DEVELOPING THE PLANT DISEASE MODEL TO MANAGE THE COCOA BLACK POD DISEASE

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FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITI MALAYSIA SABAH
2019

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THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

FACULTY OF SCIENCE AND NATURAL RESOURCES
UNIVERSITI MALAYSIA SABAH
2019

UNIVERSITI MALAYSIA SABAH

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excepts, equations, summaries and references, which have been duly acknowledged.

12 September 2019

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Albert Ling Sheng Chang

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ACKNOWLEDGMENTS

I would like to thank "God – The Almighty" for providing me the gracious gifts of all strength with patience and courage bestowed upon me to overcome various challenges during the accomplishment of this thesis.

With great pleasure, I would like to express my deepest gratitude to my supervisors, Professor Dr. Ho Chong Mun, Associate Professor Dr. Chong Khim Phin, and Dr. Darmesah Gabda for their valuable guidance, precious suggestions, affectionate criticism and inspiring help in accomplishing this thesis. Without their help, I would not have brought this thesis into its present form.

I acknowledge my heartfelt thanks to Lembaga Koko Malaysia (LKM), especially the previous and present Director General of LKM, Datuk Dr. Lee Choon Hui and Datin Norhaini Udin for sponsoring my study and provided the supports in allowing me to use the LKM's facilities and field plot for my study. Besides that, I also would like to thank two Deputy Director General of LKM, Dr. Ramle Kasin and Dr. Ahmad Kamil Mohd. Jaaffar, and the Director of Cocoa Upstream Technology Division, Haya Ramba for their encouraging supports during my thesis preparation.

I would like to express my respectful gratitude to my examiners, examiner 1, examiner 2 and examiner 3 who have given a lot of input and suggestions for the improvement of my thesis.

I would also like to extend my sincerest thanks and appreciation to my supporting staff in the fields, Sarinah Ambia, Zamri Kamari, Jenrry Sompokon and Yahya Mohd. Noor for their hard work in helping me for data collection. Without their help this thesis would have never been accomplished as it should be.

I personally would like to express my sincere gratitude to my beloved parents, my late father Ling Sing Kee, my mother Wee Buoi Choo, my parent-in-law, my sisters, my colleagues, and also all my friends who have supported me with their prayers and blessings. And to the special one my beloved wife Wong Shuk Shyan, my daughter Daphne Ling Mei Ying and my son Darren Ling Yong Li who always standing by my side with all helps and cooperation at the time when I most needed it.

The last but not least, to all parties who have involved either directly or indirectly in the completion of this thesis, thank you so much for all of your help, guidance, and supports.

Thank you.

Albert Ling Sheng Chang

12 September 2019

ABSTRACT

Cocoa smallholder in Malaysia facing a problem of low productivity for the past 10 years and one of the reasons was due to the cocoa black pod disease. The resistant breeding was the best long term solution to the cocoa black pod disease problem that need a reliable screening technique to predict the disease severity progress and identify the resistance level of genotypes. As for the short term solutions, it is important to know which combination of control measures is effective in controlling the cocoa black pod disease incidence. Fungicide application was the most preferred control measure by the cocoa smallholders and can be effectively applied by forecasting when the cocoa disease incidence was likely to be at economic threat. Currently, there are no existing statistical model that can be used for predicting disease severity and estimating the area under disease progress curve to rank the genotype's resistant level in cocoa and also statistical model that can forecast the disease incidence and used in decision making for fungicide application. This study has four objectives to be achieved. The first objective is to develop the nonlinear statistical model of the cocoa black pod severity progress using Monomolecular, Exponential, Logistic and Gompertz models and followed by estimating the Area Under Disease Progress Curve (AUDPC) on four cocoa genotypes of different resistant categories (i.e. KKM 4 (susceptible), KKM 5 (moderately susceptible), BR 25 (moderately resistant) and QH1003 (resistant) at two pod development stages (i.e. young pod and mature pod). The measurements for disease severity was made daily for a duration of six days after inoculated with *Phytophthora palmivora*. The results of study has identified Gompertz model as the best fitted nonlinear model with the smallest values of the Akaike Information Criterion test and the Bayesian Information Criterion test. The second objective is to determine resistance of cocoa genotypes against the cocoa black pod disease by using AUDPC value. The results of study showed the estimated AUDPC value proved that the new protocol of screening the mature genotype's resistant level to the cocoa black pod disease severity gave 100% accuracy with similar results to the field assessment compared to standard assessment that gave 50% accuracy. The third objective is to develop a statistical model to forecast the cocoa black pod incidence by comparing ARIMA approach and ARIMAX approach. The results of the study proved ARIMAX models, known as combination linear regression and the ARIMA process performance better than ARIMA models based on the mean squared error, root mean squared error and mean absolute error. The fourth objective is to estimate losses from the cocoa black pod incidence by using the best fitted model developed in this study. The results showed integrated treatment of pruning, fungicide application and phytosanitary gave the lowest forecasted economic losses, followed by the integrated treatment of pruning and phytosanitary and then integrated treatment of fungicide application and phytosanitary. In conclusion, the Gompertz model built on disease severity in this study can potentially assist breeders to determine the genotypes' resistant level to the cocoa black pod disease while the ARIMAX model built on disease incidence can guide the cocoa farmers to decide when to apply fungicide based on the expected losses and the cost of applying fungicide.

ABSTRAK

MEMBANGUNKAN MODEL PENYAKIT TUMBUHAN UNTUK MENGURUS PENYAKIT BUAH KOKO HITAM

Pekebun kecil koko di Malaysia menghadapi masalah produktiviti yang rendah sejak 10 tahun yang lalu dan salah satu sebabnya adalah penyakit buah hitam koko. Pembiakbakaan yang rintang adalah penyelesaian jangka panjang terbaik untuk masalah penyakit buah koko hitam yang memerlukan teknik penyaringan dengan kebolehpercayaan untuk meramalkan perkembangan keparahan penyakit dan mengenal pasti tahap kerintangan genotip. Bagi penyelesaian jangka pendek, adalah penting untuk mengetahui kombinasi kawalan yang berkesan dalam mengawal kejadian penyakit buah hitam koko. Penggunaan racun kulat adalah kawalan yang paling disukai oleh pekebun kecil koko dan boleh digunakan dengan berkesan dengan meramal bila kejadian penyakit buah hitam koko mungkin berada pada ancaman ekonomi. Pada masa ini, tidak ada model statistik sedia ada yang boleh digunakan untuk meramalkan keparahan penyakit dan menganggarkan kawasan di bawah keluk perkembangan penyakit untuk menilai tahap kerintangan genotip dalam koko dan juga model statistik yang boleh meramalkan kejadian penyakit dan digunakan dalam membuat keputusan untuk aplikasi racun kulat. Kajian ini mempunyai empat objektif untuk dicapai. Objektif pertama adalah untuk membangunkan model statistik tak linear untuk perkembangan keparahan buah hitam koko menggunakan model Monomolecular, Eksponen, Logistik dan Gompertz dan diikuti dengan menganggarkan luas di bawah keluk perkembangan penyakit (AUDPC) pada empat genotip koko berlainan kategori kerintangan (iaitu KKM 4 (rentan), KKM 5 (sederhana rentan), BR 25 (sederhana rintang) dan QH1003 (rintang) di dua peringkat pembangunan buah koko (iaitu buah muda dan buah matang). Pengukuran untuk keparahan penyakit dibuat setiap hari selama enam hari selepas diinokulasi dengan Phytophthora palmivora*. Dapatan kajian telah mengenalpasti model Gompertz sebagai model tak linear tersuai terbaik dengan nilai terkecil dari ujian Kriteria Maklumat Akaike dan ujian Kriteria Maklumat Bayesian. Objektif kedua adalah menentukan rintangan genotip koko terhadap penyakit buah hitam koko dengan menggunakan nilai AUDPC. Dapatan kajian menunjukkan nilai anggaran AUDPC membuktikan bahawa protokol baru untuk menyaring paras kerintangan genotip yang matang terhadap keparahan penyakit buah hitam koko memberikan ketepatan 100% dengan hasil yang serupa dengan penilaian lapangan berbanding penilaian piawai yang memberikan ketepatan 50%. Objektif ketiga adalah membangunkan model statistik untuk meramalkan kejadian buah hitam koko dengan membandingkan pendekatan ARIMA dan pendekatan ARIMAX. Dapatan kajian membuktikan model ARIMAX, yang dikenali sebagai kombinasi regresi linear dengan proses ARIMA memberikan prestasi yang lebih baik daripada model ARIMA berdasarkan ralat min kuasa dua, ralat punca min kuasa dua dan ralat min mutlak. Objektif keempat adalah untuk menganggarkan kerugian dari kejadian buah hitam koko dengan menggunakan model tersuai terbaik yang dibangunkan dalam kajian ini. Keputusan menunjukkan rawatan bersepadu seperti pemangkasan, aplikasi racun kulat dan fitosanitari memberikan ramalan kerugian ekonomi yang paling rendah, diikuti dengan rawatan bersepadu seperti*

pemangkasan dan fitosanitari dan kemudian rawatan bersepadu melibatkan aplikasi racun kulat dan fitosanitari. Kesimpulannya, model Gompertz yang dibangunkan atas keparahan penyakit dalam kajian ini berpotensi membantu pembiakbaka untuk menentukan tahap kerintangan genotip terhadap penyakit buah hitam koko manakala model ARIMAX yang dibangunkan atas kejadian penyakit dapat membimbing petani koko untuk membuat keputusan bila menggunakan racun kulat berdasarkan kepada jangkaan kerugian dan kos untuk mengaplikasi racun kulat.

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ACF	-	Autocorrelation Function
ADF	-	Augmented Dickey–Fuller
AIC	-	Akaike Information Criterion
ANOVA	-	Analysis of Variance
AR	-	Autoregressive
ARIMA	-	Autoregressive Integrated Moving Average
ARIMAX	-	Autoregressive Integrated Moving Average with Exogenous Variables
BIC	-	Bayesian Information Criterion
CRDC	-	Cocoa Research and Development Center
DAI	-	Day after inoculation
DF	-	Dickey–Fuller
DMRT	-	Duncan's Multiple-Range Test
MA	-	Moving Average
MAE	-	Mean Absolute Error
MLE	-	Maximum Likelihood Estimation
MSE	-	Mean Square Error
PACF	-	Partial Autocorrelation Function
RMSE	-	Root Mean Squared Error
SAS	-	Statistical Analysis System
SRM	-	Stepwise Regression Model
SSR	-	Regression Sum of Squares
VIF	-	Variance Inflation Factor

LIST OF APPENDICES