777	1.002017902

$Y = -62.49+1.28X_1-0.75X_2-0.22X_3+e$, Where Y is the estimated black pod incidence, X_1 is relative humidity, X_2 is temperature, X_3 is rainfall and e is the error terms

Table 3: Regression and ANOVA summary output (2016)

Regression Statistics	
Multiple R	0.664833937
R Square	0.442004163
Adjusted R Square	-0.394989592
Standard Error	52.74449018
Observations	6

ANOVA

	Df	*SS*	*MS*	*F*	*Significance F*
Regression	3	4407.371	1469.124	0.52808538	0.706140632
Residual	2	5563.962	2781.981		
Total	5	9971.333			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	258.6619746	666.7694	0.387933	0.73546204	-2610.215135	3127.539084	-2610.215135	3127.539084
Relative humidity	-3.40637175	4.955305	-0.68742	0.5628308	-24.727327	17.9145835	-24.727327	17.9145835
Temperature	3.945824838	14.83101	0.266052	0.81511586	-59.86686548	67.75851516	-59.86686548	67.75851516
Rainfall	-0.256330157	0.366017	-0.70032	0.55622879	-1.831175084	1.31851477	-1.831175084	1.31851477

$Y = 258.66-3.41X_1+3.95X_2-0.26X_3+e$, Where Y is the estimated black pod incidence, X_1 is relative humidity, X_2 is temperature, X_3 is rainfall and e is the error terms

In the first year trial, the linear relationship exists between black pod incidence and relative humidity. There is a very weak positive correlation (r= 0.19) between black pod incidence and relative humidity, thus high relative humidity could bring about increase in black pod disease.

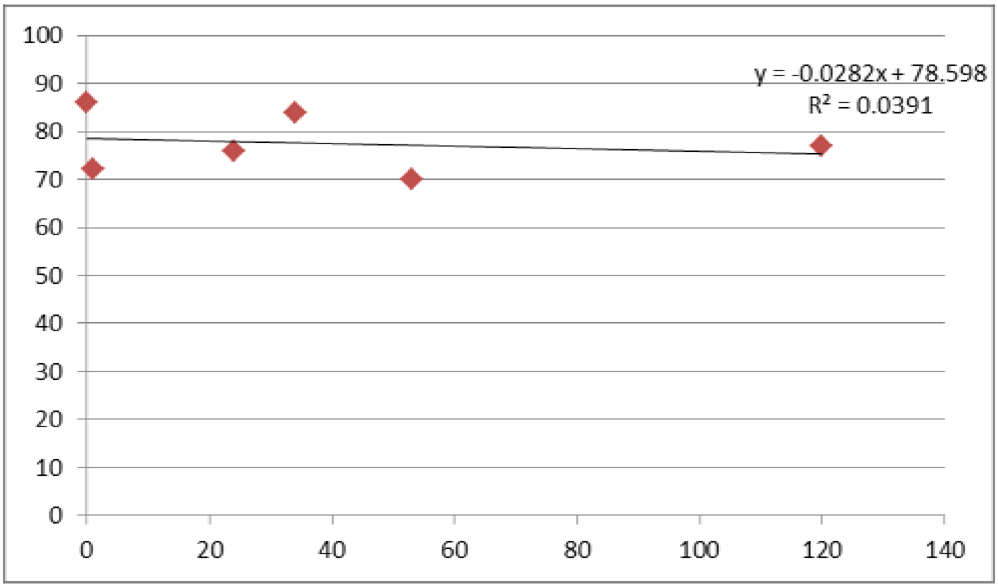

Figure 1: Correlation of black pod incidence and realtive humidity (2014)

Moderate negative correlation (r= -0.54) was recorded between black pod incidence and temperature in the study location, and increase in temperature will result in reduction of black pod disease. Also a moderate negative correlation (r= -0.43) was recorded between black pod incidence and amount of rainfall.

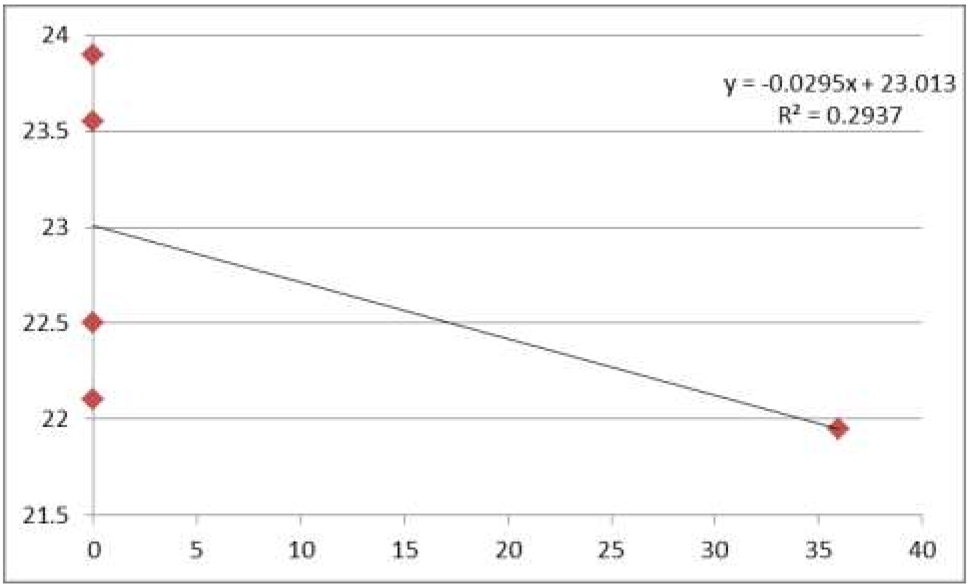

Figure 2: Correlation of black pod incidence and temperature (2014)

The finding revert the initial believe by farmers that rainfall bring about increase in black pod disease, however the status of relative humidity depict a significant factor of black pod disease.

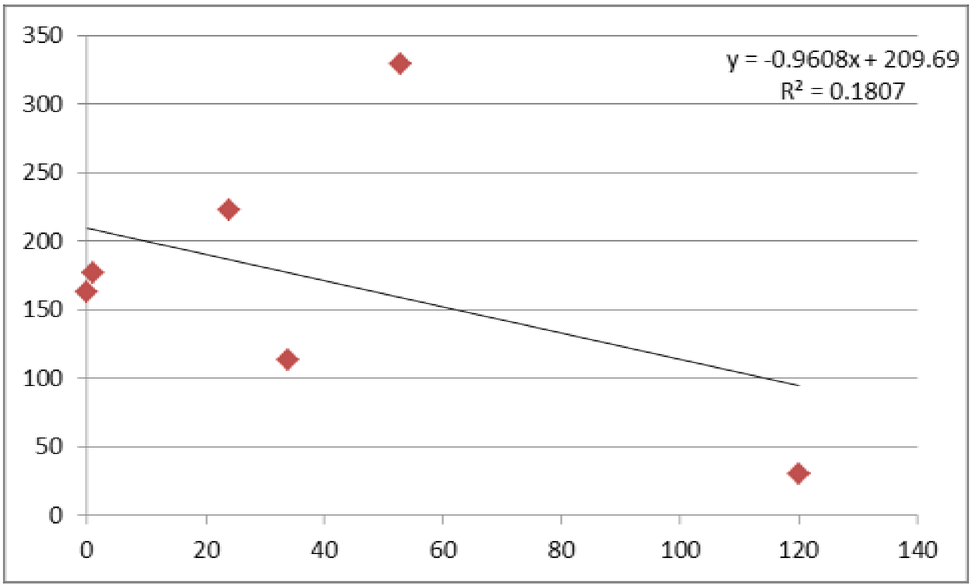

Figure 3: Correlation of black pod incidence and rainfall (2014)

The second year trial showed that a moderate positive correlation (r=0.53) was recorded in black pod disease and relative humidity. This correlation between black pod incidence and relative humidity was however stronger that what obtained in year 2014. Thus, increase in relative humidity result into a much more significant increase in black pod disease than recorded in year 2014.

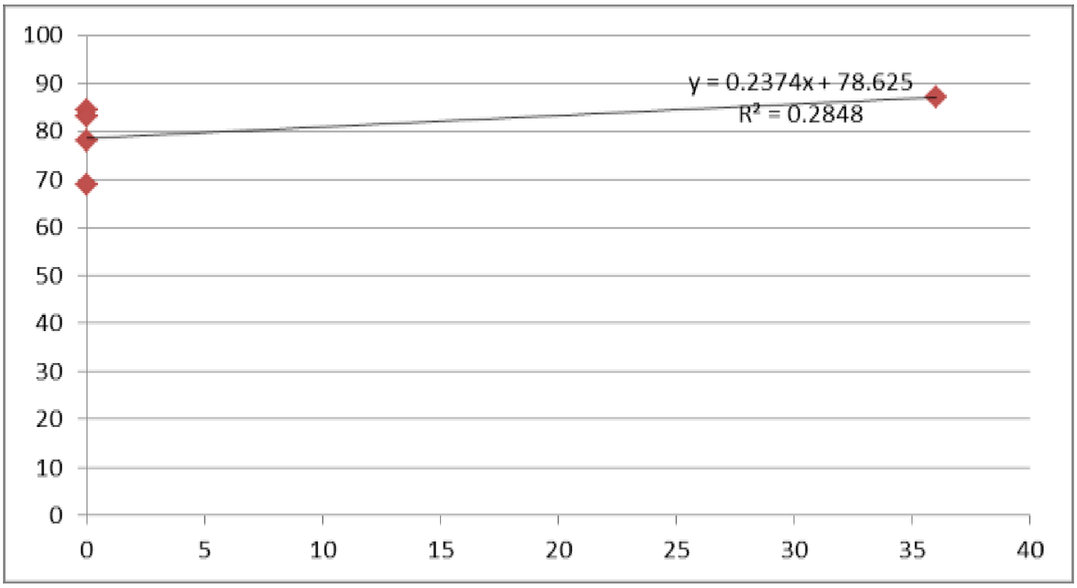

Figure 4: Correlation of black pod incidence and realtive humidity (2015)

A trend of moderate negative correlation (r= -0.54) was recorded in the relationship between black pod incidence and temperature of the environment, and similar to the year 2014 which shows a correlation r= -0.54.

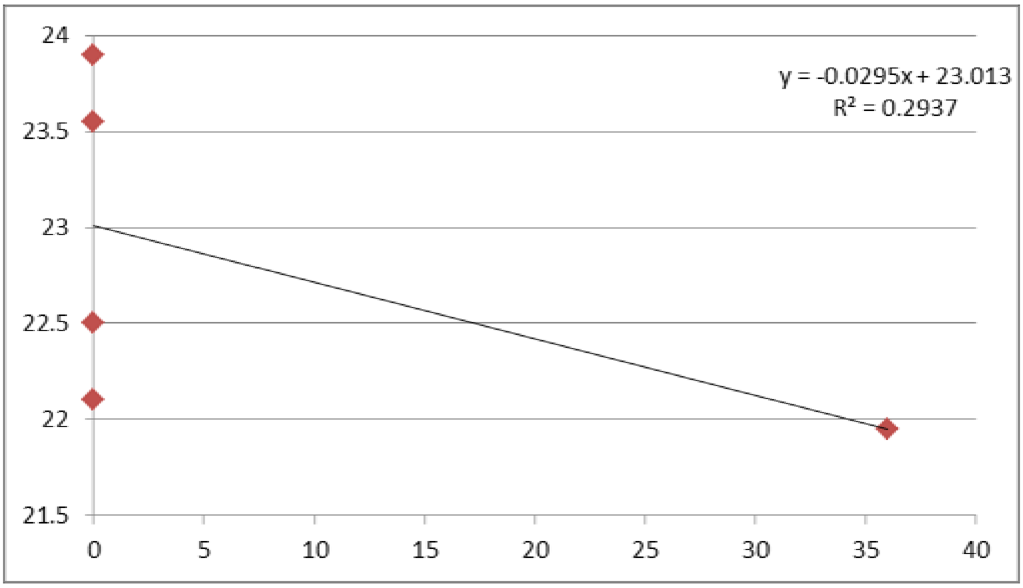

Figure 5: Correlation of black pod incidence and temperature (2015)

The linear relationship between black pod disease and rainfall in year 2015 shows a strong negative correlation (r= -0.64) and this is stronger than the relationship recorded for these two variables in year 2014.

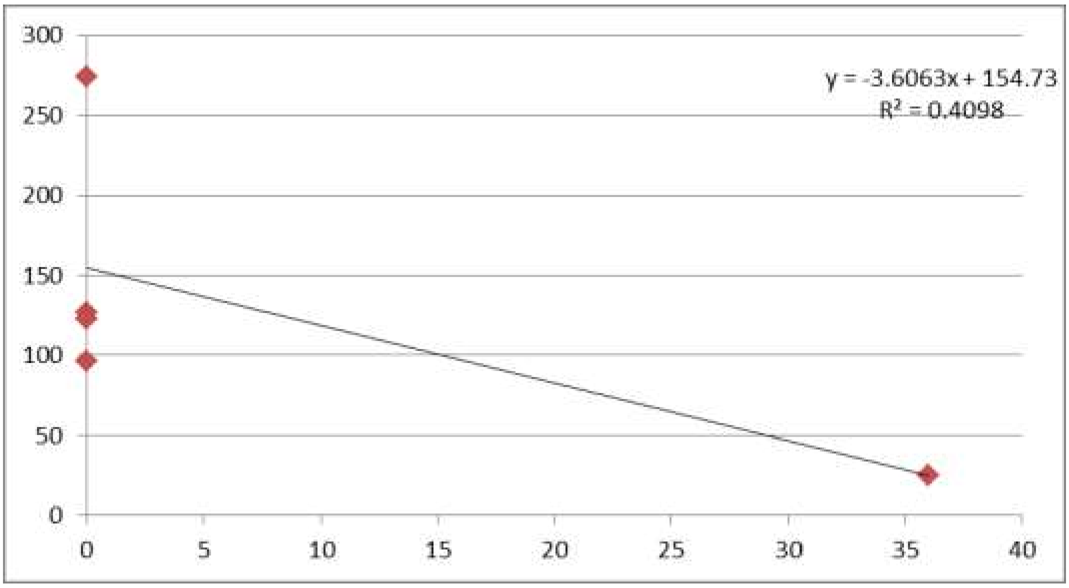

Figure 6: Correlation of black pod incidence and rainfal (2015)

The result of the third year trial depicts the effect of climate change on black pod incidence and showed a different dimension in year 2016 as a negative linear correlation (r= -0.19) was recorded between black pod disease and relative humidity.

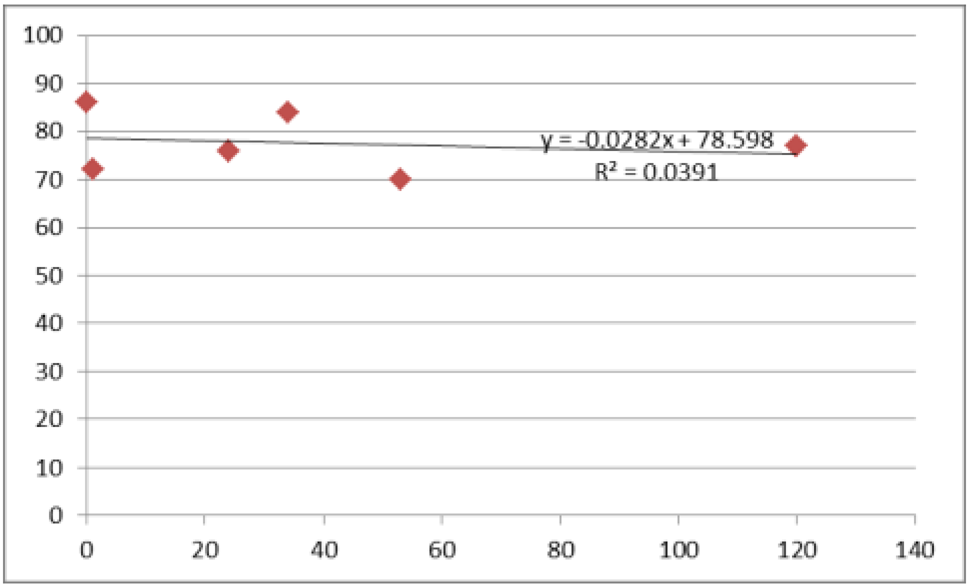

Figure 7: Correlation of black pod incidence and realtive humidity (2016)

Though the relationship was a very weak correlation, it however differ significantly from positive very weak and moderate positive correlation recorded in year 2014 and 2015 respectively.

Another variation in effect of climate on black pod disease was also observed in the relationship between black pod incidence and temperature of environment. A moderate positive correlation (r=0.53) was recorded in year 2016 while moderate negative correlation were recorded in both year 2014 and 2015 with correlation value of -0.54.

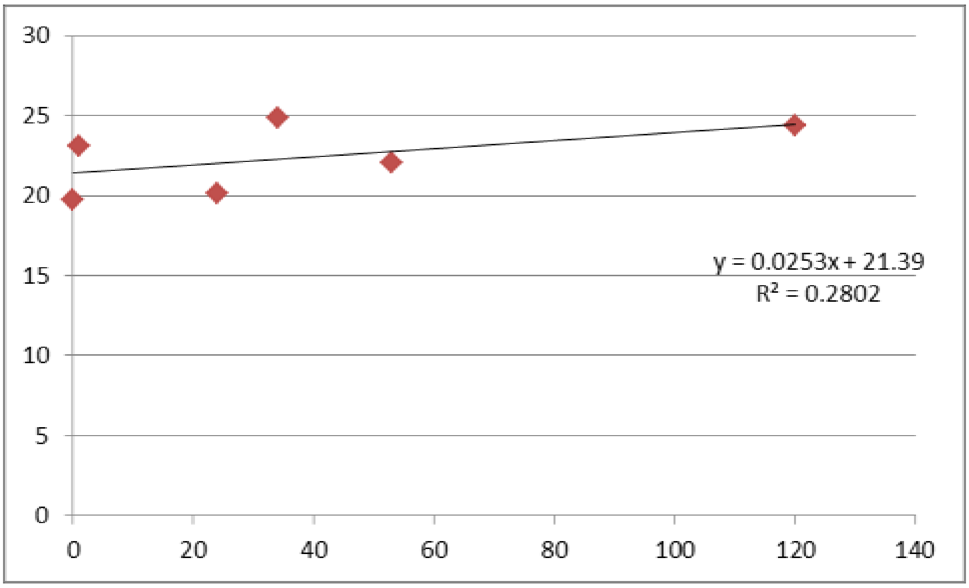

Figure 8: Correlation of black pod incidence and temperature (2016)

The relationship between black pod disease and rainfall show moderate negative correlation (r= -0.43) in year 2016 which is similar to the trend of high rainfall results into reduction of black pod incidence recorded in both year 2014 and 2016.

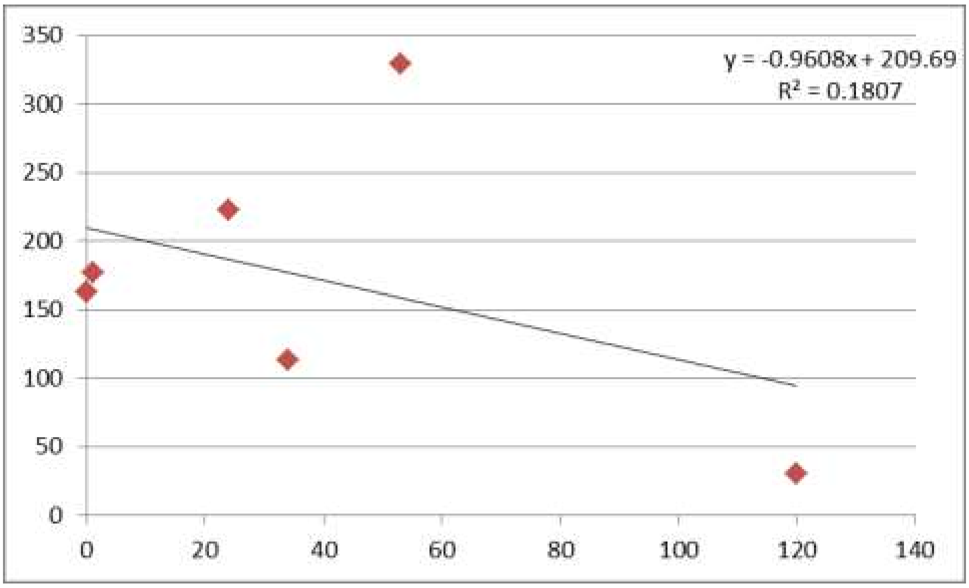

Figure 9: Correlation of black pod incidence and rainfal (2016)

Effect of weather vis-à-vis relative humidity, temperature and rainfall was established both in temporal and spatial distribution of pod rot incidence in cocoa production, The regression statistics of the three weather parameters and black pod disease incidence indicates strong relationship and high R^2 values, weather parameters significantly affect the black pod incidence in cocoa season in the trial location.

DISCUSSION

Significant effect and differences were recorded in the weather variable and the incidence of black pod disease in study location, this however negate the earlier findings of Lawal and Emaku (2007) which reported that the effect of parameters on Black pod disease incidence shows a low correlation coefficient and R-square value with no significant effect or difference between the variables. The relationship between black pod disease incidence and rainfall was reported by Lawal and Emaku (2007) to be inverse (r=-0.0025) in a study conducted in Ibadan. This corroborates the findings in this study as correlation coefficient r = -0.4251, -0.6402 and -0.4251 were recorded in 2014, 2015 and 2016 crop seasons in Ibadan. A positive but weak relationship (0.0030) was reported between humidity and black pod incidence in Ibadan, this is similar to the findings in this study except for the 2016 season which recorded weak negative correlation between black pod incidence and relative humidity. Lawal and Emaku (2007) also reported a positive relationship (0.37) between temperature and black pod incidence; this was also recorded in year 2016 crop season. However, the temperature increase is not the cause of high black pod disease incidence but the high humidity usually in the morning among other contributing factors.

CONCLUSION

Positive correlation was recorded between black pod incidence and relative humidity with exception of 2016. Negative correlation in black pod incidence and temperature also except in 2016 season and negative relationship between black pod disease and rainfall in the selected years. The effect of weather was established both in temporal and spatial distribution of pod rot incidence in cocoa production, the weather parameters and black pod disease incidence indicates strong relationship and high R-square value and significantly affect the black pod incidence in cocoa season in the trial location. A model is required to be developed in Nigeria, which could be used to forecast black pod incidence to assist farmers determine timely application of fungicide and cultural practices to control black pod incidence.

REFERENCES

Anim-Kwapong, G. and Frimpong, E. (2005). *Vulnerability of Agriculture to Climate Change Impact of Climate Change on Cocoa Production*. Accra, Ghana.

Chang, A.L.S., Ramba, H., Jaaffar, A.K.M., Phin, C.K. and Mun, H.C. (2016). Effect of climate variables on cocoa black pod incidence in Sabah using ARIMAX model. AIP Conference Proceedings 1739, 020077 (2016); doi: http://dx.doi.org/10.1063/1.4952557

Oyekale A.S., Bolaji, M.B. and Olowa, O.W. (2009). The effect of climate change on Cocoa production and Vulnerability Assessment in Nigeria. *Agricultural Journal*, Vol. 4 issue 2, Pp.77-85.

(IPCC) Intergovernmental Panel on Climate Change (2007a). Climate Change 2007; impacts. Adaptation and Vulnerability. Cambridge: Cambridge University Press.

(IPPC) Intergovernmental Panel on Climate Change (2007b). Climate Change: Synthesis Report. Contribution of working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change.

Lawal, . O. and Emaku, L. A. (2007). Evaluation of the effect of climatic changes on Cocoa production in Nigeria. African Crop Science Conference Proceedings Vol. 8. pp. 423- 426.

Opoku, I.Y., Akrofi, A.Y., Appiah, A.A. (2007). Assessment of Sanitation and Fungicide Application directed at Cocoa Tree Trunks for the control of *Phytophthora black pod* Black pod infections in pods growing in the canopy. Eur. J. plant pathol. 2007:117:167-175.

Pouliotte, J., Smit, B., and Westerhoff, L. (2009). Adaptation and Development: Livelihood and Climate Change in Subarnadad, Bangladesh. Climate Change and Development, 1, 31-46. doi: 10.3763/cdev. 2009. 0001.

Tanner, T., and Mitchell, T. (2008). Entrenchment or Enhancement: Could Climate Change Adaptation Help to Reduce Chronic Poverty? Institute of Development studies Bulletin Volume 39 (4 September), 6-15.