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CONTROL OF PARASITIC DISEASES IN COCOA USING TIME SERIES ANALYSIS

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Abstract: Ecological disturbances exert an influence on the emergence and proliferation of parasitic diseases, including, Black pod disease. Each environmental change, whether occurring as a natural phenomenon or through human intervention, changes the ecological balance and context within which disease hosts or vectors and parasites breed, develop, and transmit disease. This paper deals with these important diseases in the Ghanaian cocoa industry. The objective is to find out whether rainfall and temperature have any effect on these diseases so that plans can be made to control them. The paper has identified the models of these important cocoa diseases in Western region. The results from this work show that the dependence of phytophthora on both temperature and rainfall was not significant and rainfall may not have much influence on black pod, if any. It also came out that, if the infected trees are cutoff and burnt, the other trees may not be infected.

Keywords: Parasitic diseases, Time Series Analysis, Akaike Information Criteria.

Introduction

Ghana is one of the major producers of cocoa in the world. The crop contributed about 3.4% to total gross domestic product annually and an average of 29% to total export revenue between 1990 and 1999 (Anon., 2001) and 22% between 2000 and 2002 (Anon., 2003).
Black pod disease caused by Phytophthora palmivora (Burt) is a facultative parasite and the most widely distributed disease of cocoa. Infection, usually at either end of the pod cause charcoal brown necrotic spots which spread rapidly, later turning black with a very sharp line of demarcation between diseased and healthy host tissue. The beans of the pod become partially or wholly destroyed by brown coloured rot. Young leaves are also causes - flower produces a leaf spotting in which the spots are greenish white with brown rnargins. Pythium graminicolem C.B. causes: a Rhizome and root rot. These diseases can be controlled by spraying 1% B.M. or 0.2% D.M. 45 (Dithane M-45). Until 1985, Phytophthora palmivora was the only known causal agent for Phytophthora pod rot (black pod) disease in Ghana. The appearance of Phytophthora megakarya in 1985 in Ghana added a new dimension to the disease complex of cocoa in the country. Phytophthora disease incidence and crop losses vary from one locality and farm to another (Akrofi et al., 1997) and also fluctuate with the seasons (Dakwa, 1973).
There is therefore the need to investigate the dynamics and causes of these diseases. In this paper, we set out the task of modelling and analysing some of these processes and making inferences. The objectives of this paper are three-fold:

i. To identify the dynamics of some important cocoa diseases, namely: Phytophthora palmivora and Phytophthora megakarya.
ii. To find relationship between the prevalence of these diseases, rainfall, and temperature;
iii. To determine how such dependence if any could affect management practices.

Timely application of strategic integrated control measures is imperative for efficient disease management. In Ghana, the integration of cultural and chemical methods has been effective against P. megakarya while cultural practices alone, including judicious shade management, pruning, removal of basal chupons, mistletoes and frequent harvesting, can be sufficient to control P. palmivora (Asare-Nyako, 1974; Akrofi et al., 1997). Cultural practices are not only essential for increasing yield, but also provide the right environment for the efficient

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performance of recommended fungicides (Akrofi et al., 1997). Frequent harvesting, for instance, saves partly infected mature pods and reduces sources of sporangial inoculum while shade management, opening up the canopy and reducing basal chupons, enhances air circulation in the cocoa farm, thereby reducing disease incidence (Lass, 1985).

METHODOLOGY

In both diseases, we shall use the construction of autoregressive time series models and the construction of autoregressive exogenous models to relate the diseases to rainfall and temperature data.

Data

Secondary data were collected from the Agricultural Extension Services of Western region on some important cocoa diseases including Phytophthora palmivora and Phytophthora megakarya from January 1992 to December 1997. Values were given on prevalence, total count and percentage mortality. The data were processed to get the values on monthly basis. This was done by finding the total mortality and total count in each month. The two values were used to calculate the percentage mortality for that particular month. This was done for each of the diseases. Secondary data on rainfall, minimum temperature and maximum temperature were also collected from the meteorological department of Western region, from January 1992 to December 1997.

Estimation of model parameters

The method of least squares was used to estimate the regression coefficients and was given by:

$$\hat{b} = (X'X)^{-1} X'Y$$

Where Y represents the dependent variable, in this case, the set of monthly percentage mortality and $X = Y_{t-1}$

Adequacy test

To check for adequacy, the autocorrelations of the residuals were examined using the Q statistics. For the model $AR(p, d, q)$ to be adequate, the calculated value of Q should be less than x^2 with $k - p - q$ degrees of freedom where k is the first k autocorrelations being checked, p is the order of the AR process and q is the order of the MA process. Q is given by the expression

$$Q = n(n+2)\sum_{i}^{k}\left(\frac{r_i^2}{n-k}\right)$$

where n is the length of the time series or number of lags. For all the diseases, the first twenty-four autocorrelations of the residuals were used to calculate the values for Q. Table 3.1 gives us the degrees of freedom and critical values corresponding to the various $ARIMA$ models.

Discussion

Table 1 shows the Akiake Information Criteria, the Residual Variances and the Calculated Q Values of the indicated $ARIMA$ models for Phytophthora palmivora, using the first sixty values of the data. From the table the model can be an autoregressive model of order one, $AR(1)$.

ARIMA MODEL	*A.I.C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0,0)	423.20613	65.502925	25.467
(1,1,0)	441.33408	100.02019	48.982
(2,0,0)	424.95400	66.314128	24.904
(2,1,0)	431.03888	82.039792	32.934
(1,0,1)	424.92718	66.286008	24.603
(1,1,1)	421.34822	67.789975	25.777
(0,0,1)	423.11802	65.403278	25.468
(0,1,1)	419.15920	66.926971	25.183
(0,0,2)	424.88876	66.240929	24.183
(0,1,2) (INV.)	420.93151	65.737648	26.932

Table 1 Phytophthora palmivora-using the first sixty values of the monthly percentage mortality

This does not have the least residual variance and the least Q value but for the sake of parsimony, it can be selected. When all the seventy two values are used, as shown in Table 2, we also get the best model to be an autoregressive model of order one, $AR(1)$. Auto-regressive model is the dual of a moving average model.

ARIMA MODEL	*A.I.C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0,0)	505.92031	64.134783	27.153
(1,1,0)	530.55913	99.855645	55.111
(2,0,0)	507.54957	64.688139	26.768
(2,1,0)	518.42312	82.543588	34.790
(1,0,1)	507.38176	64.459084	24.790
(1,1,1)	504.82758	66.943767	25.526
(0,0,1)	505.89112	64.108028	27.252
(0,1,1)	502.81878	65.970192	25.547
(0,0,2)	507.60163	64.737656	26.672
(0,1,2)	504.8276	66.943320	25.532

Table 2 Phytophthora palmivora disease-using monthly percentage mortality

Since it is easier to deal with an auto-regressive model we can choose the least among the AR models. In this case we can go in for the $AR(1)$ model. The ARIMA model was given as:

$$Y_t = (0.089747)Y_{t-1} + 13.929474.$$

Adequacy Test for Phytophthora palmivora Disease

For adequacy, the calculated value of Q should be less than the critical value of Q. The calculated values of Q, using the first sixty values and all the seventy-two values were 24.467 and 27.153 respectively which were all less than the critical values in the case of $AR(2)$. For $AR(1)$, the calculated values of Q, using the first sixty values and all the seventy-two values were respectively 25.467 and 26.768.

The autoregressive exogenous model of Phytophthora palmivora versus total rainfall

Phytophthora palmivora correlate best with total rainfall but the correlation was not strong. The ARX Model for Phytophthora palmivora and total rainfall was $ARX(1, 0)$. That is an autoregressive exogenous model of order one. This model had the parameters below:

$a_1 = 0.090882, \quad B_1 = 0.023624$ and $c = 11.590580$ Hence the model is of the form: $Y_t = (0.0900882)Y_{t-1} + (0.023624)X_{t-1} + 11.590580\ X_t$ is the corresponding value for total rainfall.

	MEAN	*ST.DEV.*	*R.M.S.*	*CORR.*	R^2	*F. VALUE*	*SIG.*
MAX.TEMP	31.285	2.300	64.209	0.033	0.0011	0.0744	0.786
AV. TEMP	26.731	1.363	64.233	0.026	0.0007	0.0485	0.826
MIN. TEMP	22.14	0.805	64.276	-0.005	0.00003	0.0018	0.966
TOTAL RAINFALL	102.032	80.583	62.135	0.183	0.0333	2.414	0.125*

Table 3 Summary of basic statistics-correlation and regression analysis between Phytophthora palmivora disease and the independent variables; temperature and total rainfall (using percentage mortalities)

VARIABLE	*B*	*S. E. B*	*95% CONFIDENCE INTERVAL*	*BETA*
Total Rainfall	.018037	.011609	-005116 .04191191	.182583
Constant	12.050652	1.505652	9.048369 15.052936	

Table 4 Phytophthora palmivora and total rainfall

ARX. MODEL	*A. I. C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0)	432.605	75.347	22.88*
(1,1)	450.27	114.40	42.8
2,0)	434	76.528	22.75
(2,1)	440.672	94.989	32.395

Table 5 The autoregressive exogenous analysis (arx model of phytophthora palmivora versus total rainfall using the first sixty values of percentage monthly mortality

	B	*S. E. B*	*T-RATIO*	*APPROX. PROB.*
ARX(1)	0.07616	0.133163	0.5719	0.56963
ARX(2)	-	-	-	-
TOTAL RAINFALL	0.021178	0.0147217	1.43859	0.15573
CONST.	11.9812	1.89566	6.3256	0.0004

Table 6 *ARX (1,0)* model phytophthora palmivora versus total rainfall

The tables 7 and 8 show the Akaike Information Criteria, the Residual Variances and the Calculated Q Values of the indicated Arima models for Phytophthora megakarya disease, using the first sixty values of the data and also all the seventy-two values. From the table an autoregressive model of order one, $AR(1)$ has the least residual variance of 3.8554671 and the least Akaike Information Criterion $(A.I.C)$ of 253.36202. When all the seventy-two values were used we also got the best model to be an autoregressive model of order one, $AR(1)$. This had the least residual variance of 3.40882 and the least Akaike Information Criterion $(A.I.C)$ of 294.75189.

ARIMA MODEL	*A.I.C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0,0)	249.75189	3.4088225	15.637
(1,1,0)	309.09789	4.4173056	26.598
(2,0,0)	296.54955	3.4465920	15.871
(2,1,0)	302.94802	3.9813477	20.454
(1,0,1)	296.3817	3.4382483	15.902
(1,1,1) (INV.)	291.99589	3.3407101	15.292
(0,0,1)	295.79729	3.4592373	15.055
(0,1,1)	294.16487	3.4995989	19.686
(0,0,2)	297.60157	3.4987164	15.713
(0,1,2) (INV.)	291.64085	3.2943629	14.132

Table 7 Phytophthora megakarya-using monthly percentage mortality

ARIMA MODEL	*A.I.C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0,0)	253.36202	3.8554671	13.502
(1,1,0)	264.4205	4.9901874	21.253
(2,0,0)	255.11613	3.9038261	13.398
(2,1,0)	260.4547	4.5717918	18.901
(1,0,1)	255.0022	3.8961172	13.473
(1,1,1)	253.42986	4.027491	16.713
(0,0,1)	254.37284	3.9221114	13.503
(0,1,1) (INV.)	252.33416	3.9189675	18.319
(0,0,2)	256.0517	3.9674890	13.643
(0,1,2) (INV.)	250.4935	3.6767592	14.204

Table 8 Phytophthora megakarya-using monthly percentage mortality

Adequacy Test

For adequacy, the calculated value of Q should be less than the critical value of Q. The calculated values of Q by using the first sixty values and all the seventy-two values, where 13.502 and 15.637 respectively which were all less than the critical values.

Parameters for the Univariate Model $\mathrm{AR}(1)$

The parameters were found as

$$a_1 = 0.341337 \qquad \text{and} \qquad c = 2.8453263.$$

This implies that the model is of the form

$$Y_t = a_1 Y_{t-1} + c$$

This implies that

$$Y_t = (0.3413337)Y_{t-1} + 2.8453263$$

SUMMARY OF BASIC STATISTICS

	MEAN	*ST.DEV.*	*R.M.S.*	*CORR.*	R^2	*F. VALUE*	*SIG.*
MAX.TEMP	31.285	2.300	3.531	0.305	0.093	7.175	0.009
AV. TEMP	26.731	1.363	3.606	0.271	0.075	5.561	0.021
MIN. TEMP	22.140	0.805	3.884	0.049	0.0024	0.166	0.685
TOTAL RAINFALL	102.03	80.583	3.836	-0121	0.015	1.046	0.310

Table 9 Correlation and regression analysis between phytophthora megakarya disease and the independent variables; temperature and total rainfall (using percentage mortalities)

VARIABLE	*B*	*S. E. B*	*95% CONFIDENCE INTERVAL*		*BETA*
MAX. TEMP.	.0.259704	0.096952	0.066340	0.453067	0.304918
Constant	-5.416503	3.041245	-11.482074	0.649068	

Table 10 phytophthora megakarya and maximum temperature

ARX. MODEL	*A. I. C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0)	294.02368	3.3295586	14.118*
(1,1)	309.99103	4.4104015	26.128
(2,0)	295.96316	3.3731892	14.250
(2,1)	302.28885	3.8866204	19.367

Table 11 The autoregressive analysis (arx. model) of phytophthora megakarya disease and average temperature-using the percentage monthly mortality (72 values)

ARX. MODEL	*A. I. C.*	*RES. VARIANCE*	*Q. VALUE*
(1,0)	251.547	3.683	12.245*
(1,1)	265.8545	5.02695	21.817
(2,0)	253.6077	3.74855	12.242
(2,1)	259.81215	4.43955	18.43

Table 12 The autoregressive analysis (arx. model) of phytophthora megakarya disease and average temperature-using the first sixty values of percentage monthly mortality

Bivariate analysis of phytophthora megakarya

Phytophthora megakarya correlated best with maximum temperature. The ARX model for Phytophthora megakarya and maximum temperature was an autoregressive exogenous model of order one, $ARX\ (1,\ 0)$. This model had the parameters below:

$a_1 = 0.2346317,\quad b_1 = 0.2474914 \quad \text{and} \quad c = -\ 4.90604.$

Hence the model is of the form below.

$Y_t = (0.2346317)Y_{t-1} + (0.2474914)X_t - \ 4.90604$ where X_t is the corresponding maximum temperature.

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