MOLECULAR CHARACTERIZATION OF *Phytophthora palmivora* Butler AND EVALUATION OF *Morinda citrifolia* L. LEAF EXTRACT FOR CONTROLLING STEM CANKER ON DURIAN

By

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Commercial durian production in Malaysia has doubled in the last decade and durian growers are receiving premium price from their fruits from local and international consumers. Stem canker, caused by *Phytophthora palmivora* is a major problem for durian farmers in Malaysia, but limited studies addressed their genetic diversity using multiple genes. Therefore, this study was conducted to characterize *Phytophthora* species from main durian orchards infected by stem canker in Malaysia using morphological, sequence analyses of the internal transcribed spacer (ITS) regions of ribosomal deoxyribonucleic acid (rDNA) and cytochrome oxidase c (COX) regions. Fungicides containing metalaxyl and phosphonate have been long used for this disease management in durian fields. However, the repeated and extensive use of similar fungicide developed resistant *Phytophthora* isolates. Research into new approaches of managing such pathogens are of importance. *Morinda citrifolia*, a medicinally valued plant that are commonly found in Malaysia can be a beneficial complement to chemical fungicides. This study was also to identify the compounds of *M. citrifolia* leaf crude extracts extracted using methanol, acetone, ethyl acetate and hexane. In addition, this study was carried out to evaluate *in vitro* and *in vivo* efficacy of *M. citrifolia* leaf crude extracts against the mycelial growth of *P. palmivora.* A total of 21 *Phytophthora* isolates were obtained from water-soaked lesions of durian stem tissues collected from 4 different states of Malaysia in 2019, Selangor (*n*=10), Perak (*n*=4), Pahang (*n*=4) and Melaka (*n*=3). All isolates had morphological characteristics similar to that of *P. palmivora.* For molecular identification, the results of BLASTn using the ITS and COX sequences identified them as *P. palmivora* with 99-100% with *P. palmivora* culture (GenBank accession no. ON834450 for the ITS region and JF771543 for the Cox region). Results of phylogenetic analyses of the ITS rDNA and COX confirmed that all *Phytophthora* isolates belonged to *P. palmivora* and clustered into one clade with reference *P. palmivora* isolates, supported by high bootstrap values for the ITS (100%) and COX (76%) regions. Pathogenicity tests showed all isolates were

pathogenic on durian leaves, where PMM02 had significantly the lowest virulence among all isolates with a lesion diameter of 64.04 mm at day 8. The detached leaf assays using durian leaves of D10, D24 and Mousang King varieties showed there was significance among durian varieties, where D10 was proven to be more susceptible towards *P. palmivora.* GC-MS analysis of *M. citrifolia* leaves crude extract revealed the presence of squalene. *In vitro* evaluation of *M. citrifolia* crude extracts acetone and ethyl acetate showed an effective concentration 50% (EC_{50}) values of 36.12 mg/mL and 38.10 mg/mL, respectively. Plate treated with acetone solvent at 60 mg/mL altered the morphology and inhibit the mycelial growth of *P. palmivora* at microscopic observation using scanning electron microscope. *In vivo* bioassay evaluation, plants treated with *M. citrifolia* extract of ethyl acetate 76 mg/mL had a lesion growth of 30.24 mm on the stem. This treatment was not significantly difference to control positive treatment applied with Ridomil fungicide. *M. citrifolia* methanol, acetone and ethyl acetate contain antifungal compounds and can be used as biofungicides for stem canker disease management.

Keywords: antifungal activity, canker, *Durio zibethinus*, *Morinda citrifolia,* oomycete

SDG: GOAL 9: Industry, Innovation and Infrastructure

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENCIRIAN MOLEKUL *Phytophthora palmivora* Butler DAN PENILAIAN EKSTRAK DAUN *Morinda citrifolia* L. UNTUK MENGAWAL PENYAKIT KANKER DURIAN

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Pengeluaran durian secara komersial di Malaysia telah meningkat dua kali ganda beberapa dekad yang lalu dan penanam durian menerima harga premium terhadap buah-buahan mereka daripada pengguna tempatan dan antarabangsa. Kanker batang yang disebabkan oleh *Phytophthora palmivora* adalah masalah utama bagi penanam durian di Malaysia, tetapi kajian berkenaan kepelbagaian genetik menggunakan pelbagai gen adalah terhad. Oleh itu, kajian ini dijalankan untuk mencirikan spesies *Phytophthora* daripada dusun durian utama yang dijangkiti kanker batang di Malaysia menggunakan morfologi dan analisis jujukan kawasan *internal transcribed spacer* (ITS) *ribosomal deoxyribonucleic acid* (rDNA) dan *cytochrome oxidase c* (COX). Racun kulat yang mengandungi metalaksil dan fosfonat telah lama digunakan untuk pengurusan penyakit tanaman durian. Walaubagaimanapun, penggunaan racun kulat yang sama dan secara berpanjangan telah menghasilkan populasi *Phytophthora* yang rintang terhadap racun tersebut. Penyelidikan berkaitan pendekatan baru untuk menguruskan patogen seperti ini adalah penting. *Morinda citrifolia,* tumbuhan perubatan bernilai tinggi biasa ditemui di Malaysia boleh menjadi pelengkap yang bermanfaat kepada racun kulat kimia. Kajian ini juga adalah untuk mengenalpasti sebatian ekstrak mentah daun *M. citrifolia* yang diekstrak menggunakan methanol, aseton, etil asetat dan heksana. Di samping itu, kajian ini dijalankan untuk menilai keberkesanan *in vitro* dan *in vivo* ekstrak mentah daun *M. citrifolia* terhadap pertumbuhan miselia *P. palmivora*. Sebanyak 21 isolat *Phytophthora* dipencil daripada simptomatik tisu batang durian yang disampel pada tahun 2019 dari 4 negeri di Malaysia, negeri Selangor (*n*=10), Perak (*n*=4), Pahang (*n*=4) dan Melaka (*n*=3). Semua isolat mempunyai ciri morfologi yang serupa dengan *P. palmivora*. Untuk pengenalpastian molekul, hasil BLASTn menggunakan jujukan ITS dan COX telah mengenalpasti isolat sebagai *P. palmivora* dengan 99-100% dengan kultur *ex-type P. palmivora* (GenBank ON834450 untuk primer ITS dan JF771543 untuk primer COX). Keputusan analisis filogenetik ITS rDNA dan COX mengesahkan bahawa semua isolat *Phytophthora* adalah *P. palmivora* dan

dikelompokkan ke dalam satu kluster dengan rujukan isolat *P. palmivora*, disokong oleh nilai *bootstrap* yang tinggi bagi primer ITS (100%) dan Cox (76%). Ujian patogenisiti menunjukkan semua pencilan adalah patogenik pada daun durian, di mana PMM02 mempunyai tahap virulen yang paling rendah di antara semua isolat dengan diameter lesi 64.04 mm pada hari ke 8. Ujian daun *detach* menggunakan daun durian varieti D10, D24 dan Mousang King menunjukkan D10 terbukti lebih rentan terhadap patogen *P. palmivora*. Analisis GC-MS terhadap ekstrak mentah daun *M. citriifolia* mendedahkan kehadiran *squalene*. Penilaian *in vitro* ekstrak mentah *M. citrifolia* aseton dan etil asetat memberikan kepekatan keberkesanan sebanyak 50% (EC_{50}) dengan nilai masing-masing, 36.12 mg/mL dan 38.10 mg/mL. Rawatan pelarut aseton dalam piring petri pada 60 mg/mL dilihat telah mengubah morfologi dan menghalang pertumbuhan miselium *P. palmivora* pada pemerhatian mikroskopik menggunakan *Scanning Electron Microscope.* Penilaian *in vivo* bioesei, pokok yang dirawat dengan ekstrak *M. citrifolia* etil asetat 76 mg/mL mempunyai pertumbuhan lesi 30.24 mm pada batang. Rawatan ini tidak mempunyai perbezaan yang signifikan dengan rawatan positif yang mengandungi racun kulat Ridomil. Ekstrak mentah *M. citrifolia* metanol, aseton dan etil asetat mengandungi sebatian antikulat dan boleh digunakan sebagai biofungisid dalam pengurusan penyakit kanker batang durian.

Kata Kunci: antikulat, *Durio zibethinus*, kanker, *Morinda citrifolia,* oomycete

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LIST OF ABBREVIATIONS

DNA	Deoxyribonucleic Acid
rDNA	Ribosomal Deoxyribonucleic Acid
ITS	Internal Transcribed Spacer
COXI	Cytochrome c oxidase subunit 1
COXII	Cytochrome c oxidase subunit 2
Ha	Hectare
°C	Degree Celsius
Mt	Metric Ton
BLAST	Basic Local Alignment Search Tool
RNA	Ribonucleic Acid
%	Percentage
CMA	Corn Meal Agar
g	Gram
L	Litre
mL	Millilitre
PCNB	Pentachloronitrobenzene
V8	Campbell's Vegetable 8 Juice
µL	Microliter
TBE	Tris borate EDTA
kb	Kilobase
V	Volts
PCR	Polymerase chain reaction
ANOVA	Analysis of Variance
PDA	Potato Dextrose Agar

L/B	Length/ breadth
bp	Base pair
rpm	Revolutions per minute
ppm	Parts per million
ATP	Adenosine triphosphate
EC_{50}	Effective Concentration
mg	Miligram
SAS	Statistical Analysis System
PIRG	Percentage inhibition of radial growth

CHAPTER 1

INTRODUCTION

Durian (*Durio zibethinus)* is a sought-after fruit especially in Asian countries. In Malaysia specifically, this economically important crop valued at RM 7.49 billion (Department of Agriculture, 2020) is the largest cultivated crop making it a major source of income for both small scale and commercial farmers. Stem canker disease caused by *Phytophthora palmivora* is still a major issue for durian growers. *Phytophthora palmivora* is considered one of the most destructive organisms causing stem canker in almost all growth stages of durian. Despite several efforts conducted to mitigate the losses caused by this disease, the pathogen's diversity has been a significant element in disease management. Hence, analysis of the genetic diversity is essential in understanding the species' evolutionary process and the development of an effective management strategy (Mohamed Azni *et al*., 2019). The preliminary step in identifying the *Phytophthora* species is based on morphological characteristics. As to complete the identification of the microorganism, molecular identification techniques are used as it is rapid, more accurate and sensitive (Capote *et al*., 2012). Advances in molecular methods for detecting microorganisms have helped to a better understanding of the phylogeny and molecular diversity of organisms such as the *Phytophthora* genus (Scibetta *et al.*, 2012). Furthermore, molecular approaches have been widely employed to distinguish closely related species and strains within a species (Singh *et al*., 2006).

It is stated in a phylogenetic study conducted by Baldauf *et al*. (2000), that true fungi and oomycetes are distantly related as they have different metabolic pathways. As a result, most fungicides used in the agriculture industry are ineffective in the treatment of plant disease caused by the oomycete pathogens. Thus, rapid pathogen identification is critical for disease control in terms of quarantine and disease transmission in planting materials. Several management measures have been used to control stem canker of durian, including phytosanitary measures, cultural approaches, chemical control, biological control and genetic resistance, but none have shown acceptable results or entirely control the disease so far (Guest, 2007). As a result, research into new approaches of managing such pathogens are of importance.

The *Morinda citrifolia* is a medicinally valued plant that is cultivated for its fruits, leaves and roots (Zin *et al.*, 2002). Not only are the leaves consumed as a vegetable (Zhang *et al.,* 2016), it has long been used for prevention of various chronic diseases (Lim *et al.,* 2016). Considering *M. citrifolia* leaves are commonly found in Malaysia, the use of this plant extract can be a beneficial complement to chemical fungicides.

There are currently no publications on the genetic diversity of *P. palmivora* of durian plantations in Malaysia. Moreover, identification and characterization of

this pathogen using the internal transcribed spacer (ITS) and Cytochrome c oxidase (COX) region. Also, the control of this disease is limited and there is no information on the use of *M. citrifolia* against this pathogen.

The main objectives of the study were:

i. to identify and characterize *Phytophthora palmivora* isolates causing stem canker disease on *Durio zibenthinus* using morphological, molecular and pathogenic characteristics

ii. to identify the compounds of *Morinda citrifolia* leaf crude extracts extracted using methanol, acetone, ethyl acetate and hexane

iii. to evaluate *in vitro* and *in vivo* efficacy of *Morinda citrifolia* leaf crude extracts against the mycelial growth of *Phytophthora palmivora*

REFERENCES

Abou Assi, R., Darwis, Y., Abdulbaqi, I. M., Vuanghao, L., & Laghari, M. H. (2017). *Morinda citrifolia* (Noni): A comprehensive review on its industrial uses, pharmacological activities, and clinical trials. *Arabian Journal of Chemistry*, *10*(5), 691-707. https://doi.org/10.1016/j.arabjc.2015.06.018

Alsultan, W., Vadamalai, G., Khairulmazmi, A., Saud, H. M., Al-Sadi, A. M., Rashed, O., Jaaffar, A.K.M. & Nasehi, A. (2019). Isolation, identification and characterization of endophytic bacteria antagonistic to *Phytophthora palmivora* causing black pod of cocoa in Malaysia. *European Journal of Plant Pathology*, *155*(4), 1077-1091. https://doi.org/10.1007/s10658-019-01834-8

Andrade, J. C., Morais-Braga, M. F. B., Guedes, G. M., Tintino, S. R., Freitas, M. A., Menezes, I. R., & Coutinho, H. D. (2014). Enhancement of the antibiotic activity of aminoglycosides by alpha-tocopherol and other cholesterol derivates. *Biomedicine & Pharmacotherapy*, *68*(8), 1065-1069. https://doi.org/10.1016/j.biopha.2014.10.011

Appiah, A. A., Opoku, I. Y., & Akrofi, A. Y. (2004). Natural occurrence and distribution of stem cankers caused by *Phytophthora megakarya* and *Phytophthora palmivora* on cocoa. *European journal of plant pathology*, *110*(10), 983-990. https://doi.org/10.1007/s10658-004-0811-6

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*(3), 388-398. https://doi.org/10.1080/15572536.2004.11833083

Aziz, S.D.A., Jafarah, N.F., & Yusof, Z.N.B. (2019). Phytol-containing seaweed extracts as control for *Ganoderma boninense*. *Journal of Oil Palm Research*, *31*(2), 238-247. https://doi.org/10.21894/jopr.2019.0018

Baldauf, S. L., Roger, A. J., Wenk-Siefert, I., & Doolittle, W. F. (2000). A kingdom-level phylogeny of eukaryotes based on combined protein data. *Science*, *290*(5493), 972-977. https://doi.org/10.1126/science.290.5493.972

Beakes, G. W., Glockling, S. L., & Sekimoto, S. (2012). The evolutionary phylogeny of the oomycete "fungi". *Protoplasma*, *249*(1), 3-19. https://doi.org/10.1007/s00709-011-0269-2

Beckmann, V., Irawan, E., & Wesseler, J. (2009). *The Effect of Farm Labor Organization on IPM Adoption. Empirical Evidence from Thailand* (No. 894-2016-65353). https://doi.org/10.22004/ag.econ.55767

Bouwmeester, H., Heuvelink, G. B. M., & Stoorvogel, J. J. (2016). Mapping crop diseases using survey data: The case of bacterial wilt in bananas in the

East African highlands. *European journal of agronomy*, *74*, 173-184. https://doi.org/10.1016/j.eja.2015.12.013

Bowman, K. D., Albrecht, U., Graham, J. H., & Bright, D. B. (2007). Detection of *Phytophthora nicotianae* and *P. palmivora* in citrus roots using PCR-RFLP in comparison with other methods. *European journal of plant pathology*, *119*(2), 143-158. https://doi.org/10.1007/s10658-007-9135-7

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*, *96*(10), 5878-5883. https://doi.org/10.1073/pnas.96.10.5878

Bronkhorst, J., Kasteel, M., Veen, S. V., Clough, J. M., Kots, K., Buijs, J., Gucht, J. V. D., Ketelaar, T., Govers, F., & Sprakel, J. (2021). A slicing mechanism facilitates host entry by plant- pathogenic *Phytophthora*. *Nature Microbiology*, *6*(8), 1000-1006. https://doi.org/10.1038/s41564-021-00919-7

Brown, M. S., Baysal-Gurel, F., Oliver, J. B., & Addesso, K. M. (2019). Evaluation of fungicides and biofungicide to control *Phytophthora* root rot (*Phytophthora cinnamomi* Rands) and ambrosia beetles (Coleoptera: *Curculionidae: Scolytinae*) on flowering dogwoods exposed to simulated flood events. *Crop Protection*, *124*, 104834. https://doi.org/10.1016/j.cropro.2019.05.028

Camele, I., Altieri, L., De Martino, L., De Feo, V., Mancini, E., & Rana, G. L. (2012). *In vitro* control of post-harvest fruit rot fungi by some plant essential oil components. *International Journal of Molecular Sciences*, *13*(2), 2290-2300. https://doi.org/10.3390/ijms13022290

Capote, N., Pastrana, A. M., Aguado, A., & Sánchez-Torres, P. (2012). Molecular tools for detection of plant pathogenic fungi and fungicide resistance. *Plant pathology*, *374*.

Chan, L. G., & Kwee, L. T. (1986). Comparative *in vitro* sensitivity of selected chemicals on *Phytophthora palmivora* from cocoa and durian. *PERTANIKA.*, *9*(2), 183-191.

Chen, F., Zhou, Q., Qin, C., Li, Y., & Zhan, J. (2018). Low evolutionary risk of iprovalicarb resistance in *Phytophthora infestans*. *Pesticide biochemistry and physiology*, *152*, 76-83. https://doi.org/10.1016/j.pestbp.2018.09.003

Chinnapun, D., Tian, M., Day, B., & Churngchow, N. (2009). Inhibition of a *Hevea brasiliensis* protease by a Kazal-like serine protease inhibitor from *Phytophthora palmivora*. *Physiological and Molecular Plant Pathology*, *74*(1), 27-33. https://doi.org/10.1016/j.pmpp.2009.08.005

Choi, N.H., Jang, J.Y., Choi, G.J., Choi, Y.H., Jang, K.S., Min, B.S., Le Dang, Q. & Kim, J.C. (2017). Antifungal activity of sterols and dipsacus saponins isolated from *Dipsacus asper* roots against phytopathogenic

fungi. *Pesticide Biochemistry and Physiology*, *141*, 103-108. https://doi.org/10.1016/j.pestbp.2016.12.006

Cohen, S., Allasia, V., Venard, P., Notter, S., Vernière, C., & Panabières, F. (2003). Intraspecific variation in *Phytophthora citrophthora* from citrus trees in Eastern Corsica. *European Journal of Plant Pathology*, *109*(8), 791-805. https://doi.org/10.1023/A:1026190318631

Collinge, D. B., Jørgensen, H. J., Latz, M. A., Manzotti, A., Ntana, F., Rojas Tayo, E. C., & Jensen, B. (2019). Searching for novel fungal biological control agents for plant disease control among endophytes. *Endophytes for a growing world*, *31*, 25.

Compean, K. L., & Ynalvez, R. A. (2014). Antimicrobial activity of plant secondary metabolites: A review. *Research Journal of Medicinal Plant*, *8*(5), 204. https://doi.org/10.3923/rjmp.2014.204.213

Cooke, B. M. (2006). Disease assessment and yield loss. In *The epidemiology of plant diseases* (pp. 43-80). Springer, Dordrecht. https://doi.org/10.1007/1-4020-4581-6_2

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*(1), 17-32. https://doi.org/10.1006/fgbi.2000.1202

de Araujo Gomes, R.B., de Souza, E.S., Barraqui, N.S.G., Tosta, C.L., Nunes, A.P.F., Schuenck, R.P., Ruas, F.G., Ventura, J.A., Filgueiras, P.R. & Kuster, R.M. (2020). Residues from the Brazilian pepper tree (*Schinus terebinthifolia* Raddi) processing industry: Chemical profile and antimicrobial activity of extracts against hospital bacteria. *Industrial Crops and Products*, *143*, 111430. https://doi.org/10.1016/j.indcrop.2019.05.079

Deng, S., West, B. J., & Jensen, C. J. (2010). A quantitative comparison of phytochemical components in global noni fruits and their commercial products. *Food Chemistry*, *122*(1), 267-270. https://doi.org/10.1016/j.foodchem.2010.01.031

Department of Agriculture, Malaysia (2020). Fruit Crop Statistics, 11-14pp. Available online: http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/maklumat_pertanian/perangkaan_tanaman/perangkaan_buah_2020.pdf (accessed on 13 December 2021).

Dicklow, M.B. & Madeiras, A. (2018) Biofungicides Fact Sheet, UMass Extension Greenhouse Crops and Floriculture, University of Massachusetts Amherst. Available online: https://ag.umass.edu/greenhouse-floriculture/fact-sheets/biofungicides#:~:text=Biofungicdes%20are%20formulations%20of%20living,the%20activity%20of%20plant%20pathogens. (accessed on 10 April 2023).

Doohan, F.M., Brennan, J., Cooke, B.M. (2003). Influence of climatic factors on *Fusarium* species pathogenic to cereals. In: Xu, X., Bailey, J.A., Cooke, B.M. (eds) Epidemiology of Mycotoxin Producing Fungi. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-1452-5_10

Drenth, A. (1994). Molecular genetic evidence for a new sexually reproducing population of *Phytophthora infestans* in Europe. Wageningen University and Research.

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

Drenth, A., & Sendall, B. (2001). Practical guide to detection and identification of *Phytophthora*. *Tropical Plant Protection*, *1*, 32-33.

El Khetabi, A., Lahlali, R., Ezrari, S., Radouane, N., Nadia, L., Banani, H. & Barka, E. A. (2022). Role of plant extracts and essential oils in fighting against postharvest fruit pathogens and extending fruit shelf life: A review. *Trends in Food Science & Technology*. https://doi.org/10.1016/j.tifs.2022.01.009

Elliott, M., Shamoun, S. F., & Sumampong, G. (2015). Effects of systemic and contact fungicides on life stages and symptom expression of *Phytophthora ramorum in vitro* and *in planta*. *Crop Protection*, *67*, 136-144. https://doi.org/10.1016/j.cropro.2014.10.008

Elsey, B., & Sirichoti, K. (2001). The adoption of integrated pest management (IPM) by tropical fruit growers in Thailand as an example of change management theory and practice. *Integrated Pest Management Reviews*, *6*, 1-14. https://doi.org/10.1023/A:1020691321022

Erasto, P., Grierson, D. S., & Afolayan, A. J. (2007). Evaluation of antioxidant activity and the fatty acid profile of the leaves of *Vernonia amygdalina* growing in South Africa. *Food Chemistry*, *104*(2), 636-642. https://doi.org/10.1016/j.foodchem.2006.12.013

Erwin, D.C. and Ribeiro, O.K. (1996). *Phytophthora* diseases worldwide. St. Paul, Minnesota: APS Press.

Essomé, C. S., Djuissi, D. T., Thierry, M., Mvondo, D. N., Kuaté, W. N. T., Ngatsi, P. Z., Bolie, H., Nsangou, A. K., Heu, A., Mboussi, S. B., & Ambang, Z. (2022). Antifungal Potential of Acetone and Ethyl Acetate Extracts of *Thevetia peruviana* on Development of *Phytophthora colocasiae*, Causal Agent of Late Blight of Taro (*Colocasia esculenta* (L.) Schott) from Three Agro-Ecological Zones of Cameroon. *International Journal of Pathogen Research*, *11*(3-4), 1–12. https://doi.org/10.9734/ijpr/2022/v11i2208

Fawke, S., Doumane, M., & Schornack, S. (2015). Oomycete interactions with plants: infection strategies and resistance principles. *Microbiology and*

Molecular Biology Reviews, *79*(3), 263-280. https://doi.org/10.1128/MMBR.00010-15

Food and Agriculture Organization. (2021) Available online: https://www.fao.org/pest-and-pesticide-management/ipm/integrated-pest-management/en/ (accessed on 13 December 2021).

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. https://doi.org/10.1017/S0953756200003087

Franco, A. J. D., Merca, F. E., Rodriguez, M. S., Balidion, J. F., Migo, V. P., Amalin, D. M., & Fernando, L. M. (2019). DNA-based electrochemical nanobiosensor for the detection of *Phytophthora palmivora* (Butler) Butler, causing black pod rot in cacao (*Theobroma cacao* L.) pods. *Physiological and Molecular Plant Pathology*, *107*, 14-20. https://doi.org/10.1016/j.pmpp.2019.04.004

Freeman, B. C., & Beattie, G. A. (2008). An overview of plant defenses against pathogens and herbivores. *The Plant Health Instructor,* 1–12. https://doi.org/10.1094/PHI-I- 2008-0226-01.

Gangaraj, K. P., & Rajesh, M. K. (2020). Dataset of dual RNA-sequencing of *Phytophthora palmivora* infecting coconut (*Cocos nucifera* L.). *Data in brief*, *30*, 105455. https://doi.org/10.1016/j.dib.2020.105455

Ghimire, B. K., Seong, E. S., Yu, C. Y., Kim, S. H., & Chung, I. M. (2017). Evaluation of phenolic compounds and antimicrobial activities in transgenic *Codonopsis lanceolata* plants via overexpression of the γ-tocopherol methyltransferase (γ-tmt) gene. *South African Journal of Botany*, *109*, 25-33. https://doi.org/10.1016/j.sajb.2016.12.022

Gnamusch, E., Ryder, N. S., & Paltauf, F. (1992). Effect of squalene on the structure and function of fungal membranes. *Journal of Dermatological Treatment*, *3*(sup1), 9-13. https://doi.org/10.3109/09546639209088694

Goun, E., Cunningham, G., Chu, D., Nguyen, C., & Miles, D. (2003). Antibacterial and antifungal activity of Indonesian ethnomedical plants. *Fitoterapia*, *74*(6), 592-596. https://doi.org/10.1016/S0367-326X(03)00117-5

Grünwald, N. J., Martin, F. N., Larsen, M. M., Sullivan, C. M., Press, C. M., Coffey, M. D., Hansen, E. M., and Parke, J. L. (2011). Phytophthora-ID. org: a sequence-based *Phytophthora* identification tool. *Plant Disease*, *95*(3), 337-342. https://doi.org/10.1094/PDIS-08-10-0609

Guest, D. (2007). Black pod: diverse pathogens with a global impact on cocoa yield. *Phytopathology,* 97: 1650-1653. https://doi.org/10.1094/PHYTO-97-12-1650

Guest, D. I., & Bompeix, G. (1990). The complex mode of action of phosphonates. *Australasian Plant Pathology*, *19*(4), 113-115. https://doi.org/10.1071/APP9900113

Guest, D., & Grant, B. (1991). The complex action of phosphonates as antifungal agents. *Biological Reviews*, *66*(2), 159-187. https://doi.org/10.1111/j.1469-185X.1991.tb01139.x

Hansen, E. M., Reeser, P. W., & Sutton, W. (2012). *Phytophthora* beyond agriculture. *Annual review of phytopathology*, *50*, 359-378. https://doi.org/10.1146/annurev-phyto-081211-172946

Haque, E., Irfan, S., Kamil, M., Sheikh, S., Hasan, A., Ahmad, A., Lakshmi, V., Nazir, A. & Mir, S.S. (2016). Terpenoids with antifungal activity trigger mitochondrial dysfunction in *Saccharomyces cerevisiae*. *Microbiology*, *85*(4), 436-443. https://doi.org/10.1134/S0026261716040093

Harish, S., Kavino, M., Kumar, N., Balasubramanian, P., & Samiyappan, R. (2009). Induction of defence-related proteins by mixtures of plant growth promoting endophytic bacteria against Banana bunchy top virus. *Biological Control*, *51*(1), 16-25. https://doi.org/10.1016/j.biocontrol.2009.06.002

Heckman, C., Kanagasundaram, S., Cayer, M. & Paige, J. (2007). Preparation of cultured cells for scanning electron microscope. Protoc. Exch. Available online: https://protocols.scienceexchange.com/protocols/preparation-of-cultured-cells-for-scanning-electron-microscope (accessed on 13 December 2021).

Herman, R. P. (1998). Oxylipin production and action in fungi and related organisms. In Rowley AF, Kuhn H, Schewe T (Eds). *Eicosanoids and related compounds in plants and animals.* (pp. 115–132). London, Portland Press.

Holderness, M. (1992). Comparison of metalaxyl/ cuprous oxide sprays and potassium phosphonate as sprays and trunk injections for control of *Phytophthora palmivora* pod rot and canker of cocoa. *Crop Protection*, *11*(2), 141-147. https://doi.org/10.1016/0261-2194(92)90097-O

Hong, C., Richardson, P. A. & Kong, P. (2008). Pathogenicity to ornamental plants of some existing species and new taxa of *Phytophthora* from irrigation water. *Plant disease*, *92*(8), 1201-1207. https://doi.org/10.1094/PDIS-92-8-1201

Hsu, B., Coupar, I. M., & Ng, K. (2006). Antioxidant activity of hot water extract from the fruit of the Doum palm, *Hyphaene thebaica*. *Food Chemistry*, *98*(2), 317-328. https://doi.org/10.1016/j.foodchem.2005.05.077

Inoue, Y., Hada, T., Shiraishi, A., Hirose, K., Hamashima, H., & Kobayashi, S. (2005). Biphasic effects of geranylgeraniol, teprenone, and phytol on the growth of *Staphylococcus aureus*. *Antimicrobial Agents and Chemotherapy*, *49*(5), 1770-1774. https://doi.org/10.1128/AAC.49.5.1770-1774.2005

Jayaraman, S. K., Manoharan, M. S., & Illanchezian, S. (2008). Antibacterial, antifungal and tumor cell suppression potential of *Morinda citrifolia* fruit extracts. *International Journal of Integrative Biology*, *3*(1), 44-49.

John, W. C., Anyanwu, N. C. J., & Ayisa, T. (2016). Evaluation of the effects of the extract of *Vernonia amygdalina* on fungi associated with infected tomatoes (*Lycopersicon esculentum*) in Jos North Local Government Area, Plateau State, Nigeria. *Annual Research & Review in Biology*, 1-8. https://doi.org/10.9734/ARRB/2016/23698

Jung, T., Pérez-Sierra, A., Durán, A., Jung, M. H., Balci, Y., & Scanu, B. (2018). Canker and decline diseases caused by soil-and airborne *Phytophthora* species in forests and woodlands. *Persoonia-Molecular Phylogeny and Evolution of Fungi*, *40*(1), 182-220. https://doi.org/10.3767/persoonia.2018.40.08

Kamoun, S., Furzer, O., Jones, J. D., Judelson, H. S., Ali, G. S., Dalio, R. J., & Govers, F. (2015). The Top 10 oomycete pathogens in molecular plant pathology. *Molecular Plant Pathology*, *16*(4), 413-434. https://doi.org/10.1111/mpp.12190

Kavino, M., Harish, S., Kumar, N., Saravanakumar, D., & Samiyappan, R. (2008). Induction of systemic resistance in banana (*Musa* spp.) against Banana bunchy top virus (BBTV) by combining chitin with root-colonizing *Pseudomonas fluorescens* strain CHA0. *European Journal of Plant Pathology*, *120*(4), 353-362. https://doi.org/10.1007/s10658-007-9223-8

Khompatara, K., Pettongkhao, S., Kuyyogsuy, A., Deenamo, N., & Churngchow, N. (2019). Enhanced resistance to leaf fall disease caused by *Phytophthora palmivora* in rubber tree seedling by *Sargassum polycystum* extract. *Plants*, *8*(6), 168. https://doi.org/10.3390/plants8060168

Krishnaiah, D., Sarbatly, R., & Nithyanandam, R. (2012). Microencapsulation of *Morinda citrifolia* L. extract by spray-drying. *Chemical Engineering Research and Design*, *90*(5), 622-632. https://doi.org/10.1016/j.cherd.2011.09.003

Kromann, P., Pérez, W. G., Taipe, A., Schulte-Geldermann, E., Sharma, B. P., Andrade-Piedra, J. L., & Forbes, G. A. (2012). Use of phosphonate to manage foliar potato late blight in developing countries. *Plant disease*, *96*(7), 1008-1015. https://doi.org/10.1094/PDIS-12-11-1029-RE

Krzyśko-Łupicka, T., Walkowiak, W., & Białoń, M. (2019). Comparison of the fungistatic activity of selected essential oils relative to *Fusarium*

graminearum isolates. *Molecules*, *24*(2), 311. https://doi.org/10.3390/molecules24020311

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7: Molecular Evolutionary Genetics Analysis Version 7.0 for Bigger Datasets. *Molecular biology and evolution*, *33*(7), 1870–1874. https://doi.org/10.1093/molbev/msw054

Kumar, V. A., Ammani, K., Siddhardha, B., Sreedhar, U., & Kumar, G. A. (2013). Differential biological activities of the solvent extracts of *Ceriops decandra* (Griff.) and their phytochemical investigations. *Journal of Pharmacy Research*, *7*(7), 654-660. https://doi.org/10.1016/j.jopr.2013.05.024

Larkin, M. A., Blackshields, G., Brown, N. P., Chenna, R., McGettigan, P. A., McWilliam, H. & Higgins, D. G. (2007). Clustal W and Clustal X version 2.0. *bioinformatics*, *23*(21), 2947-2948. https://doi.org/10.1093/bioinformatics/btm404

Latifah, M., Kamaruzaman, S., Abidin, M. Z., & Nusaibah, S. A. (2018). Identification of Phytophthora spp. from perennial crops in Malaysia, its pathogenicity and cross-pathogenicity. *Sains Malaysiana*, *47*(5), 909-921. http://dx.doi.org/10.17576/jsm-2018-4705-06

Lawrence, S. A., Robinson, H. F., Furkert, D. P., Brimble, M. A., & Gerth, M. L. (2021). Screening a Natural Product-Inspired Library for Anti-Phytophthora Activities. *Molecules*, *26*(7), 1819. https://doi.org/10.3390/molecules26071819

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*(4), 636-653. https://doi.org/10.1093/oxfordjournals.molbev.a040750

Li, Y., Fabiano-Tixier, A. S., Chemat, F., Li, Y., Fabiano-Tixier, A. S., & Chemat, F. (2014). Essential oils: From conventional to green extraction. *Essential oils as reagents in Green Chemistry*, 9-20. https://doi.org/10.1007/978-3-319-08449-7_2

Lim, S. L., Mustapha, N. M., Goh, Y. M., Bakar, N. A. A., & Mohamed, S. (2016). Metastasized lung cancer suppression by *Morinda citrifolia* (Noni) leaf compared to Erlotinib via anti-inflammatory, endogenous antioxidant responses and apoptotic gene activation. *Molecular and Cellular Biochemistry*, *416*(1), 85-97. https://doi.org/10.1007/s11010-016-2698-x

Lim, T.K. & Sijam, K. (2015). Penyakit Tanaman Durian. Kuala Lumpur: Dewan Bahasa dan Pustaka. ISBN: 9789836216007.

Lim, W. H., & Yassin, I. (1985). Chemical control of *Phytophthora* patch canker of durian, *Durio zibethinus* Murr. [Malaysia]. *Teknologi Buah Buahan*.

Lima, D., Santos, A.L.D., Celestino, A.O., Sampaio, N., Baldez, J., Melecchi, M.I., Bjerk, T.R., Krause, L.C. & Caramão, E.B. (2019). Ultrasonic extracts

of *Morinda citrifolia* L.: Characterization of volatile compounds by gas chromatography-mass spectrometry. *Journal of the Brazilian Chemical Society*, *30*, 132-139. https://doi.org/10.21577/0103-5053.20180162

Keith, L. M., Sugiyama, L. S., Matsumoto, T. K., & Nagao, M. A. (2014, August). Disease management strategy for macadamia quick decline. In XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): 1109 (pp. 237-242). https://doi.org/10.17660/ActaHortic.2016.1109.38

Liu, D., Pan, Y., Li, K., Li, D., Li, P., & Gao, Z. (2020). Proteomics reveals the mechanism underlying the inhibition of *Phytophthora sojae* by propyl gallate. *Journal of Agricultural and Food Chemistry*, *68*(31), 8151-8162. https://doi.org/10.1021/acs.jafc.0c02371

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*(3), 432-445. https://doi.org/10.1007/s40333-017-0015-5

Ma, Y., Li, X., Hou, L. X., & Wei, A. Z. (2019). Extraction solvent affects the antioxidant, antimicrobial, cholinesterase and HepG2 human hepatocellular carcinoma cell inhibitory activities of *Zanthoxylum bungeanum* pericarps and the major chemical components. *Industrial Crops and Products*, *142*, 111872. https://doi.org/10.1016/j.indcrop.2019.111872

Mahdikhani, M., Matinfar, M., & Aghaalikhani, A. (2018). First report of *Phytophthora palmivora* causing crown and root rot of pistachio trees in northern Iran. *Journal of Plant Pathology*, *100*(3), 583-583. https://doi.org/10.1007/s42161-018-0032-z

Maizatul-Suriza, M., Dickinson, M., & Idris, A. S. (2019). Molecular characterization of *Phytophthora palmivora* responsible for bud rot disease of oil palm in Colombia. *World Journal of Microbiology and Biotechnology*, *35*(3), 1-23. https://doi.org/10.1007/s11274-019-2618-9

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*(2), 269-284. https://doi.org/10.1080/15572536.2004.11833112

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*(8), 1080-1103. https://doi.org/10.1094/PDIS-12-11-1036-FE

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. https://doi.org/10.1016/j.fgb.2014.02.006

Martin, F. N., Tooley, P. W., & Blomquist, C. (2004). Molecular detection of *Phytophthora ramorum*, the causal agent of sudden oak death in California, and two additional species commonly recovered from diseased plant material. *Phytopathology*, *94*(6), 621-631. https://doi.org/10.1094/PHYTO.2004.94.6.621

Masi, M., & Evidente, A. (2021). Sphaeropsidin A: A pimarane diterpene with interesting biological activities and promising practical applications. *ChemBioChem*, *22*(23), 3263-3269. https://doi.org/10.1002/cbic.202100283

Mateus, S. D., Adalberto, C. C. F., Renato, D. A. S., Ildon, R. D. N., Talita, P. D. S. F., Raimundo, W. D. S. A., & Gil, R. D. S. (2017). Evaluation of essential oils for preventive or curative management of melon gummy stem blight and plant toxicity. *Journal of Medicinal Plants Research*, *11*(26), 426-432. https://doi.org/10.5897/JMPR2017.6405

McDonald, S., Prenzler, P. D., Antolovich, M., & Robards, K. (2001). Phenolic content and antioxidant activity of olive extracts. *Food chemistry*, *73*(1), 73-84. https://doi.org/10.1016/S0308-8146(00)00288-0

Mchau, G. R., & Coffey, M. D. (1994). Isozyme diversity in *Phytophthora palmivora*: evidence for a southeast Asian centre of origin. *Mycological Research*, *98*(9), 1035-1043. https://doi.org/10.1016/S0953-7562(09)80430-9

McMahon, P., & Purwantara, A. (2004). 6.1 *Phytophthora* on cocoa. *Diversity and management of Phytophthora in Southeast Asia*, 104-114.

Micera, M., Botto, A., Geddo, F., Antoniotti, S., Bertea, C.M., Levi, R., Gallo, M.P. and Querio, G. (2020). Squalene: more than a step toward sterols. *Antioxidants*, *9*(8), 688. https://doi.org/10.3390/antiox9080688

Misman, N., Samsulrizal, N. H., Noh, A. L., Wahab, M. A., Ahmad, K., & Ahmad Azmi, N. S. (2022). Host Range and Control Strategies of *Phytophthora palmivora* in Southeast Asia Perennial Crops. *Pertanika Journal of Tropical Agricultural Science*, *45*(4). https://doi.org/10.47836/pjtas.45.4.09

Miyake, N., & Nagai, H. (2017). Efficacy of phosphonate in controlling white powdery rot of fig caused by *Phytophthora palmivora*. *Journal of General Plant Pathology*, *83*(6), 390-397. https://doi.org/10.1007/s10327-017-0746-3

Miyake, N., & Nagai, H. (2019). Pathogenicity of *Phytophthora palmivora* to fig fruits after its long-term storage in water. *Journal of General Plant Pathology*, *85*(4), 251-256. https://doi.org/10.1007/s10327-019-00847-9

Mohamed Azni, I. N. A., Sundram, S., & Ramachandran, V. (2019). Pathogenicity of Malaysian *Phytophthora palmivora* on cocoa, durian,

rubber and oil palm determines the threat of bud rot disease. *Forest Pathology*, *49*(6), e12557. https://doi.org/10.1111/efp.12557

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. https://doi.org/10.1111/jph.12620

Morton, J. F. (1992). The ocean-going noni, or Indian Mulberry (*Morinda citrifolia,* Rubiaceae) and some of its "colorful" relatives. *Economic Botany*, *46*(3), 241-256. https://www.jstor.org/stable/4255440

Moushib, L. I., Witzell, J., Lenman, M., Liljeroth, E., & Andreasson, E. (2013). Sugar beet extract induces defence against *Phytophthora infestans* in potato plants. *European journal of plant pathology*, *136*(2), 261-271. https://doi.org/10.1007/s10658-012-0160-9

Nana, W. L., Eke, P., Fokom, R., Bakanrga-Via, I., Begoude, D., Tchana, T., & Fekam Boyom, F. (2015). Antimicrobial activity of *Syzygium aromaticum* and *Zanthoxylum xanthoxyloides* essential oils against *Phytophthora megakarya. Journal of Phytopathology*, *163*(7-8), 632-641. https://doi.org/10.1111/jph.12363

Noiarsa, P., Ruchirawat, S., Otsuka, H., & Kanchanapoom, T. (2006). A new iridoid glucoside from the Thai medicinal plant, Morinda elliptica Ridl. Journal of Natural Medicines, 60, 322–324. https://doi.org/10.1007/s11418-006-0003-0

O'Gara, E., Sangchote, S., Fitzgerald, L., Wood, D., Seng, A. C., & Guest, D. I. (2004). Infection biology of *Phytophthora palmivora* Butl. in *Durio zibethinus* L. (Durian) and responses induced by phosphonate. In A. Drenth & D. I Guest (Eds.), *Diversity and management of* Phytophthora *in Southeast Asia* (pp. 42-52). Australian Centre for International Agricultural Research (ACIAR).

Opoku, I. Y., Akrofi, A. Y., & Appiah, A. A. (2007). Assessment of sanitation and fungicide application directed at cocoa tree trunks for the control of *Phytophthora* black pod infections in pods growing in the canopy. *European Journal of Plant Pathology*, *117*(2), 167-175. https://doi.org/10.1007/s10658-006-9082-8

Osorio, P. R. A., Leão, E. U., Veloso, R. A., Mourão, D. D. S. C., & Santos, G. R. D. (2018). Essential oils for alternative teak rust control. *Floresta e Ambiente*, *25*. https://doi.org/10.1590/2179-8087.039116

Pandy, V., Narasingam, M., & Mohamed, Z. (2012). Antipsychotic-like activity of Noni (*Morinda citrifolia* Linn.) in mice. *BMC complementary and alternative medicine*, *12*(1), 1-9. https://doi.org/10.1186/1472-6882-12-186

Pang, Z., Chen, L., Miao, J., Wang, Z., Bulone, V., & Liu, X. (2015). Proteomic profile of the plant-pathogenic oomycete *Phytophthora capsici* in response to the fungicide pyrimorph. *Proteomics*, *15*(17), 2972-2982. https://doi.org/10.1002/pmic.201400502

Pham, D.Q., Pham, H.T., Han, J.W., Nguyen, T.H., Nguyen, H.T., Nguyen, T.D., Nguyen, T.T.T., Ho, C.T., Pham, H.M., Vu, H.D. & Choi, G.J. (2021). Extracts and metabolites derived from the leaves of *Cassia alata* L. exhibit *in vitro* and *in vivo* antimicrobial activities against fungal and bacterial plant pathogens. *Industrial Crops and Products*, *166*, 113465. https://doi.org/10.1016/j.indcrop.2021.113465

Pongpisutta, R., & Sangchote, S. (2004). Morphological and host range variability in *Phytophthora palmivora* from durian in Thailand. *Diversity and management of Phytophthora in Southeast Asia*, 53.

Puig, A. S., Ali, S., Strem, M., Sicher, R., Gutierrez, O. A., & Bailey, B. A. (2018). The differential influence of temperature on *Phytophthora megakarya* and *Phytophthora palmivora* pod lesion expansion, mycelia growth, gene expression, and metabolite profiles. *Physiological and Molecular Plant Pathology*, *102*, 95-112. https://doi.org/10.1016/j.pmpp.2017.12.002

Pusztahelyi, T., Holb, I. J., & Pócsi, I. (2015). Secondary metabolites in fungus-plant interactions. *Frontiers in Plant Science*, *6*, 573. https://doi.org/10.3389/fpls.2015.00573

Qi, R., Wang, T., Zhao, W., Li, P., Ding, J., & Gao, Z. (2012). Activity of Ten Fungicides against *Phytophthora capsici* Isolates Resistant to Metalaxyl. *Journal of Phytopathology*, *160*(11-12), 717-722. https://doi.org/10.1111/jph.12009

Rahman, M. Z., Uematsu, S., Coffey, M. D., Uzuhashi, S., Suga, H., & Kageyama, K. (2014). Re-evaluation of Japanese *Phytophthora* isolates based on molecular phylogenetic analyses. *Mycoscience*, *55*(4), 314-327. https://doi.org/10.1016/j.myc.2013.11.005

Rahman, M. Z., Uematsu, S., Suga, H., & Kageyama, K. (2015). Diversity of *Phytophthora* species newly reported from Japanese horticultural production. *Mycoscience*, *56*(4), 443-459. https://doi.org/10.1016/j.myc.2015.01.002

Rani, A., Kumar, V., Verma, S. K., Shakya, A. K., & Chauhan, G. S. (2007). Tocopherol content and profile of soybean: genotypic variability and correlation studies. *Journal of the American Oil Chemists' Society*, *84*(4), 377-383. https://doi.org/10.1007/s11746-007-1040-x

Rauha, J. P., Remes, S., Heinonen, M., Hopia, A., Kähkönen, M., Kujala, T. & Vuorela, P. (2000). Antimicrobial effects of Finnish plant extracts containing flavonoids and other phenolic compounds. *International Journal of Food Microbiology*, *56*(1), 3-12. https://doi.org/10.1016/S0168-1605(00)00218-X

Razali, N., Mat-Junit, S., Abdul-Muthalib, A. F., Subramaniam, S., & Abdul-Aziz, A. (2012). Effects of various solvents on the extraction of antioxidant phenolics from the leaves, seeds, veins and skins of *Tamarindus indica* L. *Food Chemistry*, *131*(2), 441-448. https://doi.org/10.1016/j.foodchem.2011.09.001

Rebollar-Alviter, A., Madden, L. V., & Ellis, M. A. (2007). Pre-and post-infection activity of azoxystrobin, pyraclostrobin, mefenoxam, and phosphite against leather rot of strawberry, caused by *Phytophthora cactorum*. *Plant Disease*, *91*(5), 559-564. https://doi.org/10.1094/PDIS-91-5-0559

Reddy, L. H., & Couvreur, P. (2009). Squalene: A natural triterpene for use in disease management and therapy. *Advanced Drug Delivery Reviews*, *61*(15), 1412-1426. https://doi.org/10.1016/j.addr.2009.09.005

Reeslev, M., & Kjoller, A. (1995). Comparison of biomass dry weights and radial growth rates of fungal colonies on media solidified with different gelling compounds. *Applied and Environmental Microbiology*, *61*(12), 4236-4239. https://doi.org/10.1128/aem.61.12.4236-4239.1995

Rhimi, W., Salem, I. B., Iatta, R., Chaabane, H., Saidi, M., Boulila, A., & Cafarchia, C. (2018). *Dittrichia viscosa* L. leaves lipid extract: An unexploited source of essential fatty acids and tocopherols with antifungal and anti-inflammatory properties. *Industrial Crops and Products*, *113*, 196-201. https://doi.org/10.1016/j.indcrop.2018.01.032

Rogozhin, E. A., Vasilchenko, A. S., Barashkova, A. S., Smirnov, A. N., Zavriev, S. K., & Demushkin, V. P. (2020). Peptide extracts from seven medicinal plants discovered to inhibit oomycete *Phytophthora infestans*, a causative agent of potato late blight disease. *Plants*, *9*(10), 1294. *https://doi.org/10.3390/plants9101294*

Saludes, J. P., Garson, M. J., Franzblau, S. G., & Aguinaldo, A. M. (2002). Antitubercular constituents from the hexane fraction of *Morinda citrifolia* Linn.(Rubiaceae). *Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives*, *16*(7), 683-685. https://doi.org/10.1002/ptr.1003

Sang, S., Liu, G., He, K., Zhu, N., Dong, Z., Zheng, Q. & Ho, C. T. (2003). New unusual iridoids from the leaves of noni (*Morinda citrifolia* L.) show inhibitory effect on ultraviolet B-induced transcriptional activator protein-1 (AP-1) activity. Bioorganic & medicinal chemistry, 11(12), 2499-2502. https://doi.org/10.1016/S0968-0896(03)00180-9

Sang, S., Wang, M., & He, K. (2002). Chemical components in noni fruits and leaves (Morinda citrifolia L.) in Quality Management of Nutraceuticals, Ho, C.T., Zheng, Q.Y. (eds). ASC Symp Ser 803, American Chemical Society, Washington, DC. *https://doi.org/*10.1021/bk-2002-0803.ch010

Sarria, G. A., Martinez, G., Varon, F., Drenth, A., & Guest, D. I. (2016). Histopathological studies of the process of *Phytophthora palmivora*

infection in oil palm. *European Journal of Plant Pathology*, *145*(1), 39-51. https://doi.org/10.1007/s10658-015-0810-9

Scheuerell, S., & Mahaffee, W. (2002). Compost tea: principles and prospects for plant disease control. *Compost Science & Utilization*, *10*(4), 313-338. https://doi.org/10.1080/1065657X.2002.10702095

Scibetta, S., Schena, L., Chimento, A., Cacciola, S. O., & Cooke, D. E. (2012). A molecular method to assess *Phytophthora* diversity in environmental samples. *Journal of microbiological methods*, *88*(3), 356-368. https://doi.org/10.1016/j.mimet.2011.12.012

Sena, K., Crocker, E., Vincelli, P., & Barton, C. (2018). *Phytophthora cinnamomi* as a driver of forest change: Implications for conservation and management. *Forest Ecology and Management*, *409*, 799-807. https://doi.org/10.1016/j.foreco.2017.12.022

Simamora, A. V. Hahuly, M. V. & Henuk, J. B. (2021). Endophytic fungi as potential biocontrol agents of *Phytophthora palmivora* in the cocoa plant. *Biodiversitas Journal of Biological Diversity*, *22*(5). https://doi.org/10.13057/biodiv/d220519

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*(6), 497-502.

Singh, B., & Sharma, R. A. (2020). Indian Morinda species: A review. *Phytotherapy research*, *34*(5), 924-1007. https://doi.org/10.1002/ptr.65

Singh, D. R. (2012). *Morinda citrifolia* L.(Noni): A review of the scientific validation for its nutritional and therapeutic properties. *Journal of Diabetes and Endocrinology*, *3*(6), 77-91. *https://doi.org/*10.5897/JDE10.006

Sitepu, D. and Mustika, I. (2000). Diseases of black pepper and their management in Indonesia. In P.N.Ravindran(Eds), Black Pepper, *Piper nigrum*. (pp. 297-305). Volume 13 of the book series Medicinal and Aromatic Plants- Industrial Profiles. Harwood Acedemic Publisher.

Sousa, S.G., Oliveira, L.A., de Aguiar Magalhães, D., de Brito, T.V., Batista, J.A., Pereira, C.M.C., de Souza Costa, M., Mazulo, J.C.R., de Carvalho Filgueiras, M., Vasconselos, D.F.P. & da Silva, D.A. (2018). Chemical structure and anti-inflammatory effect of polysaccharide extracted from *Morinda citrifolia* Linn (Noni). *Carbohydrate polymers*, *197*, 515-523. https://doi.org/10.1016/j.carbpol.2018.06.042

Stenberg, J. A. (2017). A conceptual framework for integrated pest management. *Trends in plant science*, *22*(9), 759-769. https://doi.org/10.1016/j.tplants.2017.06.010

Su, B. N., Pawlus, A. D., Jung, H. A., Keller, W. J., McLaughlin, J. L., & Kinghorn, A. D. (2005). Chemical constituents of the fruits of *Morinda citrifolia* (Noni) and their antioxidant activity. *Journal of Natural Products*, *68*(4), 592-595. https://doi.org/10.1021/np0495985

Suchinina, T. V., Shestakova, T. S., Petrichenko, V. M. & Novikova, V. V. (2011). Solvent polarity effect on the composition of biologically active substances, UV spectral characteristics, and antibacterial activity of *Euphrasia brevipila* herb extracts. *Pharmaceutical Chemistry Journal*, *44*(12), 683-686. https://doi.org/10.1007/s11094-011-0542-x

Sunpapao, A., & Pornsuriya, C. (2014). Effects of chitosan treatments on para rubber leaf fall disease caused by *Phytophthora palmivora* Butler - A laboratory study. *Songklanakarin Journal of Science and Technology*, *36*(5), 507–512.

Suranant, S., & Saichol, K. (2001). Durian: king of tropical fruit. *Durian: king of tropical fruit.* New York: CABI Publishing.

Sutela, S., Poimala, A., & Vainio, E. J. (2019). Viruses of fungi and oomycetes in the soil environment. *FEMS Microbiology Ecology*, *95*(9), fiz119. https://doi.org/10.1093/femsec/fiz119

Syed Ab Rahman, S. F., Singh, E., Pieterse, C. M. J., & Schenk, P. M. (2018). Emerging microbial biocontrol strategies for plant pathogens. *Plant Science*, *267*, 102–111. https://doi.org/10.1016/j. plantsci.2017.11.012

Tabet Zatla, A., Dib, M. E. A., Djabou, N., Ilias, F., Costa, J., & Muselli, A. (2017). Antifungal activities of essential oils and hydrosol extracts of *Daucus carota* subsp. sativus for the control of fungal pathogens, in particular gray rot of strawberry during storage. *Journal of Essential Oil Research*, *29*(5), 391-399. https://doi.org/10.1080/10412905.2017.1322008

Takashima, J., Ikeda, Y., Komiyama, K., Hayashi, M., Kishida, A., & Ohsaki, A. (2007). New constituents from the leaves of *Morinda citrifolia*. *Chemical and Pharmaceutical Bulletin*, *55*(2), 343-345. https://doi.org/10.1248/cpb.55.343

Tala, M. F., Ansary, M. W. R., Talontsi, F. M., Kowa, T. K., Islam, M. T., & Tane, P. (2018). Anthraquinones and flavanols isolated from the vegetable herb *Rumex abyssinicus* inhibit motility of *Phytophthora capsici* zoospores. *South African Journal of Botany*, *115*, 1-4. https://doi.org/10.1016/j.sajb.2017.11.015

Tashiro, N., Uematsu, S., Ide, Y., & Matsuzaki, M. (2012). First report of *Phytophthora palmivora* as a causal pathogen of citrus brown rot in Japan. *Journal of General Plant Pathology*, *78*(3), 233-236. https://doi.org/10.1007/s10327-012-0378-6

Thompson, A. (1934). A disease of durian trees. *The Malaysian Agriculture Journal* 22, 369-371.

Tiwari, P., Kumar, B., Kaur, M., Kaur, G., & Kaur, H. (2011). Phytochemical screening and extraction: a review. *Internationale pharmaceutica sciencia*, *1*(1), 98-106.

Tripathi, P., & Dubey, N. K. (2004). Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. *Postharvest Biology and Technology*, *32*(3), 235-245. https://doi.org/10.1016/j.postharvbio.2003.11.005

Truong, D. H., Nguyen, D. H., Ta, N. T. A., Bui, A. V., Do, T. H., & Nguyen, H. C. (2019). Evaluation of the use of different solvents for phytochemical constituents, antioxidants, and *in vitro* anti-inflammatory activities of *Severinia buxifolia*. *Journal of Food Quality*, *2019*. https://doi.org/10.1155/2019/8178294

Tsao, P. H., & Ocana, G. (1969). Selective isolation of species of *Phytophthora* from natural soils on an improved antibiotic medium. *Nature*, *223*(5206), 636-638. https://doi.org/10.1038/223636a0

Turkmen, N., Sari, F., & Velioglu, Y. S. (2006). Effects of extraction solvents on concentration and antioxidant activity of black and black mate tea polyphenols determined by ferrous tartrate and Folin–Ciocalteu methods. *Food Chemistry*, *99*(4), 835-841. https://doi.org/10.1016/j.foodchem.2005.08.034

Vawdrey, L. L., Langdon, P., & Martin, T. (2005a). Incidence and pathogenicity of *Phytophthora palmivora* and *Pythium vexans* associated with durian decline in far northern Queensland. *Australasian Plant Pathology*, *34*, 127-128. https://doi.org/10.1071/AP04093

Vawdrey, L. L., Martin, T. M., & De Faveri, J. (2005b). A detached leaf bioassay to screen Durian cultivars for susceptibility to *Phytophthora palmivora. Australasian plant pathology*, *34*(2), 251-253. https://doi.org/10.1071/AP05005

Villa, N. O., Kageyama, K., Asano, T., & Suga, H. (2006). Phylogenetic relationships of Pythium and *Phytophthora* species based on ITS rDNA, cytochrome oxidase II and β-tubulin gene sequences. *Mycologia*, *98*(3), 410-422. https://doi.org/10.1080/15572536.2006.11832676

Walters, D., Raynor, L., Mitchell, A., Walker, R., & Walker, K. (2004). Antifungal activities of four fatty acids against plant pathogenic fungi. *Mycopathologia*, *157*(1), 87-90. https://doi.org/10.1023/B:MYCO.0000012222.68156.2c

Wang, W., Ben-Daniel, B. H., & Cohen, Y. (2004). Control of plant diseases by extracts of *Inula viscosa*. *Phytopathology*, *94*(10), 1042-1047. https://doi.org/10.1094/PHYTO.2004.94.10.1042

Wang, X., Shen, Y., Thakur, K., Han, J., Zhang, J. G., Hu, F., & Wei, Z. J. (2020). Antibacterial activity and mechanism of ginger essential oil against

Escherichia coli and Staphylococcus aureus. *Molecules*, *25*(17), 3955. https://doi.org/10.3390/molecules25173955

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

Waterhouse, G. M. (1974). *Phytophthora palmivora* and some related species. *Phytophthora Disease of Cocoa. PH Gregory, ed*.

Widmer, T. L., & Laurent, N. (2006). Plant extracts containing caffeic acid and rosmarinic acid inhibit zoospore germination of *Phytophthora* spp. pathogenic to *Theobroma cacao*. *European Journal of plant pathology*, *115*(4), 377-388. https://doi.org/10.1007/s10658-006-9024-5

Wong, K. M. (1984). A synopsis of *Morinda* (Rubiaceae) in the Malay Peninsula, with two new species. *Mal. Nat. J*. 38, 89-98.

Xiang, W., Song, Q. S., Zhang, H. J., & Guo, S. P. (2008). Antimicrobial anthraquinones from Morinda angustifolia. *Fitoterapia*, *79*(7-8), 501-504. https://doi.org/10.1016/j.fitote.2008.04.008

Yusoff, S. F., Haron, F. F., Tengku Muda Mohamed, M., Asib, N., Sakimin, S. Z., Abu Kassim, F., & Ismail, S. I. (2020). Antifungal activity and phytochemical screening of *Vernonia amygdalina* extract against *Botrytis cinerea* causing gray mold disease on tomato fruits. *Biology*, *9*(9), 286. https://doi.org/10.3390/biology9090286

Zhang, W. M., Wang, W., Zhang, J. J., Wang, Z. R., Wang, Y., Hao, W. J., & Huang, W. Y. (2016). Antibacterial constituents of Hainan *Morinda citrifolia* (noni) leaves. *Journal of Food Science*, *81*(5), M1192-M1196. https://doi.org/10.1111/1750-3841.13302

Zhu, H., Zhang, J., Li, C., Liu, S., & Wang, L. (2020). *Morinda citrifolia* L. leaves extracts obtained by traditional and eco-friendly extraction solvents: Relation between phenolic compositions and biological properties by multivariate analysis. *Industrial Crops and Products*, *153*, 112586. https://doi.org/10.1016/j.indcrop.2020.112586

Zin, Z. M., Abdul-Hamid, A., & Osman, A. (2002). Antioxidative activity of extracts from Mengkudu (*Morinda citrifolia* L.) root, fruit and leaf. *Food Chemistry*, *78*(2), 227-231. https://doi.org/10.1016/S0308-8146(01)00402-2

Živković, S., Stojanović, S., Ivanović, Ž., Gavrilović, V., Popović, T., & Balaž, J. (2010). Screening of antagonistic activity of microorganisms against *Colletotrichum acutatum* and *Colletotrichum gloeosporioides*. *Archives of Biological Sciences*, *62*(3), 611-623. https://doi.org/10.2298/ABS1003611Z