UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION AND GENETIC DIVERSITY OF *Phytophthora palmivora* FROM COCOA IN MALAYSIA AND ITS BIOLOGICAL CONTROL USING ENDOPHYTIC BACTERIA

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By

WAEL M. K. ALSULTAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

This Thesis is dedicated to

The most precious people in my life; my Beloved Parents
Mahmoud and Fatimah
My Beloved Brothers
My Lovely sisters
For their unconditional everlasting love
They began my education
They motivated me to continue it
They will always contribute to it

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Associate Professor Ganesan Vadamalai, PhD
Faculty : Agriculture

Black pod disease of cocoa, caused by *Phytophthora palmivora,* is a serious problem to cocoa growers in Malaysia and worldwide. There are a few research efforts have been conducted to study the causal agent of black pod disease of cocoa in Malaysia. At present, there are no reports available on the determination of genetic diversity among *P. palmivora* populations in cocoa growing areas of Malaysia. Therefore, this study was initiated to isolate and identify *Phytophthora* species from main cocoa plantations infected by black pod disease in Malaysia using sequence analyses of the ITS rDNA, cytochrome c oxidase subunit 1, and translation elongation factor 1α regions. This study was also examined the genetic diversity within 56 *P. palmivora* isolates obtained from the different host, geographical regions and years in Malaysia using Inter-simple sequence repeat (ISSR) and random amplified polymorphic DNA (RAPD) markers. In addition, this study was carried out to isolate, characterize and screen bacterial endophytes from cocoa plants for their biological control activities. Their mechanisms of action as well as the ability to reduce black pod rot disease were also investigated. A total of 36 *Phytophthora* isolates were obtained from different infected cocoa plantations from five states of Malaysia. Six *Phytophthora* isolates obtained from durian and available at the Department of Plant Protection, Universiti Putra Malaysia were also used in this study. Results of phylogenetic analyses of individual and combined dataset of the ITS rDNA, COX I and *EF-1α* confirmed that all *Phytophthora* isolates belonged to *P. palmivora*. The results also confirmed that the three examined regions could differentiate *P. palmivora* at the species level. *P. palmivora* isolates obtained from cocoa and durian were clustered into different subclades based on the three regions examined. The results of both markers indicated relatively high diversity among *P. palmivora* isolates. The complete separation was based on host and year of isolation. In total, 100 endophytic bacterial isolates were obtained from healthy cocoa tissues (leaves, branches and fruits) from seven states of Malaysia. The isolated bacteria were screened by dual culture assay and culture filtrate

test for their antagonistic properties towards *P. palmivora in vitro.* The best two isolates *Pseudomonas aeruginosa* (AS1) and *Chryseobacterium proteolyticum* (AS2) with more than 80% inhibition of radial growth (PIRG) were selected for subsequent experiments. Bioactive volatile compounds from ethyl acetate crude extract were identified using gas chromatography-mass spectrometry (GC). The effectiveness of *Pseudomonas aeruginosa* and *Chryseobacterium proteolyticum* isolates in reducing black pod lesion was confirmed on detached cocoa pods. These results confirmed that these two bacterial isolates have potential to be used as bio-control agents against *P. palmivora*.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

PENCIRIAN DAN KEPELBAGAIAN GENETIK *Phytophthora palmivora* DARIPADA KOKO DI MALAYSIA DAN KAWALAN BIOLOGINYA MENGGUNAKAN ENDOFITIK BAKTERIA

Oleh

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Penyakit buah hitam koko yang disebabkan oleh *Phytophthora palmivora* adalah masalah serius bagi penanam koko di Malaysia dan seluruh dunia. Terdapat beberapa kajian telah dijalankan untuk mengetahui agen penyebab penyakit buah hitam koko di Malaysia. Buat masa sekarang tidak terdapat sebarang laporan untuk menentukan kepelbagaian genetik antara populasi *Phytophthora palmivora* di kawasan penanaman koko di Malaysia. Oleh itu, kajian telah dimulakan untuk memencilkan dan mengenalpasti spesis utama *Phytophthora* di ladang utama penanaman koko yang dijangkiti penyakit buah hitam di Malaysia menggunakan analisa bagi penjujukan ITS rDNA, sitokrom c oksidase bahagian (subunit) 1 dan bahagian faktor pemanjangan translasi 1α (*EF-1α*). Kajian juga dijalanakan untuk memeriksa kepelbagaian genetic dalam 56 pencilan *P. palmivora* yang diperolehi daripada pelbagai perumah, kawasan geografi dan tahun yang berbeza di Malaysia menggunakan *Inter Simple Sequence Repeat (ISSR)* dan penanda Penguatan Rawak DNA Polimorfik (RAPD). Disamping itu, kajian dijalankan untuk memencil, menciri dan menyaring bakteria endofit daripada pokok koko untuk aktiviti kawalan secara biologinya. Mekanisma tindakbalas dan kemampuanya untuk megurangkan penyakit reput buah hitam juga telah disiasat. Sejumlah 36 pencilan *Pytophthora* telah diperoleh daripada pelbagai ladang koko yang dijangkiti daripada lima negeri di Malaysia. Enam pencilan *Phytophthora* yang diperoleh daripada durian yang terdapat di Jabatan Perlindungan Tumbuhan di Univerisiti Putra Malaysia juga telah digunakan dalam kajian ini. Keputusan daripada analisa filogenetik secara individu atau gabungan bagi set data ITS rDNA, COX1, dan *EF1-α* telah pasti hingga ke peringkat spesis bahawa semua pencilan *Phytophthora* adalah *P. palmivora*. Pencilan *P. palmivora* yang diperoleh daripada durian dan koko telah dikelompokkan kepada subklad berbeza berdasarkan tiga kawasan yang diperiksa. Keputusan daripada kedua-dua penanda menunjukkan relatif kepelbagaian yang tinggi diantara pencilan *P. palmivora*. Perpisahan yang lengkap adalah berdasarkan perumah dan tahun pemencilan. Kesemuanya 100

pencilan bakteria endofit telah diperoleh daripada tisu koko yang sihat (daun, batang, buah) daripada 7 buah negeri di Malaysia. Bakteria yang telah dipencilkan telah disaringkan menggunakan esei kultur berkembar dan ujian tapisan kultur untuk sifat antagonis kepada *P. palmivora* secara in vitro. Dua pencilan terbaik *Pseudomonas aeruginosa* (AS1) dan *Chryseobacterium proteolyticum* (AS2) dengan lebih daripada 80% halangan pertumbuhan jejari (PIRG) telah dipilih untuk eksperimen seterusnya. Kompaun bioaktif yang meruap daripada ekstrak etil asetat mentah telah dikenalpasti menggunakan kromatografi gas- spektrometri jisim (GC). Keberkesanan pencilan *Pseudomonas aeruginosa* dan *Chryseobacterium proteolyticum* dalam mengurangkan luka penyakit buah hitam telah dipastikan pada buah koko yang dicabut. Keputusanya telah mengesahkan bahawa kedua-dua pencilan bakteria ini mempunyai potensi untuk digunakan sebagai agen kawalan bio melawan *P. palmivora.*

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
FAO	Food and Agriculture Organization of the United Nations
LSD	Least Significant Difference
VJA	Vegetable Juice Agar
pH	Potential Hydrogen
SAS	Statistical Analysis System
UPM	Universiti Putra Malaysia
BLAST	Basic Local Alignment Search Tool
USD	United States Dollar
PCR	Polymerase chain reaction
ITS	Internal Transcribed Spacer
COX I	Cytochrome c oxidase subunit 1
EF-1α	Translation elongation factor 1α
DNA	Deoxyribonucleic acid
rRNA	Ribosomal Ribonucleic Acid
EDTA	Disodium ethylene diamine tetraacetate
Min	Minute
Sec	Second
CTAB	Hexadecyltrimethyl-Ammonium Bromide
TBE	Tris borate EDTA
UV	Ultra violet
V	Volts
Bp	Base pair
Tris	Tris (hydroxymethyl) aminomethane
Kb	Kilo base
DAI	Days after inoculation
ISSR	Inter-simple sequence repeat
RAPD	Random amplified polymorphic DNA
rpm	Revolutions per minute

CHAPTER 1

INTRODUCTION

Cocoa (*Theobroma cacao* L.) from the family Malvacea, is an economically important tree in many tropical countries where it is grown as well as for many chocolate manufacturing countries that process the beans into a range of confectionery products. Cocoa is produced in countries in a belt between 10ºN and 10ºS of the Equator, where the climate is appropriate for growing cocoa trees. The largest producing countries are Côte d'Ivoire, Ghana and Indonesia. (ICCO, 2013). The global economic importance of cocoa cannot be underestimated, as it plays key roles in producing and non-producing countries. Ivory Coast, Ghana, Nigeria and Cameron are the major producer of cocoa beans in the African continent. While Indonesia, Malaysia and Papua New Guinea are the top major producing countries in Asia and Oceania. The largest cocoa producing countries in Americans are Brazil, Ecuador and Colombia. Almost 90% of world cocoa production comes from small farmers of under 5 hectares (ICCO, 2013).

In many countries, plant diseases are the limiting factor for cocoa production. Cocoa crop is affected by many diseases caused by fungi, viruses and bacteria, besides nutritional disorders with estimated losses ranged between 30 to 40% of global production (ICCO, 2015). Rapid identification of pathogens is significant for integrated disease management. *Phytophthora* species are a serious threat to the cocoa industry worldwide. Accurate identification of *Phytophthora* species based on morphological characteristics is very essential to support the preliminary step of identification. However, molecular identification methods are faster, more specific and more sensitive than morphological identification of *Phytophthora* species (Capote et al., 2012). With the development of molecular techniques together with the recent comprehensive multigene phylogenetic analysis of the genus (Blair et al., 2008), sequence databases are available to simplify identification of unknown species.

Black pod disease can be managed primarily using resistant cultivars (Adejumo TO, 2005). This is the destructive cosmopolitan genus of Oomycete and it is of primary interest due to many *Phytophthora* species are plant pathogens of significant economic importance. Phylogenetic analyses have assisted in clarifying equivocation in the traditional classification system of *Phytophthora*. Development in molecular biology has brought new influential tools to fungal taxonomists such as the means to clarify the relationship among fungal species and the possibility for rapid identification of isolates. Moreover, molecular methods have been extensively used to differentiate between closely related species and to distinguish strains within a species (Singh et al., 2006). Several management strategies are used to control black pod of cocoa such as phytosanitary, chemical control, cultural methods, biological control and genetic resistance, but none has been able to generate acceptable results and completely controlled the disease so far (Guest, 2007).

Currently, there is no report available on the determination of genetic diversity among *Phytophthora palmivora* populations in cocoa plantations of Malaysia. Also, little is known about the use of endophytes to control black pod of cocoa in Malaysia. Biological control research of black pod disease conducted in Malaysia revealed that certain bacteria isolated from the surfaces of infected cocoa pods are antagonistic to *P. palmivora* such as *Burkholderia* sp., *Pseudomonas putida* biotype A and *Bacillus* sp. (Ahmad Kamil, 2004). Moreover, there are a few research efforts have been conducted to identify the causal agent of black pod disease of cocoa in Malaysia using sequence analysis of the internal transcribed spacer (ITS) region only (Mohamed et al., 2017). Thus, the objective of the present research was to identify *Phytophthora* isolates causing black pod disease in the infected cocoa plantations in Malaysia, determine the genetic diversity within the isolates and determine its biological control using endophytic bacteria for effective management strategies.

The specific objectives of this study were as follow:

(i) To isolate, characterize and identify *Phytophthora* isolates from cocoa plantations in Malaysia using sequence analyses of the ITS, COX I and *EF-1α*.
(ii) To examine the genetic diversity within *P. palmivora* isolates using ISSR and RAPD markers.
(iii) To isolate, characterize and screen bacterial endophytes from cocoa plants for their biological control activities and to determine the mechanisms of antagonistic endophytes to control the disease.
(iv) To investigate the efficacy of endophytic bacteria in *P. palmivora* suppression on Detached pod.

REFERENCES

Abu-El Samen, F. M., Secor, G. A., & Gudmestad, N. C. (2003). Genetic variation among asexual progeny of *Phytophthora infestans* detected with RAPD and AFLP markers. *Plant Pathology*, 52: 314-325.

Acebo-Guerrero, Y., Hernández-Rodríguez, A., Heydrich-Pérez, M., El Jaziri, M., & Hernández-Lauzardo, A. N. (2012). Management of black pod rot in cacao (*Theobroma cacao* L.): a review. *Fruits*, 67, 41-48.

Adejumo, T. O. (2005). Crop protection strategies for major diseases of cocoa, coffee and cashew in Nigeria. *African Journal of Biotechnology*, 4: 143-150.

Afsharmanesh, H., Ahmadzadeh, M., Javan-Nikkhah, M., & Behboudi, K. (2010). Characterization of the antagonistic activity of a new indigenous strain of *Pseudomonas fluorescens* isolated from onion rhizosphere. *Journal of Plant Pathology*, 187-194.

Agrios, G. N. (2005). Plant pathology 5th Edition: Elsevier Academic Press. Burlington, Ma. USA, 79-103.

Ahmad Kamil M. J. (2004). Antagonistic activities of epiphytic bacteria on black pod disease of cocoa. Master's Thesis. The Senate of Universiti Putra, Malaysia.

Akrofi, A. Y., & Opoku, I.Y. (2000). Managing *Phytophthora megakarya* pod rot disease: The Ghana Experience. 13 th International Cocoa Research Conference, Kota Kinabalu, Sabah.

Akrofi, A. Y., Terlabie, J. L., Amoako-Attah, I., & Asare, E. K. (2017). Isolation and characterization of bacteria from different cacao progenies and their antagonistic activity against the black pod disease pathogen, *Phytophthora palmivora*. *Journal of Plant Diseases and Protection*, 124:143-152.

Akrofi, A.Y., Amoako-Atta, I., Assuah, M., & Asare, E.K. (2015). Black pod disease on cacao (*Theobroma cacao*, *L*) in Ghana: Spread of *Phytophthora megakarya* and role of economic plants in the disease epidemiology. *Crop Protection* 72: 66-75.

Appiah, A. Á., Flood, J., Archer, S. Á., & Bridge, P. Á. (2004). Molecular analysis of the major *Phytophthora* species on cocoa. *Plant Pathology*, 53: 209-219.

Ardakani, S. S., Heydari, A., Tayebi, L., & Mohammadi, M. (2010). Promotion of cotton seedlings growth characteristics by development and use of new bioformulations. *International Journal of Botany*, 6: 95-100.

Arnold, A. E., & Herre, E. A. (2003). Canopy cover and leaf age affect colonization by tropical fungal endophytes: ecological pattern and process in *Theobroma cacao* (Malvaceae). *Mycologia*, 95: 388-398.

Arnold, A. E., & Lutzoni, F. (2007). Diversity and host range of foliar fungal endophytes: are tropical leaves biodiversity hotspots?. *Ecology*, 88: 541-549.

Arnold, A. E., Maynard, Z., Gilbert, G. S., Coley, P. D., & Kursar, T. A. (2000). Are tropical fungal endophytes hyperdiverse?. *Ecology letters*, 3: 267-274.

Aryantha, I. P., Cross, R., & Guest, D. I. (2000). Suppression of *Phytophthora cinnamomi* in potting mixes amended with uncomposted and composted animal manures. *Phytopathology*, 90: 775-782.

Bae, H., Sicher, R. C., Kim, M. S., Kim, S. H., Strem, M. D., Melnick, R. L., & Bailey, B. A. (2009). The beneficial endophyte *Trichoderma hamatum* isolate DIS 219b promotes growth and delays the onset of the drought response in *Theobroma cacao*. *Journal of Experimental Botany*, 60: 3279-3295.

Bailey, B.A., Bae H., Strem M.D., Crozier J., Thomas S.E., Samuels G.J., Vinyard B.T., & Holmes K.A. (2008). Antibiosis, mycoparasitism, and colonization success for endophytic *Trichoderma* isolates with biocontrol potential in *Theobroma cacao. Biological Control* 46: 24–35.

Bailey, B.A., Bae, H., Strem M.D., Roberts D.P., Thomas S.E., Crozier J., Samuels G.J., Choi I.Y., & Holmes K.A. (2006). Fungal and plant gene expression during the colonization of cacao seedlings by endophytic isolates of four *Trichoderma* species. *Planta,* 224:1449-1464.

Bajwa, W.I., Kogan, M. (2004). Cultural practices: springboard to IPM. In: Koul, O., Dhaliwal, G.S., Cuperus, G.W. (Eds.), Integrated Pest Management: Potential, Constraints and Challenges. CABI Publishing, Wallingford, UK, pp. 21–38.

Bakker, P.A.H.M., Pierterse, C.M.J., Van Loon, L.C. (2007). Induced systemic resistance by *fluorescent Pseudomonas* spp. *Phytopathology,* 97: 239–243.

Barrow, J. R., Lucero, M. E., Reyes-Vera, I., & Havstad, K. M. (2008). Do symbiotic microbes have a role in regulating plant performance and response to stress?. *Communicative & Integrative Biology*, 1: 69-73.

Bartley, B. G. D. (2005). The genetic diversity of Cacao and its utilization. Wallingford: CABI Publishing.

Bayer, C., & Kubitzki, K. (2003). Malvaceae. In K. Kubitzki (Ed.), The families and genera of vascular plants. Dicotyledons: Malvales, Capparales and non-betalain Caryophyllales (Vol. 5, pp. 225–311). Berlin: Springer.

Beakes, G.W. (1998). Evolutionary relationship among protozoa. In: Coombs, G.H., Vickerman, K., Sleigh, M.A. and Warren, A., ed., The Systematics Association Special Volume Series 56. Dordrecht, Netherlands, Kluwer Academic Publishers.

Belakhdar, G., Benjouad, A., & Abdennebi, E. H. (2015). Determination of some bioactive chemical constituents from *Thesium humile Vahl*. *Journal of Materials and Environmental Science,* 6: 2778-83.

Belimov, A., Hontzeas A., Safronova, N., Demchinskaya, V.I., Piluzza, S.V., Bulitta, G., & Glick B.R. (2005). Cadmium-tolerant plant growth-promoting bacteria associated with the roots of Indian mustard (Brassica juncea L. czern.). *Soil Biology and Biochemistry*, 37: 241-250.

Bell, W. F. (2009). Organic Agriculture and Fair Trade in Pacific Island Countries. Natural Resource Management and Environment Department, Food and Agriculture Organisation of the United Nations (FAO).

Bhattacharyya, P. N., & Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. *World Journal of Microbiology and Biotechnology*, 28: 1327-1350.

Bhavani, R., Abraham K. (2007). Efficacy of selected epiphytic microflora from pod surface against *Phytophthora* pod rot of cocoa, in: Keshavachandran R., Nazeem P., Girija D., John P.S., Peter K.V. (Eds.), Proc. Recent trends in horticultural biotechnology, ICAR Ntl. Symp. Biotechnological interventions for improvement of horticultural crops: issues and strategies, ICAR, Kerala, India, pp 871–875.

Bhavani, R., Abraham K., Vijayaraghavan R. (2007). Usefulness of epiphytic microflora from pod surface on the management of *Phytophthora* pod rot of cocoa, *International Journal of Plant Sciences*, (Muzaffarnagar) pp 178–183.

Blair, J.E., Coffey, M.D., Park, S.Y., Geiser, D.M., & Kang, S. (2008). A multi-locus phylogeny for *Phytophthora* utilizing markers derived from complete genome sequences. *Fungal Genetics and Biology,* 45: 266-277.

Blair, M.W., Panaud, O. & McCouch, S.R. (1999). Inter-simple sequence repeat (ISSR) amplification for analysis of microsatellite motif frequency and fingerprinting in rice (Oryza sativa L.). *Theoretical and Applied Genetics*, 98: 780-792.

Blaker, N. S., & Macdonald, J. D. (1983). Influences of container medium pH on sporangium formation, zoospore release, and infection of rhododendron by *Phytophthora cinnamomi*. *Plant Disease,* 67: 259-263.

Bong, C.L., & Stephen, M. (1999). *In vitro* assessment of sensitivity of cocoa clones to *Phytophthora* isolates. In: Sidek, Z., Bong, C.L., Vijaya, S.K., Ong, C.A., & Hussan, A.K., Sustainable crop protection practices in the next millennium. MCB–MAPPS Plant Protection Conference, Kota Kinabalu, Sabah, Malaysia.

Bornet, B., Muller, C., Paulus, F., & Branchard, M. (2002). Highly informative nature of inter simple sequence repeat (ISSR) sequences amplified using tri-and tetra-nucleotide primers from DNA of cauliflower (Brassica oleracea var. botrytis L.). *Genome*, 45, 890-896.

Borriss, R., Chen, X. H., Rueckert, C., Blom, J., Becker, A., Baumgarth, B., & Junge, H. (2011). Relationship of *Bacillus amyloliquefaciens* clades associated with strains DSM 7T and FZB42T: a proposal for *Bacillus amyloliquefaciens* subsp. *amyloliquefaciens* subsp. nov. and *Bacillus amyloliquefaciens* subsp. plantarum subsp. nov. based on complete genome sequence comparisons. *International journal of systematic and evolutionary microbiology*, 61: 1786-1801.

Botstein, D., White, R. L., Skolnick, M., & Davis, R. W. (1980). Construction of a genetic linkage map in man using restriction fragment length polymorphisms. *American journal of human genetics*, 32: 314.

Bowers, J. H., Bailey, B. A., Hebbar, P. K., Sanogo, S., & Lumsden, R. D. (2001). The impact of plant diseases on world chocolate production. *Plant Health Progress*, 10.

Brasier, C. M., & Griffin, M. J. (1979). Taxonomy of '*Phytophthora palmivora'* on cocoa. *Transactions of the British Mycological Society*, 72: 111-143.

Brasier, C. M., Cooke, D. E. L., & Duncan, J. M. (1999). Origin of a new *Phytophthora* pathogen through interspecific hybridization. Proceedings of the National Academy of Sciences, USA 96: 5878–5883.

Bruns, T. D., White, T. J., & Taylor, J. W. (1991). Fungal molecular systematics. *Annual Review of Ecology and systematics*, 22: 525-564.

Cao, L., Qiu, Z., You, J., Tan, H., & Zhou, S. (2005). Isolation and characterization of endophytic *streptomycete* antagonists of *Fusarium wilt* pathogen from surface-sterilized banana roots. *FEMS microbiology letters*, 247: 147-152.

Capote, N., Pastrana, A. M., Aguado, A., & Sánchez-Torres, P. (2012). Molecular tools for detection of plant pathogenic fungi and fungicide resistance. In *Plant pathology*. InTech.

Cappuccino, J. G., & Sherman, N. (2008). Microbiology: a laboratory manual (Vol. 9). Pearson/Benjamin Cummings.

Carroll, G. C. (1992). Fungal mutualism. The Fungal Community. New York: Marcel Denker, Inc, 327-354.

Chakraborty, S., Tiedemann, A. V., & Teng, P. S. (2000). Climate change: potential impact on plant diseases. *Environmental pollution*, 108: 317-326.

Chan, L. G. (1985). Comparative Studies of *Phytophthora Palmivora* from Cocoa and Durian and Their Control (Doctoral dissertation, Universiti Pertanian Malaysia).

Chang, T. T., Yang, W. W., & Wang, W. Y. (1996). Use of random amplified polymorphic DNA markers for the detection of genetic variation in

Phytophthora cinnamomi in Taiwan. *Botanical Bulletin of Academia Sinica*, 37: 165–171.

Chowdappa, P., Brayford, D., Smith, J., & Flood, J. (2003). Identification of *Phytophthora* species affecting plantation crops by RFLP of PCR-amplified internal transcribed spacer regions of ribosomal RNA. *Current Science*, 85: 34-36.

Ci, X. Q., Chen, J. Q., Li, Q. M., & Li, J. (2008). AFLP and ISSR analysis reveals high genetic variation and inter-population differentiation in fragmented populations of the endangered Litsea szemaois (Lauraceae) from Southwest China. *Plant Systematics and Evolution*, 273: 237-246.

Compant, S., Duffy, B., Nowak, J., Clément, C., & Barka, E. A. (2005). Use of plant growth-promoting bacteria for biocontrol of plant diseases: principles, mechanisms of action, and future prospects. *Applied and environmental microbiology*, 71: 4951-4959.

Cooke, D. E. L., Drenth, A., Duncan, J. M., Wagels, G., & Brasier, C. M. (2000). A molecular phylogeny of *Phytophthora* and related oomycetes. *Fungal genetics and biology*, 30:17-32.

Cooke, D. E., & Duncan, J. M. (1997). Phylogenetic analysis of *Phytophthora* species based on ITS1 and ITS2 sequences of the ribosomal RNA gene repeat. *Mycological Research*, 101: 667-677.

Costa, F. G., Zucchi, T. D., & Melo, I. S. D. (2013). Biological control of phytopathogenic fungi by endophytic actinomycetes isolated from maize (Zea mays L.). *Brazilian Archives of Biology and Technology*, 56: 948-955.

Crespel, L., Pernet, A., Le Bris, M., Gudin, S., & Oyant, L. H. S. (2009). Application of ISSRs for cultivar identification and assessment of genetic relationships in rose. *Plant breeding*, 128: 501-506.

Dey, R. K. K. P., Pal, K. K., Bhatt, D. M., & Chauhan, S. M. (2004). Growth promotion and yield enhancement of peanut (Arachis hypogaea L.) by application of plant growth-promoting rhizobacteria. *Microbiological research*, 159: 371-394.

Diby, P. A. U. L., Saju, K. A., Jisha, P. J., Sarma, Y. R., Kumar, A., & Anandaraj, M. (2005). Mycolytic enzymes produced by *Pseudomonas fluorescens* and *Trichoderma* spp. against *Phytophthora capsici*, the foot rot pathogen of black pepper (Piper nigrum L.). *Ann Microbiol*, 55, 129-133.

Doherty, K. R., Zweifel, E. W., Elde, N. C., McKone, M. J., & Zweifel, S. G. (2003). Random amplified polymorphic DNA markers reveal genetic variation in the symbiotic fungus of leaf-cutting ants. *Mycologia*, 95: 19-23.

Drenth, A., and Guest, D. I. (2004). Diversity and Management of *Phytophthora* in Southeast Asia. Australian Centre for International Agricultural Research (ACIAR).

Duncan, J. M. (1980). Persistence of mycelium of *Phytophthora Fragariae* in soil. Transactions of the British Mycological Society, 75: 383-387.

Dunne, C., Delany, I., Fenton, A., & O'Gara, F. (1996). Mechanisms involved in biocontrol by microbial inoculants. *Agronomie*, 16: 721-729.

Dura' n, A., Gryzenhout, M., Drenth, A., Slippers, B., Ahumada, R., Wingfield, B. D., & Wingfield, M. J. (2010). AFLP analysis reveals a clonal population of *Phytophthora pinifolia* in Chile. *Fungal Biolog,y* 114: 746–752.

Ecosystems Research and Development Sureau. (2015). Cacao (*Theobroma cacao Linnaeus*) Vol. 27 Nos.

Eden, M. A., Hill, R. A., & Galpoththage, M. (2000). An efficient baiting assay for quantification of *Phytophthora cinnamomi* in soil. *Plant pathology*, 49: 515-522.

Elliott, M., Shamoun, S. F., Sumampong, G., James, D., Masri, S., & Varga, A. (2009). Evaluation of several commercial biocontrol products on European and North American populations of *Phytophthora ramorum. Biocontrol Science and Technology*, 19: 1007-1021.

El-Tarabily, K. A., & Sivasithamparam, K. (2006). Non-streptomycete actinomycetes as biocontrol agents of soil-borne fungal plant pathogens and as plant growth promoters. *Soil Biology and Biochemistry*, 38: 1505-1520.

El-Tarabily, K. A., Nassar, A. H., Hardy, G. S. J., & Sivasithamparam, K. (2009). Plant growth promotion and biological control of *Pythium aphanidermatum*, a pathogen of cucumber, by endophytic actinomycetes. *Journal of Applied Microbiology*, 106: 13-26.

Erwin, D. C., & Ribeiro, O. K. (1996). *Phytophthora* diseases worldwide. American Phytopathological Society (APS Press).

Evans, H. C. (1980). Pleomorphism in Crinipellis perniciosa, causal agent of witches' broom disease of cocoa. *Transactions of the British Mycological Society*, 74: 515-523.

Fatima, Z., Saleemi, M., Zia, M., Sultan, T., Aslam, M., Rehman, R., & Chaudhary, M. F. (2009). Antifungal activity of plant growth-promoting rhizobacteria isolates against *Rhizoctonia solani* in wheat. *African Journal of Biotechnology*, 8: 219-225.

Förster, H., Cummings, M. P., & Coffey, M. D. (2000). Phylogenetic relationships of *Phytophthora* species based on ribosomal ITS 1 DNA sequence analysis with

emphasis on Waterhouse groups V and VI. *Mycological Research*, 104: 1055-1061.

Frazzon, A. P. G., Matsumura, A. T. S., & Van Der Sand, S. T. (2002). Morphological characterization and genetic analysis of Drechslera teres isolates. *Genetics and molecular biology*, 25: 235-241.

Galindo, J.J. (1992). Prospects for biological control of cacao. In: Keane, P.J., & Putter, C. A. J. (Eds.). Cocoa pest and disease management in Southeast Asia and Australasia. Rome, FAO Plant Production and Protection Paper 112.

Gally, M., Ramos, A. M., Dokmetzian, D., & Lopez, S. E. (2007). Genetic variability of *Phytophthora sojae* isolates from Argentina. *Mycologia*, 99: 877-883.

Gilbert, J. E., Lewis, R. V., Wilkinson, M. J., & Caligari, P. D. S. (1999). Developing an appropriate strategy to assess genetic variability in plant germplasm collections. *Theoretical and Applied genetics*, 98: 1125-1131.

Goodwin, P. H., & Annis, S. L. (1991). Rapid identification of genetic variation and pathotype of *Leptosphaeria maculans* by random amplified polymorphic DNA assay. *Applied and Environmental Microbiology*, 57: 2482-2486.

Gopalakrishnan, S., Pande, S., Sharma, M., Humayun, P., Kiran, B. K., Sandeep, D., & Rupela, O. (2011). Evaluation of actinomycete isolates obtained from herbal vermicompost for the biological control of *Fusarium wilt* of chickpea. *Crop Protection*, 30: 1070-1078.

Gosselin, L., Jobidon, R., & Bernier, L. (1996). Assessment of genetic variation within *Chondrostereum purpureum* from Quebec by random amplified polymorphic DNA analysis. *Mycological Research*, 100: 151-158.

Gouveia, M. M. C., Ribeiro, A., Varzea, V. M., & Rodrigues Jr, C. J. (2005). Genetic diversity in *Hemileia vastatrix* based on RAPD markers. *Mycologia*, 97: 396-404.

Griffin, M. J. (1977). Cocoa *Phytophthora* Workshop, Rothamsted Experimental Station, England, 24–26 May 1976. PANS, 23: 107-110.

Griffith, G. W., & Shaw, D. S. (1998). Polymorphisms in *Phytophthora infestans:* four mitochondrial haplotypes are detected after PCR amplification of DNA from pure cultures or from host lesions. *Applied and environmental microbiology*, 64: 4007-4014.

Guest, D. (2007). Black pod: diverse pathogens with a global impact on cocoa yield. *Phytopathology*, 97: 1650-1653.

Guest, D. I., & Keane, P. J. (2007). Vascular-streak dieback: A new encounter disease of cacao in Papua New Guinea and Southeast Asia caused by the obligate Basidiomycete *Oncobasidium theobromae. Phytopathology*, 97: 1654–1657.

Guest, D. I., Anderson, R. D., Foard, H. J., Phillips, D., Worboys, S., & Middleton, R. M. (1994). Long-term control of *Phytophthora* diseases of cocoa using trunk-injected phosphonate. *Plant Pathology*, 43: 479-492.

Gupta, C. P., Kumar, B., Dubey, R. C., & Maheshwari, D. K. (2006). Chitinase-mediated destructive antagonistic potential of *Pseudomonas aeruginosa* GRC 1 against *Sclerotinia sclerotiorum* causing stem rot of peanut. *Biocontrol,* 51: 821-835.

Haas, B. J., Brian, J., Kamoun, S., Zody, M. C., Michael C., Jiang, R. H., Handsaker, R. E., Robert, E., Cano, L. M., & Bozkurt, T. O. (2009). Genome sequence and analysis of the Irish potato famine pathogen *Phytophthora infestans. Nature*, 461(7262), 393.

Hanada, R. E., de Jorge Souza, T., Pomella, A. W., Hebbar, K. P., Pereira, J. O., Ismaiel, A., & Samuels, G. J. (2008). *Trichoderma martiale* sp. nov., a new endophyte from sapwood of *Theobroma cacao* with a potential for biological control. *mycological research*, 112: 1335-1343.

Harman, G. E., Hayes, C. K., Lorito, M., Broadway, R. M., Di Pietro, A., Peterbauer, C., & Tronsmo, A. (1993). Chitinolytic enzymes of *Trichoderma harzianum:* purification of chitobiosidase and endochitinase. *Phytopathology*, 83: 313-318.

Hasan, S., Gupta, G., Anand, S., Chaturvedi, A., & Kaur, H. (2013). Biopotential of microbial antagonists against soilborne fungal plant pathogens. *International Journal of Agriculture and Food Science Technology*, 4: 37–39.

Hashem, M., Alamri, S. A., Alrumman, S. A., & Moustafa, M. F. (2016). Suppression of phytopathogenic fungi by plant extract of some weeds and the possible mode of action. *British microbiology research journal*, 15: 1-13.

Hassi, M., El Guendouzi, S., Haggoud, A., David, S., Ibnsouda, S., Houari, A., & Iraqui, M. (2012). Antimycobacterial activity of a *Brevibacillus laterosporus* strain isolated from a Moroccan soil. *Brazilian Journal of Microbiology*, 43: 1516-1522.

Hayat, R., Ali, S., Amara, U., Khalid, R., & Ahmed, I. (2010). Soil beneficial bacteria and their role in plant growth promotion: a review. *Annals of Microbiology*, 60: 579-598.

Herre, E. A., Mejía, L. C., Kyllo, D. A., Rojas, E., Maynard, Z., Butler, A., & Van Bael, S. A. (2007). Ecological implications of anti-pathogen effects of tropical fungal endophytes and mycorrhizae. *Ecology*, 88: 550-558.

Hibbett, D.S (1992). Ribosomal RNA and fungal systematic. *Transactions of the Mycological Society of Japan*, 33: 533-556.

Hsouna, A. B., Trigui, M., Mansour, R. B., Jarraya, R. M., Damak, M., & Jaoua, S. (2011). Chemical composition, cytotoxicity effect and antimicrobial activity

of *Ceratonia siliqua* essential oil with preservative effects against *Listeria* inoculated in minced beef meat. *International journal of food microbiology*, 148: 66-72.

Hu, X. F., Ying, F. X., He, Y. B., Gao, Y. Y., Chen, H. M., & Chen, J. S. (2008). Characterization of *Pectobacterium carotovorum* subsp. *carotovorum* causing soft-rot disease on *Pinellia ternata* in China. *European journal of plant pathology*, 120: 305-310.

Husen, E. (2016). Screening of soil bacteria for plant growth promotion activities *in vitro*. *Indonesian Journal of Agricultural Science*, 4: 27-31.

Hyde, K.D., Soytong, K. (2008). The fungal endophyte dilemma. Fungal Divers 33:163–173.

ICCO (International, Cocoa Organization). (2003). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

ICCO (International, Cocoa Organization). (2010). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

ICCO (International, Cocoa Organization). (2012). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

ICCO (International, Cocoa Organization). (2013). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

ICCO (International, Cocoa Organization). (2015). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

ICCO (International, Cocoa Organization). (2017). The World Cocoa Economy: Past & Present. On the Internet: <http://www.icco.org.

Intana, W., Chamswarng, C., Chantrapromma, K., Yenjit, P., Suwanno, C., & Sattasakulchai, S. (2008). Use of pentyl pyrone extracted from ultraviolet-induced mutant strain of *Trichoderma harzianum* for control leaf spot of Chinese-kale. *Thai Journal of Agricultural Science*, 41: 75-80.

Iwaro, A. D., & Singh, V. (2004). Progress report on the germplasm enhancement programme for resistance to black pod disease. In: Annual Report for 2003. Cocoa Research Unit, The University of the West Indies, St. Augustyine, Trinidad. pp. 43-45.

Jayaraj, J., Parthasarathi, T., & Radhakrishnan, N. V. (2007). Characterization of a *Pseudomonas fluorescens* strain from tomato rhizosphere and its use for integrated management of tomato damping-off. *Biological Control,* 52:683–702.

Jha, P.N., Kumar, A., (2007). Endophytic colonization of Typha australis by a plant growth-promoting bacterium *Klebsiella oxytoca* GR-3. *Journal of Applied Microbiology,* 103: 1311–1320.

Joseph, B., Patra RR, Lawrence R. (2007). Characterization of plant growth promoting rhizobacteria associated with chickpea (*Cicer arietinum L.*). *International Journal of Plant Production,* 1: 141-151.

Jung, T., Blaschke, H., & Oßwald, W. (2000). Involvement of soilborne *Phytophthora* species in Central European oak decline and the effect of site factors on the disease. *Plant Pathology*, 49: 706-718.

Jung, T., Hudler G.W., Jensen-Tracy, S.L., Griffiths, H.M., Fleischmann, F., Osswald, W. (2005). Involvement of *Phytophthora* species in the decline of European beech in Europe and the USA. *Mycologist,* 19: 159-166.

Kamala, T., & Devi, S. I. (2012). Biocontrol properties of indigenous *Trichoderma* isolates from North-East India against *Fusarium oxysporum* and *Rhizoctonia solani*. *African Journal of Biotechnology*, 11: 8491-8499.

Kammarnjesadakul, P., Palaga, T., Sritunyalucksana, K., Mendoza, L., Krajaejun, T., Vanittanakom, N., & Chindamporn, A. (2011). Phylogenetic analysis of *Pythium insidiosum* Thai strains using cytochrome oxidase II (COX II) DNA coding sequences and internal transcribed spacer regions (ITS). *Medical mycology*, 49: 289-295.

Kang, S. H., Cho, H., Cheong, H., Ryu, C. M., Kim, J. F., & Park, S. H. (2007). Two bacterial entophytes eliciting both plant growth promotion and plant defense on pepper (*Capsicum annuum L.*). *Journal of Microbiology and Biotechnology*, 17: 96–103.

Kannapiran, E., & Ramkumar, V. S. (2011). Isolation of phosphate solubilizing bacteria from the sediments of Thondi coast, Palk Strait, Southeast coast of India. *Annals of Biological Research*, 2: 157-163.

Karanja, E. N., Boga, H. I., Muigai, A. W., Wamunyokoli, F., Kinyua, J., & Nonoh, J. O. (2012, June). Growth characteristics and production of secondary metabolites from selected novel Streptomyces species isolated from selected Kenyan national parks. In Scientific Conference Proceedings.

Kararah, M. A., Barakat, F. M., Mikhail, M. S., & Fouly, H. M. (1985). Pathophysiology in garlic cloves inoculated with *Bacillus subtilis, Bacillus pumilus* and *Erwinia carotovora*. *Egyptian Journal of Phytopathology* 17:131-140.

Khamna, S., Yokata, A., Lumyong, S. (2009). Actinomycetes isolated from medicinal plant rhizosphere soils: diversity and screening of antifungal compounds, indole-3-acetic acid and siderophore production. World. *Journal of Biotechnology*, 25: 649-655.

Khan, M.S., Zaidi, A. & Wani, P.A. (2006). Role of phosphate solubilizing microorganisms in sustainable agriculture- a review. *Agronomy for Sustainable Development,* 27: 29-43.

Kim, Y. S., Jang, B. R., Chung, I. M., Sang, M. K., Ku, H. M., Kim, K. D., & Chun, S. C. (2012). Enhancement of biocontrol activity of antagonistic *Chryseobacterium* strain KJ1R5 by adding carbon sources against *Phytophthora capsici. The Plant Pathology Journal*, 24: 164-170.

Kimura, M., & Crow, J. F. (1964). The number of alleles that can be maintained in a finite population. *Genetics*, 49: 725-738.

Kishore, G. K., Pande, S., & Podile, A.R. (2005) Phylloplane bacteria increase seedling emergence, growth and yield of field-grown groundnut (*Arachis hypogaea L.*). *Letters in Applied Microbiology*, 40: 260–268.

Koh S., & Hik, D. S. (2007). Herbivory mediates grass-endophyte relationships. *Ecology*, 88:2752-2757.

Konam, J. K., & Guest, D. I. (2004). Role of flying beetles (Coleoptera: Scolytidae and Nitidulae) in the spread of *Phytophthora* pod rot of cocoa in Papua New Guinea. *Australasian Plant Pathology*, 33: 55–59.

Konam, J., & Guest, D. I. (2002). Leaf litter mulch reduces the survival of *Phytophthora palmivora* under cocoa trees in Papua New Guinea. *Australasian Plant Pathology*, 31: 381– 383.

Krauss, U., Soberanis, W., (2001). Biocontrol of cocoa pod diseases with mycoparasite mixtures. *Biological Control,* 22: 149–158.

Kroon, L. P. N. M., Bakker, F. T., Van Den Bosch, G. B. M., Bonants, P. J. M., & Flier, W. G. (2004). Phylogenetic analysis of *Phytophthora* species based on mitochondrial and nuclear DNA sequences. *Fungal Genetics and Biology*, 41: 766-782.

Kroon, L. P., Brouwer, H., de Cock, A. W., & Govers, F. (2012). The genus *Phytophthora* anno 2012. *Phytopathology*, 102: 348-364.

Kumar, U., & Dangar, T. K. (2013). Functional Role of Plant Growth Promoting Endo-and Rhizobacteria in Major Cereal Crops. *Kheti*, 1: 37-40.

Lamour, K. H., & Hausbeck, M. K. (2001). Investigating the spatiotemporal genetic structure of *Phytophthora capsici* in Michigan. *Phytopathology*, 91: 973-980.

Lee, B. S., & Varghese, G. (1974). Studies on the genus *Phytophthora* in Malaysia. Reproduction and sexuality. *Malaysian Agricultural Research (Malasia),* 3: 137 - 149.

Lee, S. B., & Taylor, J. W. (1992). Phylogeny of five fungus-like protoctistan *Phytophthora* species, inferred from the internal transcribed spacers of ribosomal DNA. *Molecular Biology and Evolution*, 9: 636-653.

Lee, S. B., White, T. J., & Taylor, J. W. (1993). Detection of *Phytophthora* species by oligonucleotide hybridization to amplified ribosomal DNA spacers. *Phytopathology*, 83:177-181.

Leslie, J. F., & Summerell, B. A. (2006). The *Fusarium* laboratory manual. Blackwell Publishing Ltd, Iowa.

Li, P., Cao, S., Dai, Y. L., Li, X. L., Xu, D. F., Guo, M., & Gao, Z. M. (2012). Genetic diversity of *Phytophthora capsici* (Pythiaceae) isolates in Anhui Province of China based on ISSR-PCR markers. *Genetics and Molecular Research Journal,* 11: 4285-4296.

Li, P., Ma, L., Feng, Y. L., Mo, M. H., Yang, F. X., Dai, H. F., & Zhao, Y. X. (2012). Diversity and chemotaxis of soil bacteria with antifungal activity against *Fusarium wilt* of banana. *Journal of industrial microbiology & biotechnology*, 39: 1495-1505.

Lima, L. H. C., Marco, J. D., & Felix, J. R. (1998). Enzimas hidroliticas envolvidas no controle biologico por miciparasitisma. *Controle biologico*, 11: 263-304.

Linde, C., Drenth, A., & Wingfield, M. J. (1999). Gene and genotypic diversity of *Phytophthora cinnamomi* in South Africa and Australia revealed by DNA polymorphisms. *European Journal of Plant Pathology*, 105: 667-680.

Linzer, R. E., Rizzo, D. M., Cacciola, S. O., & Garbelotto, M. (2009). AFLPs detect low genetic diversity for *Phytophthora nemorosa* and *P. pseudosyringae* in the US and Europe. *mycological research*, 113: 298-307.

Liu, Y., Guo, J., Li, L., Asem, M. D., Zhang, Y., Mohamad, O. A., & Li, W. (2017). Endophytic bacteria associated with endangered plant Ferula sinkiangensis KM Shen in an arid land: diversity and plant growth-promoting traits. *Journal of Arid Land*, 9: 432-445.

Lodewyckx, C., Vangronsveld, J., Porteous, F., Moore, E. R., Taghavi, S., Mezgeay, M., & der Lelie, D. V. (2002). Endophytic bacteria and their potential applications. *Critical Reviews in Plant Sciences*, 21: 583-606.

Louden, B. C., Haarmann, D., & Lynne, A. M. (2011). Use of blue agar CAS assay for siderophore detection. *Journal of microbiology & biology education: JMBE*, 12: 51.

Macagnan, D., Romeiro, R. D. S., de Souza, J. T., & Pomella, A. W. (2006). Isolation of actinomycetes and endospore-forming bacteria from the cacao pod surface and their antagonistic activity against the witches' broom and black pod pathogens. *Phytoparasitica*, 34: 122-132.

Magat, S. S. (2005). Crop Nutrition and Fertilization Management of Selected Tropical Industrial Tree Crops. Los Baños, Laguna: PCARRD-DOST, 2005. 172 p.

Magat, S. S. (2004). Growing of Intercrops in coconut lands to generate more food and agricultutral products, jobs and enhancing farm income. Coconut Intercropping Primer. Published by PCA-Diliman, Quezon City.Dec.2004. 7p.

Magat, S., & Secretaria, M. (2007). Coconut-Cacao (Cocoa) Cropping Model. Coconut Intercropping Guide No. 7. Philippine Coconut Authority. Department of Agriculture. < http://www.pca.da.gov.ph/pdf/techno/cococacao.pdf> [2013, November 16].

Mahuku, G., Peters, R. D., Platt, H. W., & Daayf, F. (2000). Random amplified polymorphic DNA (RAPD) analysis of *Phytophthora infestans* isolates collected in Canada during 1994 to 1996. *Plant Pathology*, 49, 252-260.

Malinowski, D. P., Alloush, G. A., & Belesky, D. P. (2000). Leaf endophyte *Neotyphodium coenophialum* modifies mineral uptake in tall fescue. *Plant and Soil*, 227: 115-126.

Martin, F. N. (2000). Phylogenetic relationships among some *Pythium* species inferred from sequence analysis of the mitochondrially encoded cytochrome oxidase II gene. *Mycologia*, 92: 711–727.

Martin, F. N., & Tooley, P. W. (2003). Phylogenetic relationships among *Phytophthora* species inferred from sequence analysis of mitochondrially encoded cytochrome oxidase I and II genes. *Mycologia*, 95: 269-284.

Martin, F. N., Abad, Z. G., Balci, Y., & Ivors, K. (2012). Identification and detection of *Phytophthora*: reviewing our progress, identifying our needs. *Plant Disease*, 96: 1080-1103.

Martin, F. N., Blair, J. E., & Coffey, M. D. (2014). A combined mitochondrial and nuclear multilocus phylogeny of the genus *Phytophthora*. *Fungal Genetics and Biology*, 66: 19-32.

Mathivanan, N., & Manibhushanrao, K. (2004). An overview of current strategies on biological control of soil-borne pathogens. Vistas in applied botany. Department of Applied Botany and Biotechnology, University of Mysore, Mysore, India, pp 119–148.

Mathivanan, N., Manibhushanrao, K., & Murugesan, K. (2006). Biological control of plant pathogens. In: Anand N (ed) Recent trends in botanical research. University of Madras, Chennai, India, pp 275–323.

Maurhofer, M., Keel, C., Haas, D., & Défago, G. (1995). Influence of plant species on disease suppression by *Pseudomonas fluorescens* strain CHAO with enhanced antibiotic production. *Plant pathology*, 44: 40-50.

May, K. J., Drenth, A., & Irwin, J. A. G. (2003). Interspecific hybrids between the homothallic *Phytophthora sojae* and *Phytophthora vignae*. *Australasian Plant Pathology*, 32: 353-359.

McDermott, J. M., Brandle, U., Dutly, F., Haemmerli, U. A., Keller, S., Muller, K. E., & Wolfe, M. S. (1994). Genetic variation in powdery mildew of barley: development of RAPD, SCAR, and VNTR markers. *Phytopathology*, 84: 1316-1321.

Mchau, G. R., & Coffey, M. D. (1995). Evidence for the existence of two subpopulations in *Phytophthora capsici* and a redescription of the species. *Mycological Research*, 99: 89-102.

Meinhardt, L. W., Rincones, J., Bailey, B. A., Aime, M. C., Griffith, G. W., Zhang, D., & Pereira, G. A. (2008). *Moniliophthora perniciosa*, the causal agent of witches' broom disease of cacao: what's new from this old foe?. *Molecular plant pathology*, 9: 577-588.

Mejía, L. C., Rojas, E. I., Maynard, Z., Van Bael, S., Arnold, A. E., Hebbar, P., Samuels G.J., Robbins N., & Herre, E. A. (2008). Endophytic fungi as biocontrol agents of *Theobroma cacao* pathogens. *Biological Control*, 46: 4-14.

Meksem, K., & Kahl, G. (Eds.). (2006). The handbook of plant genome mapping: genetic and physical mapping. John Wiley & Sons.

Melnick, R. L., Zidack, N. K., Bailey, B. A., Maximova, S. N., Guiltinan, M., & Backman, P. A. (2008). Bacterial endophytes: *Bacillus* spp. from annual crops as potential biological control agents of black pod rot of cacao. *Biological Control*, 46: 46-56.

Meng, X. Q., Shoemaker, R. C., & Yang, X. B. (1999). Analysis of pathogenicity and genetic variation among *Phytophthora sojae* isolates using RAPD. *Mycological Research*, 103: 173-178.

Menzies, J. G., Bakkeren, G., Matheson, F., Procunier, J. D., & Woods, S. (2003). Use of inter-simple sequence repeats and amplified fragment length polymorphisms to analyze genetic relationships among small grain-infecting species of Ustilago. *Phytopathology*, 93: 167-175.

Minorsky, P. V. (2008). On the inside. *Plant Physiology* 146: 323–324 Neilands J. B., Nakamura K. (1991). In: Winkelmann G (ed) CRC handbook of microbial iron chelates. CRC Press, Florida, pp 1–14.

Mishra, M., Kumar, U., Mishra, P. K., & Prakash, V. (2010). Efficiency of plant growth promoting rhizobacteria for the enhancement of *Cicer arietinum L.* growth and germination under salinity. *Advances in Biological Research,* 4: 92-96.

Mohamed Azni, I. N. A., Sundram, S., Ramachandran, V., & Abu Seman, I. (2017). An *in vitro* investigation of Malaysian *Phytophthora palmivora* isolates and pathogenicity study on oil palm. *Journal of Phytopathology*, *165*(11-12), 800-812.

Montealegre, J. R., Reyes, R., Pérez, L. M., Herrera, R., Silva, P., & Besoain, X. (2003). Selection of bioantagonistic bacteria to be used in biological control of *Rhizoctonia solani* in tomato. *Electronic Journal of Biotechnology*, 6: 115-127.

Morath, S. U., Hung, R., & Bennett, J. W. (2012). Fungal volatile organic compounds: a review with emphasis on their biotechnological potential. *Fungal Biology Reviews,* 26: 73-83.

Mueller, U. G., & Wolfenbarger, L. L. (1999). AFLP genotyping and fingerprinting. *Trends in ecology & evolution*, 14: 389-394.

Mukherjee, G., & Sen, S. K. (2006). Purification, characterization, and antifungal activity of chitinase from Streptomyces venezuelae P10. *Current microbiology*, 53: 265-269.

Nair, K. P. (2010). Cocoa (*Theobroma cacao L.)*. The agronomy and economy of important tree crops of the developing world, 131-180.

Nath, V. S., Sankar, M. S. A., Hegde, V. M., Jeeva, M. L., Misra, R. S., Veena, S. S., & Raj, M. (2014). Analysis of genetic diversity in *Phytophthora colocasiae* causing leaf blight of taro (*Colocasia esculenta*) using AFLP and RAPD markers. *Annals of microbiology*, 64: 185-197.

Nautiyal, C. S. (1999). An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. *FEMS microbiology Letters*, 170: 265-270.

Neuhaus, J. M., (1999). Plant chitinases. In: Pathogenesis related Proteins in Plants. (S. Muthukrishnan, S.K. Datta, ed.), CRC Press, Washington, DC, USA, 77–104.

Nimnoi, P., Pongsilp, N., & Lumyong, S. (2010). Endophytic actinomycetes isolated from *Aquilaria crassna* Pierre ex Lec and screening of plant growth promoters production. *World Journal of Microbiology and Biotechnology*, 26: 193-203.

Ochwo, M. K. N., Kamoun, S., Adipala, E., Rubaihayo, P. R., Lamour, K., & Olanya, M. (2002). Genetic diversity of *Phytophthora infestans* (Mont.) de Bary in the eastern and western highlands of Uganda. *Journal of Phytopathology*, 150: 541-542.

Omont, H. (2001). Cocoa. IPGRI – Commodity Chains. http://www.fao.org. (Accessed 20 May, 2015).

Ongena, M., Jourdan, E., Adam, A., Paquot, M., Brans, A., Joris, B., ... & Thonart, P. (2007). Surfactin and fengycin lipopeptides of *Bacillus subtilis* as elicitors of induced systemic resistance in plants. *Environmental microbiology*, 9: 1084-1090.

Opoku, I. Y., & Wheeler, B. E. J. (1998). Survival of *Phytophthora palmivora* and *Phytophthora megakarya* on and in roots of cocoa seedlings. *Cocoa Growers' Bulletin,* 51, 33–41.

Opoku, I. Y., Appiah, A. A., Akrofi, A. Y., & Owusu, G. K. (2000). *Phytophthora megakarya*: a potential threat to the cocoa industry in Ghana. *Ghana Journal of Agricultural Science*, 33: 237-248.

Oudemans, P., & Coffey, M. D. (1991). A revised systematics of twelve papillate *Phytophthora* species based on isozyme analysis. *Mycological Research*, 95: 1025-1046.

Padwick, G.W. (1956). Losses caused by plant diseases in the Colonies. Volume 1, Phyto pathological papers. Kew, England, Commonwealth Mycological Institute. (No. 632 P33).

Pal, K. K., & Gardener, B. M. (2006). Biological control of plant pathogens. *The plant health instructor*, 2: 1117-1142.

Paramageetham, C., & Prasada Babu, G. (2012). Antagonistic Activity of *Fluorescent Pseudomonads* against a Polyphagous Soil Born Plant Pathogen-Sclerotium rolfsii. 1: 436.

Pathma, J., Kennedy, R. K., & Sakthivel, N. (2011). Mechanisms of *fluorescent pseudomonads* that mediate biological control of phytopathogens and plant growth promotion of crop plants. In Bacteria in agrobiology: Plant growth responses (pp. 77-105). Springer Berlin Heidelberg.

Paul, D., Anandaraj, M., Kumar, A., & Sarma, Y. R. (2005). Antagonistic mechanisms of *fluorescent pseudomonads* against *Phytophthora capsici* in black pepper (Piper nigrum L.). *Journal of Spices and Aromatic Crops*, 14: 122-129.

Peakall, R. O. D., & Smouse, P. E. (2012). GenAlEx 6.5: genetic analysis in Excel. Population genetic software for teaching and research-an update. *Bioinformatics* 28: 2537-2539.

Peters, R. D., Clark, R. J., Coffin, A. D., Sturz, A. V., Lambert, D. H., & Miller, J. S. (2005). Limited genetic diversity in North American isolates of *Phytophthora erythroseptica* pathogenic to potato based on RAPD analysis. *Plant disease*, 89: 380-384.

Petros, Y., Merker, A., & Zeleke, H. (2008). Analysis of genetic diversity and relationships of wild *Guizotia* species from Ethiopia using ISSR markers. *Genetic Resources and Crop Evolution*, 55: 451-458.

Phillips, L. A., Germida, J. J., Farrell, R. E., & Greer, C. W. (2008). Hydrocarbon degradation potential and activity of endophytic bacteria associated with prairie plants. *Soil Biology and Biochemistry*, 40: 3054-3064.

Phillips-Mora, W., & Wilkinson, M. J. (2007). Frosty pod of cacao: a disease with a limited geographic range but unlimited potential for damage. *Phytopathology*, 97: 1644-1647.

Podile, A. R., & Kishore, G. K. (2006). Plant growth-promoting rhizobacteria. In Plant-associated bacteria (pp. 195-230). Springer Netherlands.

Prabukumar, S., Rajkuberan, C., Ravindran, K., & Sivaramakrishnan, S. (2015). Isolation and characterization of endophytic fungi from medicinal plant *Crescentia cujete L.* and their antibacterial, antioxidant and anticancer properties. *International Journal of Pharmacy and Pharmaceutical Sciences,* 7: 316-321.

Qin, S., Xing, K., Jiang, J. H., Xu, L. H., & Li, W. J. (2011). Biodiversity, bioactive natural products and biotechnological potential of plant-associated endophytic actinobacteria. *Applied Microbiology and Biotechnology*, 89: 457-473.

Radhajeyalakshmi, R., Meena, B., Thangavelu, R., Deborah, S. D., Vidhyasekaran, P., & Velazhahan, R. (2000). A 45-kDa chitinase purified from pearl millet (*Pennisetum glaucum*) (L.) R. Br.) shows antifungal activity. *Journal of Plant Diseases and Protection*, 107: 605–616.

Rahman M. Z., Uematsu S., Takeuchi T., Shirai K., Ishiguro Y., Suga H., & Kageyama K. (2014). Two new species, *Phytophthora nagaii* sp. nov. and *P. fragariaefolia* sp. nov., causing serious diseases on rose and strawberry plants, respectively, in Japan. *Journal of General Plant Pathology,* 80: 348-365.

Rassouli, M. H., Khavazi, K., Rahimian, H., Malakouti, M. J., & Asadi-Rahmani, H. (2005). An evaluation of the potential of indigenous *Fluorescent Pseudomonds* of wheat rhizosphere for producing siderophore. *Iran Journal of Soil and Water Science*, 20: 133-143.

Ray, T., & Roy, S. C. (2008). Genetic diversity of Amaranthus species from the Indo-Gangetic plains revealed by RAPD analysis leading to the development of ecotype-specific SCAR marker. *Journal of heredity*, 100: 338-347.

Reiter, B., Pfeifer, U., Schwab, H., & Sessitsch, A. (2002). Response of endophytic bacterial communities in potato plants to infection with *Erwinia carotovora* subsp. atroseptica. *Applied and Environmental Microbiology*, 68: 2261-2268.

Reynolds, K. M., Gold, H. J., Bruck, R. I., Benson, D. M., and Lee Campbell, C. (1986). Simulations of the spread of *Phytophthora cinnamomi* causing a root rot of Fraser fir in nursery beds. *Phytopathology*, 76: 1190-1201.

Ristaino, J. B., & Gumpertz, M. L. (2000). New frontiers in the study of dispersal and spatial analysis of epidemics caused by species in the genus *Phytophthora*. *Annual Review of Phytopathology*, 38: 541-576.

Rizzo, D. M., Garbelotto, M., & Hansen, E. M. (2005). *Phytophthora ramorum*: integrative research and management of an emerging pathogen in California and Oregon forests. *Annual Review of Phytopathology*, 43: 309-335.

Ross, I. L., Alami, Y., Harvey, P. R., Achouak, W., & Ryder, M. H. (2000). Genetic diversity and biological control activity of novel species of closely related *pseudomonads* isolated from wheat field soils in South Australia. *Applied and Environmental Microbiology*, 66: 1609-1616.

Rubini, M. R., Silva-Ribeiro, R. T., Pomella, A. W., Maki, C. S., Araújo, W. L., Dos Santos, D. R., & Azevedo, J. L. (2005). Diversity of endophytic fungal community of cacao (*Theobroma cacao* L.) and biological control of *Crinipellis perniciosa*, causal agent of Witches' Broom Disease. *International Journal of Biological Sciences*, 1:24-33.

Ryan, R. P., Germaine, K., Franks, A., Ryan, D. J., & Dowling, D. N. (2008). Bacterial endophytes: recent developments and applications. *FEMS microbiology letters*, 278: 1-9.

Sabah Government (2001a). Sabah cocoa sector. Sabah Government, Malaysia [accessed 22 June 2001]. On the Internet:http://www.ssl.sabah.gov.my/clh/english/economy/agriculture_cocoa.htm.

Sahaf, B. Z., Moharramipour, S., & Meshkatalsadat, M. H. (2007). Chemical constituents and fumigant toxicity of essential oil from *Carum copticum* against two stored product beetles. *Insect Science*, 14: 213-218.

Sambrook, J., Fritsch, E. F., & Maniatis, T. (1989). Molecular cloning: a laboratory manual. 2rd edition, Cold Spring Harbor Laboratory Press, Cold Spring Harbour, New York, USA. pp. 9.31-9.57.

Samuel, S. & Muthukkaruppan, S. M. (2011). Characterization of plant growth promoting rhizobacteria and fungi associated with rice, mangrove and effluent contaminated soil. *Current Botany* 2: 22-25.

Sapak, Z., Meon, S. A. R. I. A. H., & Ahmad, Z. A. M. (2008). Effect of endophytic bacteria on growth and suppression of *Ganoderma* infection in oil palm. *International Journal of Agriculture and Biology,* 10: 127-132.

Sarker, A., Talukder, N. M., & Islam, M. T. (2014). Phosphate solubilizing bacteria promote growth and enhance nutrient uptake by wheat. *Plant Science Today*, 1: 86-93.

Saxena, J. (2010). Characterization of *Pseudomonas aeruginosa* RM-3 as a potential biocontrol agent. *Mycopathologia*, 170(3), 181-193.

Schulz, B., Römmert, A. K., Dammann, U., Aust, H. J., & Strack, D. (1999). The endophyte-host interaction: a balanced antagonism?. *Mycological Research*, 103: 1275-1283.

Senthilkumar, M., Govindasamy, V., Annapurna, K., (2007). Role of antibiosis in suppression of charcoal rot disease by soybean endophyte *Paenibacillus* sp. HKA-15. *Current Microbiology,* 55: 25–29.

Shearer, B. L. (1992). Plant Disease research in the Dept. of Conservation and Land Management. Dieback-What is the Future, Perth, WA, The Northern Sandplains Dieback Working Party.

Sheng, M., Tang, M., Zhang, F., & Huang, Y. (2011). Influence of arbuscular mycorrhiza on organic solutes in maize leaves under salt stress. *Mycorrhiza*, 21: 423-430.

Sheoran, N., Nadakkakath, A. V., Munjal, V., Kundu, A., Subaharan, K., Venugopal, V., & Kumar, A. (2015). Genetic analysis of plant endophytic *Pseudomonas putida* BP25 and chemo-profiling of its antimicrobial volatile organic compounds. *Microbiological research*, 173: 66-78.

Siddiqui, I. A., Shaukat, S. S., Sheikh, I. H., & Khan, A. (2006). Role of cyanide production by *Pseudomonas fluorescens* CHA0 in the suppression of root-knot nematode, *Meloidogyne javanica* in tomato. *World Journal of Microbiology and Biotechnology*, 22: 641-650.

Silva, P. D., & Nahas, E. (2002). Bacterial diversity in soil in response to different plans, phosphate fertilizers and liming. *Brazilian Journal of Microbiology*, 33: 304-310.

Silva, W. P., Karunanayake, E. H., Wijesundera, R. L., & Priyanka, U. M. (2003). Genetic variation in *Corynespora cassiicola*: a possible relationship between host origin and virulence. *Mycological research*, 107: 567-571.

Silvar, C., Merino, F., & Diaz, J. (2006). Diversity of *Phytophthora capsici* in Northwest Spain: analysis of virulence, metalaxyl response, and molecular characterization. *Plant Disease*, 90: 1135-1142.

Singh, B. P., Saikia, R., Yadav, M., Singh, R., Chauhan, V. S., & Arora, D. K. (2006). Molecular characterization of *Fusarium oxysporum* f. sp. ciceri causing wilt of chickpea. *African Journal of Biotechnology*, 5: 497-502.

Singh, L. S., Sharma, H., & Talukdar, N. C. (2014). Production of potent antimicrobial agent by actinomycete, Streptomyces sannanensis strain SU118 isolated from phoomdi in Loktak Lake of Manipur, India. *BMC microbiology*, 14: 278.

Singh, Y., Singh, J., & Pandey, A. K. (2013). Molecular markers in diagnosis and management of fungal pathogens: A review. *International Journal of Advanced Biotechnology and Research*, 4: 180-188.

Sivakamasundari, R., & Usharani, G. (2012). Studies on the influence of *Pseudomonas fluorescens* and chemicals on the biocontrol sheath blight incidence in rice. *International Journal of Pharmaceutical & Biological Archives*, 3: 973-977.

Smibert, R. M., & Krieg, N. R. (1994). Phenotypic characterization. in methods for general and molecular bacteriology. *American Society for Microbiology,* 611-651.

Smith, N. J., Williams, J. T., Plucknett, D. L., & Talbot, J. P. (2018). Tropical forests and their crops. New York, USA, Cornell University Press.

Sreenivasan, T. N., & Dabydeen, S. (1989). Modes of penetration of young cocoa leaves by *Crinipellis perniciosa. Plant Disease,* 73: 478-481.

Stamps, D. J., Waterhouse, G. M., Newhook, F. J., & Hall, G. S. (1990). Revised tabular key to the species of *Phytophthora*. *Mycological Papers* 162, 1-28.

Sturz, A. V., Christie, B. R., & Nowak, J. (2000). Bacterial endophytes: potential role in developing sustainable systems of crop production. *Critical reviews in plant sciences*, 19: 1-30.

Swadling, I. R., & Jeffries, P. (1998). Antagonistic properties of two bacterial biocontrol agents of grey mould disease. *Biocontrol Science and Technology*, 8: 439-448.

Taechowisan, T., Peberdy, J. F., & Lumyong, S. (2003). Chitinase production by endophytic Streptomyces aureofaciens CMUAc130 and its antagonism against phytopathogenic fungi. *Annals of microbiology*, 53: 447-462.

Taghavi S., Garafola C., Monchy S., Newman L., Hoffman A., Weyens N., Barac T., Vangronsveld J., van del Lelie D. (2009). Genome survey and characterization of endophytic bacteria exhibiting a beneficial effect on growth and development of poplar trees. *Applied and Environmental Microbiology*, 75:748-757.

TAI, L.H. (1970). Studies of *Phytophthora palmivora*, the causal organism of patch canker disease of durian. Cawangan Perkembangan, Jabatan Pertanian, K. Lumpur. 7 pp.

Talbot, N. J. (Ed.). (2001). Molecular and cellular biology of filamentous fungi: a practical approach (Vol. 249). Oxford University Press, USA.

Tamura, K., Stecher, G., Peterson, D., Filipski, A., & Kumar, S. (2013). MEGA6: molecular evolutionary genetics analysis version 6.0. *Molecular biology and evolution,* 30: 2725-2729.

Tey, C., & Bong, C. L. (1990). Cocoa. Proceedings of the MCB–MCGC workshop on cocoa agricultural research. Kuala Lumpur, Malaysian Cocoa Growers' Council, 78–92.

Tey, C., & Lee, B. S., (1994). Chemical control on black pod disease of cocoa. In Proceeding 4th International Conference on Plant Protection in The Tropics. Kuala Lumpur: 181-184.

Thrower, L. B. (1960a). Observations on the diseases of cacao pods in Papua and New Guinea I. Fungi associated with mature pods. *Tropical Agriculture,* 37: 111–120.

Tiwari, V., Roy, R., & Tiwari, M. (2015). Antimicrobial active herbal compounds against Acinetobacter baumannii and other pathogens. *Frontiers in microbiology*, *6*: 618.

Tokala, R. K., Strap, J. L., Jung, C. M., Crawford, D. L., Salove, M. H., Deobald, L. A., & Morra, M. J. (2002). Novel plant-microbe rhizosphere interaction involving Streptomyces lydicus WYEC108 and the pea plant (*Pisum sativum*). *Applied and environmental microbiology*, 68: 2161-2171.

Tooley, P. W., Carras, M. M., & Falkenstein, K. F. (1996). Relationships among group IV *Phytophthora* species inferred by restriction analysis of the ITS2 region. *Journal of Phytopathology*, 144: 363-369.

Tsao, P. H., & Alizadeh, A. (1988). Recent advances in the taxonomy and nomenclature of the so-called *Phytophthora palmivora* MF4 occurring on cocoa and other tropical crops. Proceedings. In 10. International Cocoa Research Conference, 17-23 May 1987Santo Domingo (R. Dominicana) (No. 633.74063 I61p 1987). Cocoa Producers' Alliance, Lagos (Nigeria).

Turner, P. D. (1961a). Strains of *Phytophthora palmivora* (Butl.) from *Theobroma cacao* L. II. Isolates from non-African countries. *Transactions of the British Mycological Society,* 44: 409-416.

Uysal, H., Fu, Y. B., Kurt, O., Peterson, G. W., Diederichsen, A., & Kusters, P. (2010). Genetic diversity of cultivated flax (*Linum usitatissimum* L.) and its wild progenitor pale flax (*Linum bienne* Mill.) as revealed by ISSR markers. *Genetic resources and crop evolution*, 57: 1109-1119.

Validov, S., Mavrodi, O., La Fuente, L. D., Boronin, A., Weller, D., Thomashow, L., & Mavrodi, D. (2005). Antagonistic activity among 2, 4-diacetylphloroglucinol-producing *fluorescent Pseudomonas* spp. *FEMS microbiology letters*, 242: 249-256.

van't Klooster, J. W., van den Berg-Velthuis, G., van West, P., & Govers, F. (2000). *tef1*, a *Phytophthora infestans* gene encoding translation elongation factor 1α. *Gene*, 249: 145-151.

Varma, A., Bakshi, M., Lou, B., Hartmann, A., & Oelmueller, R. (2012). *Piriformospora indica*: a novel plant growth-promoting mycorrhizal fungus. *Agricultural Research*, 1: 117-131.

Verma, V. C., Gond, S. K., Kumar, A., Mishra, A., Kharwar, R. N., & Gange, A. C. (2009). Endophytic actinomycetes from *Azadirachta indica* A. Juss. isolation, diversity and anti-microbial activity. *Microbial ecology*, 57: 749-756.

Vos, P., Hogers, R., Bleeker, M., Reijans, M., Lee, T. V. D., Hornes, M., Frijters, A., Pot, J., Peleman, J., Kuiper, M., & Zabeau, M. (1995). AFLP: a new technique for DNA fingerprinting. *Nucleic acids research*, 23: 4407-4414.

Wahyudi, A. T., & Astuti, R. I. (2011). Screening of *Pseudomonas* sp. isolated from rhizosphere of soybean plant as plant growth promoter and biocontrol agent. *American Journal of Agricultural and Biological Science*.

Wang, Z., Langston, D. B., Csinos, A. S., Gitaitis, R. D., Walcott, R. R., & Ji, P. (2009). Development of an improved isolation approach and simple sequence repeat markers to characterize *Phytophthora capsici* populations in irrigation ponds in southern Georgia. *Applied and environmental microbiology*, 75: 5467-5473.

Waterhouse, G. M. (1963). Key to the species of *Phytophthora* de Bary. Commonwealth Mycological Institute, Kew, UK*, Mycological Papers,* 92, 22.

Whipps, J. M. (1997). Developments in the biological control of soil-borne plant pathogens. In *Advances in botanical research* (Vol. 26, pp. 1-134). Academic Press.

Whisson, S. C., Drenth, A., Maclean, D. J., & Irwin, J. A. G. (1994). Evidence for outcrossing in *Phytophthora sojae* and linkage of a DNA marker to two avirulent genes. *Current genetics*, 27: 77-82.

White, T. J., Bruns, T., Lee, S. J. W. T., & Taylor, J. L. (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. PCR protocols: a guide to methods and applications, 18: 315-322.

Williams, G. E., & Asher, M. J. C. (1996). Selection of rhizobacteria for the control of *Pythium ultimum* and *Aphanomyces cochlioides* on sugar-beet seedlings. *Crop Protection*, 15: 479-486.

Williams, J. G., Kubelik, A. R., Livak, K. J., Rafalski, J. A., & Tingey, S. V. (1990). DNA polymorphisms amplified by arbitrary primers are useful as genetic markers. *Nucleic acids research*, 18: 6531-6535.

Wood, G. A. R., & Lass, R. A. (2001). Cocoa (4th ed.). Oxford: Blackwell Science.

Xu, F., & Sun, M. (2001). Comparative analysis of phylogenetic relationships of grain amaranths and their wild relatives (Amaranthus; Amaranthaceae) using internal transcribed spacer, amplified fragment length polymorphism, and double-primer fluorescent intersimple sequence repeat markers. *Molecular Phylogenetics and Evolution*, 21: 372-387.

Yang, E. J., & Chang, H. C. (2010). Purification of a new antifungal compound produced by Lactobacillus plantarum AF1 isolated from kimchi. *International journal of food microbiology*, 139: 56-63.

Yang, Z. H., Zhu, J. H., & Zhang, F. G. (2008). Genetic diversity of Chinese isolates of *Phytophthora infestans* revealed by AFLP analysis. *Mycosystema*, 27: 351-359.

Yasmin, F., Othman, R., Sijam, K., & Saad, M. S. (2010). Characterization of beneficial properties of plant growth-promoting rhizobacteria isolated from sweet potato rhizosphere. *African Journal of Microbiology Research* 3: 815-821.

Yeh, F. C. (1997). Population genetic analysis of co-dominant and dominant marker and quantitative traits. *Belgian Journal of Botany,* 130: 129-157.

Yeh, F. C., Yang, R. C., Boyle, T. B. J., Ye, Z. H., & Mao, J. X. (1997). The user-friendly shareware for population genetic analysis. Biology and Biotechnology Center, University of Alberta, Canada.

Zentmyer, G. A. (1980). *Phytophthora cinnamomi* and the diseases it causes. St Paul, Minnesota, *American Phytopathological Society*, Monograph No. 10.

Zhang, L. J., & Dai, S. L. (2010). Genetic variation within and among populations of Orychophragmus violaceus (Cruciferae) in China as detected by ISSR analysis. *Genetic resources and crop evolution*, 57: 55-64.

Zhang, X., Li, B., Wang, Y., Guo, Q., Lu, X., Li, S., & Ma, P. (2013). Lipopeptides, a novel protein, and volatile compounds contribute to the antifungal activity of the biocontrol agent *Bacillus atrophaeus* CAB-1. *Applied microbiology and biotechnology*, 97: 9525-9534.

Zhang, Y., Qi, H., Taylor, R., Xu, W., Liu, L. F., & Jin, S. V. (2007). The role of autophagy in mitochondria maintenance: characterization of mitochondrial functions in autophagy-deficient S. cerevisiae strains. *Autophagy*, 3: 337-346.

Zilber-Rosenberg, I., & Rosenberg, E. (2008). Role of microorganisms in the evolution of animals and plants: the hologenome theory of evolution. *FEMS microbiology reviews*, 32: 723-735.

BIODATA OF STUDENT

Wael Alsultan, son of Mahmoud and Fatimah, was born in 1987 in Palestine. He obtained the degree in Plant Production and Protection at the Faculty of Agriculture and Environment, Al-Azhar University – Gaza, with a GPA 81.23% rating very good in 2009. He was ranked the first among the graduates in his graduation year. Therefore, he was selected to join the academic staff of the faculty as an instructor. A part of the duties at the faculty was to teach the practical sessions and prepare the laboratory experiments for students, as well as assisting researchers in their laboratory work in the field of plant pathology and entomology. He obtained his Master of Science in Plant Pathology at the Faculty of Agriculture, Universiti Putra Malaysia, with a GPA 3.55 in August 2015. He began working for his Doctor of Philosophy under the supervision of the late supervisor Assoc. Prof. Dr. Jugah Kadir at the Faculty of Agriculture, Universiti Putra Malaysia in 2015. Then Associate Professor Dr. Ganesan Vadamalai at the Faculty of Agriculture, Universiti Putra Malaysia in 2018.

LIST OF PUBLICATIONS

Wael Alsultan, Jugah Kadir, Ganesan Vadamalai, Halimi Mohd Saud & Ahmed Kamil M.J (2016). Potential of Endophytic Bacteria for Control Black Pod Disease of Cocoa. Kuching City, Sarawak: Proceedings from the 9th International Conference on Plant Protection in the Tropics (9th ICPPT), Aug.3-5, Malaysia.

Wael Alsultan, Ganesan Vadamalaı, Khairulmazmi Ahmad & Osamah Rashed (2017). Detection and Identification of Cacao Black Pod Causal Agent by Polymerase Chain Reaction (PCR), International Conference on Big Data Applications in Agriculture (ICBAA2017), Malaysia.

Wael Alsultan, Ganesan Vadamalai, Ahmad Khairulmazmi, Halimi Mohd Saud, Abdullah M. Al-Sadi, Osamah Rashed, Ahmad Kamil Mohd Jaaffarand & Abbas Nasehi (2019). Isolation, identification and characterization of endophytic bacteria antagonistic to *Phytophthora palmivora* causing black pod of cocoa in Malaysia. *European Journal of Plant Pathology.* (Accepted with minor correction).

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