UNIVERSITI PUTRA MALAYSIA

ISOLATION AND IN VITRO ANTAGONISTIC SCREENINGS OF OIL PALM (Elaeis guineensis Jacq.) FUNGAL ENDOPHYTES AS BIOCONTROL AGENTS AGAINST Ganoderma boninense Pat.

ALLICIA ANAK JACK

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By

ALLICIA ANAK JACK

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Degree of Master of Science

May 2014

DEDICATION

This thesis is dedicated to my beloved parents, sisters, family, great friends & my late supervisor Allahyarhamah Professor Dr. Faridah Abdullah

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ISOLATION AND *IN VITRO* ANTAGONISTIC SCREENINGS OF OIL PALM (*Elaeis guineensis* Jacq.) FUNGAL ENDOPHYTES AS BIOCONTROL AGENTS AGAINST *Ganoderma boninense* Pat.

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May 2014

Chairman : Professor Umi Kalsom Yusuf, PhD

Faculty : Science

Basal stem rot (BSR) disease is the principal disease of oil palm. The main aim of present studies is to screen the efficacy of oil palm root fungal endophytes as new potential biocontrol agents of BSR disease. Oil palm seedlings were subjected to five treatments: (i) *Trichoderma harzianum*-infused mulch (TC); (ii) *Ganoderma boninense* and simultaneous application of *T. harzianum* mulch (GB + TC); (iii) *G. boninense* (GB); (iv) *Glomus* sp. (arbuscular mycorrhizal fungi) (AM) and, (v) no treatment as control. The results revealed that the highest number of fungal endophytes were obtained from the TC treatment with 75 isolates and the lowest, 20 isolates were from the AM treatment. However, treatment with the highest diversity index was represented by AM treatment with 14 species of endophytic fungi isolated. Overall, 225 isolates of endophytic fungi were obtained in this study and seven species were recorded as dominant namely *Chaetomium trilaterale*, *Chaetomium gracile*, *Chaetomium cupreum*, *Penicillium janthinellum*, *Penicillium aculeatum*, *Eupenicillium javanicum* and *Paecilomyces* sp. All isolates were screened *in vitro* against *G. boninense* (PER 71). The dual culture bioassay showed that isolates AM26, GB03 and AM23 displayed the strongest antifungal activity against PER 71 with mean PIRG value of 98.9%, 97.8% and 97.5% respectively. Only 11 isolates recorded mean percentage inhibition of radial growth (PIRG) values of > 80% and retested for *in vitro* antagonistic volatile organic compounds (VOCs) screening. Results from VOCs screening showed that isolates AM26, AM23, GB03 and AM17 produced inhibitory effects with average PIRG values of > 50%. AM26 and AM23 produced VOCs that retarded the growth of PER 71 after the second days of incubation with mean PIRG value of 67.5% and 64.6% respectively. Fungal molecular identification based on internal transcribed spacer (ITS) regions has confirmed that AM26, AM23 and GB03 were *Daldinia eschscholzii*. Present study demonstrated that *D. eschscholzii* had shown great antimicrobial characteristics against *G. boninense in vitro*. The VOCs produced by this species offers very good prospects for integrated management of BSR disease as it has the potential to be developed as an

alternative to chemical fumigation. Thus, further *in vivo* studies should be carried out to confirm its efficacy as pathogen biocontrol agent.

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

PEMENCILAN DAN SARINGAN ANTAGONISTIK *IN VITRO* KULAT ENDOFIT KELAPA SAWIT (*Elaeis guineensis* Jacq.) SEBAGAI AGEN KAWALAN BIOLOGI KE ATAS *Ganoderma boninense* Pat.

Oleh

ALLICIA ANAK JACK

Mei 2014

Pengerusi : Professor Umi Kalsom Yusuf, PhD

Fakulti : Sains

Penyakit reput pangkal batang (RPB) merupakan penyakit prinsipal kelapa sawit. Tujuan utama kajian ini adalah untuk menyaring keberkesanan kulat endofit akar kelapa sawit sebagai agen kawalan biologi baru berpotensi untuk penyakit RPB. Anak kelapa sawit telah diberi lima rawatan: (i) *Trichoderma harzianum* terapan sungkupan (TC); (ii) *Ganoderma boninense* dan aplikasi berturutan *T. harzianum* terapan sungkupan (GB + TC); (iii) *G. boninense* (GB); (iv) *Glomus* sp. (kulat mikoriza arbuskul) (MA) dan, (v) tiada rawatan sebagai kawalan. Keputusan menunjukkan bilangan kulat endofit yang tertinggi diperolehi dari rawatan TC dengan jumlah 75 isolat dan bilangan terendah 20 isolat diperolehi daripada rawatan MA. Walau bagaimanapun rawatan MA mencatatkan indeks kepelbagaian tertinggi dengan 14 spesies kulat terpencil. Secara keseluruhan, 225 isolat kulat endofit telah diperolehi dan tujuh spesies dominan telah direkod iaitu *Chaetomium trilaterale*, *Chaetomium gracile*, *Chaetomium cupreum*, *Penicillium janthinellum*, *Penicillium aculeatum*, *Eupenicillium javanicum* dan *Paecilomyces* sp. Kesemua isolat disaring secara *in vitro* ke atas *G. boninense* (PER 71). Bioesei dua kultur menunjukkan isolat AM26, GB03 dan AM23 mempamerkan aktiviti antikulat terkuat ke atas PER 71 dengan nilai min PPPR masing-masing iaitu 98.9%, 97.8% dan 97.5%. Hanya sebelas isolat mencatatkan min peratus perencatan pertumbuhan radius (PPPR) > 80% dan diuji semula untuk saringan antagonistik *in vitro* sebatian organik meruap (SOM). Keputusan saringan SOM menunjukkan isolat AM26, AM23, GB03 dan AM17 telah menghasilkan kesan perencatan dengan purata nilai PPPR > 50%. AM26 dan AM23 menghasilkan SOM yang merencatkan pertumbuhan PER 71 selepas hari kedua inkubasi dengan nilai min PPPR 67.5% dan 64.6%. Pengecaman molekul kulat berdasarkan kawasan penjarak tertranskripsi dalaman (PTD) mengesahkan bahawa AM26, AM23 dan GB03 adalah *Daldinia eschscholzii*. Kajian ini menunjukkan *D. eschscholzii* mempamerkan ciri-ciri antimikrob ke atas *G. boninense* secara *in vitro*. SOM yang dihasilkan oleh spesies ini menawarkan prospek yang sangat baik unuk kawalan bersepadu penyakit RPB dan mempunyai potensi untuk dibangunkan sebagai alternatif kepada fumigasi kimia. Oleh

itu, ujikaji lanjut secara *in vivo* seharusnya dilakukan untuk memastikan keberkesanannya sebagai agen kawalan biologi patogen.

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I certify that a Thesis Examination Committee has met on 21 May 2014 to conduct the final examination of Allicia anak Jack on her thesis entitled "Isolation and *In Vitro* Antagonistic Screenings of Oil Palm (*Elaeis guineensis* Jacq.) Fungal Endophytes as Biocontrol Agents Against *Ganoderma boninense*" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Hishamuddin bin Omar, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Internal Examiner)

Nur Ashikin Psyquay binti Abdullah, PhD
Associate Professor
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia (Bintulu Campus)
(Internal Examiner)

Nazlina Ibrahim, PhD
Associate Professor
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)

NORITAH OMAR, PhD
Associate Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 June 2014

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Umi Kalsom Yusuf, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Tan Soon Guan, PhD
Professor
Faculty of Biotechnology
Universiti Putra Malaysia
(Member)

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LIST OF ABBREVIATIONS

>	More than
<	Less than
µL	Microliter
AM	Arbuscular mycorrhiza fungi treatment
AMF	Arbuscular mycorrhiza fungi
BLAST	Basic Local Alignment Search Tool
BSR	Basal stem rot
BCA	Biocontrol agent
bp	Base pair
°C	Celsius
CF	Colonization frequency
CPO	Crude palm oil
D	Simpson's index
DMRT	Duncan's Multiple Range Test
DNA	Deoxyribonucleic acid
ddH_2O	Double distilled water
dNTP	Deoxyribose triphosphate
EB	Ethidium bromide
EDTA	Ethylenediaminetetraacetic acid
FB	Fruit bunch
FEB	Fresh fruit bunches
GB	*Ganoderma boninense*
GB+TC	*Ganoderma boninense* with simultaneous application of *Trichoderma*-infused mulch
H'	Shannon-Wiener diversity index
HCI	Hydrochloric acid
HIV	Human immunodeficiency virus
IOPRI	Indonesian Oil Palm Research Institute
ITS	Internal transcribed spacer
$MgCl_2$	Magnesium chloride
MITI	Ministry of International Trade and Industry
mM	Milimolar

MMT	Million metric tons
MPOB	Malaysian Palm Oil Board
NaCl	Sodium chloride
PCR	Polymerase chain reaction
PDA	Potato Dextrose Agar
PDB	Potato Dextrose Broth
p_i	Number of individual within species divided by the total fungal isolates
psi	Pound per square
PIRG	Percentage inhibition of radial growth
PKC	Palm kernel cake
POME	Palm oil mill effluent
rDNA	Ribosomal deoxyribonucleic acid
RPB1	RNA (Ribonucleic Acid) Polymerase II
rpm	Rotation per minute
SAS	Statistical Analysis System
SDS	Sodium dodecyl sulphate
SE	Standard error
TAE	Tris-acetate-EDTA
Taq	*Thermus aquaticus*
TC	*Trichoderma harzianum*-infused mulch
TFC	Total flavonoid content
TPC	Total phenolic content
USDA	United States Department of Agriculture
UV	Ultraviolet
VOCs	Volatile organic compounds

CHAPTER 1

INTRODUCTION

Oil palm (*Elaies guineensis* Jacq.) is the world highest yielding oil producing crop. Palm oil production constituted 53.83 million metric tons (MMT) out of the total 157.76 MMT world vegetable oil production. Followed by soybean at 43.18 MMT and rapseed (23.80 MMT) (Anonymous, 2013c). Today, there has been rapid expansion of oil palms cultivated areas in Malaysia. Oil palm plantation development include not only in the Peninsular, but also in the East Malaysia. Today more than five million hectares of land in Malaysia are under oil palm cultivation (Anonymous, 2013b). Expansion process has involved in large scale conversion of forest land and replanting of the existing plantation. Intense monoculture of oil palms after few decades has resulted in environmental imbalance. Although monoculture practices produce much food or yields for international commerce, single crops are also vulnerable to disease and pest problems. These in turn lead to the increasing applications of more potent pesticides and chemical fertilizers to the lands to fight diseases and weeds, causing pollution, soil degradation and persistent occurrence of pesticides resistant disease in which eventually affecting the quality of the crop yields and productions.

The oil palm industry is one of the major revenue earners of Malaysia. However, this lucrative industry may face a bleak future with the constant attack by the Basal Stem Rot (BSR) disease which was reported to be major constraint of oil palm plantations in Southeast Asia, causing severe economic loss especially in Malaysia and Indonesia (Wong *et al*., 2012). BSR disease of oil palm is caused by the white-rot fungus *Ganoderma boninense*. The white-rot mode of attack involved the degradation of lignin component of the wood leaving the white cellulose exposed. Symptoms of disease include water stress, one-sided mottling of the canopy or yellowing of the fronds followed by necrosis, multiple unopened spears and production of basidiocarps (fruiting body) on the lower stem. Once oil palm showed visible symptoms, at least 50% of the basal stem tissues have been colonized by *G. boninense* and the infection was already firmly established (Laila *et al*., 2012b).

Although the BSR disease has been long known, there are no current effective method of early detection and controlling the disease. Numerous agronomic practises were suggested in the past to control the disease such as trench digging and soil mounding around diseased palms, collecting fruiting body from palm base, fungicidal treatment by trunk injection in affected palm and stump treatment. However, none was able to generate satisfactory results due to lack of understanding of this disease aetiology. They were either too time consuming, costly, labour intensive and detrimental to environment and human health. *Ganoderma* has various resting stages which were the factors that add to the ineffectiveness of fungicides due to degradation in the soil before they could reach the targeted area. Therefore, integrated biological control and the breeding of resistant oil palm progenies have been suggested as a sustainable solution for the constraints. The use of biocontrol agent (BCA) is more preferable since it can be developed over shorter time scale compared to resistant progenies breeding process.

The use of biological control approaches have become popular alternatives in managing several crop diseases. There were increasing reports on the use of BCA such as beneficial bacteria, fungi and plant endophytes in combating diseases in commercial crops such as soybean, wheat, fruits and vegetables (Mercier *et al*., 2004; Mercier *et al*., 2005; Lacey *et al*., 2006; Ownley *et al*., 2008; Chatterton *et al*., 2008). As a result, they were extensively explored and proven to be able of achieving promising result. Biological control aims at inhibiting the growth of the pathogen and subsequently its entry into the host plant. Control can be achieved through treatment of susceptible host plants with antagonistic microorganisms. The BCAs are mainly fungi and bacteria from soil rizhosphere, or endophytic microorganisms which associated with internal tissues of plants.

Hypothetically, microbes that originally isolated from any part of the host plant itself may be better adapted to that specific plant species and give better control of diseases than microbes isolated from other plant species or resources. As they experience less competition and soil fungistasis from resident soil microbes, the chances of survival for endophytes in host plants are also enhanced. Therefore endophytic fungi of root parts are chosen as the antagonist candidates since evidences showed that the main mode of infection by *G. boninense* is by roots invasion. They are also expected to be able to compete with the pathogen as both share similar niche, source of nutrients and establishment sites which is the vascular tissues limiting *G. boninense* for both nutrients and space during its proliferation. In addition to this study, the diversity and abundancy of oil palm roots endophytic fungi were also observed.

To date, the information on fungal endophytes dynamics and mechanism of interaction among the endophytic fungi themselves or with the host plants and are still understudy. Most reports described the diversity of fungi isolated from healthy plant or of other resources in natural environment. This study is driven by the intriguing factor on how fungal endophytes population in oil palm roots were altered when the seedlings were subjected to the infections of different fungal treatments in a glass house condition. With the presence of inoculums, the occurrence of certain fungal endophytes was predicted to be correlate with other fungi. The presence of some common fungi would be negatively correlated with the presence of others because they may suppress the growth of other fungi by secondary metabolite production, parasitism, or competition for resources.

In the present study, the effects of different fungal inoculum to the diversity of the oil palm seedlings root fungal endophytes were observed and compared. The oil palm seedlings were artificially infected with the pathogen (*G. boninense*) itself, treated with the BCA (*T. harzianum*), *G. boninense* with simultaneously application *T. harzianum* and arbuscular mycorrhizal fungi with non-inoculated seedlings as control. The ability of the fungal endophytes obtained from both diseased and healthy plants to produce antimicrobial metabolites were determined by *in vitro* screening against *G. boninense* .

1.2 Objectives

1.2.1 General objective

The aim of this study was to develop a biocontrol against BSR by using endophytic fungi isolated from roots of oil palm seedlings.

1.2.2 Specific objectives

1. To determine the diversity and abundance of root fungal endophytes of oil palm seedlings subjected to different fungal inoculums.

2. To screen the efficacy of the isolated fungal endophytes against *G. boninense* in *in vitro* study.

3. To identify and select potential endophytic fungi by morphological characterization and phylogenetics.

REFERENCES

Abdullah, F., Rusli, M. H., and Sebran, N. H. 2005. Bacteria from an oil palm agricultural system and their interactions with *Ganoderma boninense* and *Trichoderma harzianum*. *Pertanika Journal of Tropical Agricultural Science* 28: 95-102.

Abdul Hayat, M. S., Kamziah, A. K., Faridah-Hanum, I., Awang Noor, A. G. and Nazre, M. 2010. Assessment of plant species diversity at Pasir Tengkorak Forest Reserve, Langkawi Island, Malaysia. *Journal of Agricultural Science* 2(1): 31-38.

Adebola, M. O. and Amadi, J. E. 2010. Antagonistic activities of *Paecilomyces* and *Rhizopus* species against the cocoa black pod pathogen (*Phytophthora palmivora*). *African Scientist* 11(4): 235-239.

Agarwal, T., Malhotra, A., Biyani, M. and Trivedi, P. C. 2011. *In vitro* interaction of *Trichoderma* isolates against *Aspergillus niger*, *Chaetomium* sp. and *Penicillium* sp. *Indian Journal of Fundamental and Applied Life Sciences* 1(3): 125-128.

Aji, F. A., Munajat, Q., Pratama, A. P., Kalamullah, H., Aprinaldi, Setiyawan, J. and Arymurthy, A. M. 2013. Detection of palm oil leaf disease with image processing and neural network classification on mobile device. *International Journal of Computer Theory and Engineering* 5(3): 528-532.

Amirita, A., Sindhu, P., Swetha, J., Vasanthi, N. S. and Kannan, K. P. 2012. Enumeration of endophytic fungi from medicinal plants and screening of extracellular enzymes. *World Journal of Science and Technology* 2(2): 13-19.

Anonymous. 2006. CABI Europe IMI Description of Fungi and Bacteria No. 1695: *Daldinia eschscholzii.* Retrieved 2 February 2012 from http://www.cabi.org/dfb/FullTextPDF /2007/20073003885.pdf.

Anonymous. 2013a. MITI Report 2012: Driving transformation powering growth. Ministry of International Trade and Industry Malaysia: Kuala Lumpur.

Anonymous. 2013b. MPOB Economics & Industry Development Division. Retrieved 3 November 2013 from http://econ.mpob.gov.my/economy/

Anonymous. 2013c. USDA World vegetable oils production 2008/09-2012/13. Retrieved 11 November 2013 from http:// www.ers.usda.gov/data-products/oil-crops-yearbook.aspx#

Ames, L. M. 1969. *A Monograph of The Chaetomiaceae*. Germany: Verlag Von J. Cramer.

Anis, M., Kamarudin, H., Astimar, A. A. and Mohd. Basri, W. 2011. Plywood from oil palm trunks. *Journal of Oil Palm Research* 23: 1159-1165.

Atkins, S. D. and Clark, I. M. 2004. Fungal molecular diagnostics: a mini review. *Journal of Applied Genetics* 45(1): 3-15.

Bailey, B. A., Bae, H., Strem, M. D., Crozier, J., Thomas, S. E., Samuels, G. J., Vinyard, B. T. and Holmes, K. A. 2008. Antibiosis, mycoparasitism, and colonization success for endophytic *Trichoderma* isolates with biological control potential in *Theobroma cacao*. *Biological Control* 46(1): 24-35.

Bivi, M. R., Farhana, M. S. N., Khairulmazmi, A. and Idris, A. 2010. Control of *Ganoderma boninense*: a causal agent of basal stem rot disease in oil palm with endophytes bacteria *in vitro*. *International Journal Agriculture & Biology* 12: 833-839.

Boddy, L. 2000. Interspecific combative interactions between wood-decaying basidiomycetes. *FEMS Microbiology Ecology* 31: 185-194.

Bridge, P. D. and Arora, D. K. 1998. Interpretation of PCR methods for species definition. In *Applications of PCR in Mycology*, ed. P. D. Bridge, D. K. Arora, C. A. Reddy and R. P. Elander, pp. 63-84. United Kingdom: CABI Publishing.

Borman, A. M., Linton, C. J., Miles, S. J. and Johnson, E. M. 2008. Molecular identification of pathogenic fungi. *Journal of Antimicrobial Chemotherapy* 61: 7-12.

Chatterton, S., Jayaraman, J. and Punja, Z. K. 2008. Colonization of cucumber plants by the biocontrol fungus *Clonostachys rosea* f. *catenulata. Biological Control* 46: 267-278.

Choubey, P. 2012. Isolation and characterization of fungal strains as biocontrol agents. *World Journal of Science and Technology* 2(6): 66-68.

Chen, X. Y., Qi, Y. D., Wei, J. H., Zhang, Z., Wang, D. L., Feng, J. D. and Gan, B. C. 2011. Molecular identification of endophytic fungi from medicinal plant *Huperzia serrata* based on rDNA ITS analysis. *World Journal of Microbiology and Biotechnology* 27: 495-503.

Chung, G. F. 2011. Management of *Ganoderma* disease in oil palm plantation. *The Planter* 87(1022): 325-339.

Coca-Morante, M. and Mamani-Alvarez, F. 2012. Control of leaf spot diseases on ecotypes of Faba bean (*Vicia faba* L.) produced in the Andean Region of Bolivia. *American Journal of Plant Sciences* 3: 1150-1158.

Cooper, R. M., Flood, J. and Rees, R. W. 2011. *Ganoderma boninense* in oil palm plantations: Current thinking on epidemiology, resistance and pathology. *The Planter* 87 (1024): 515-526.

Corley, R. H. V. and Tinker, P.B. 2003. *The Oil Palm*. New Jersey: John Wiley & Sons.

Dandurand, L. M. and Knudsen, G. R. 1993. Influence of *Pseudomonas fluorescens* on hyphal growth and biocontrol efficacy of *Trichoderma harzianum* in the spermosphere and rhizosphere of pea. *Phytopathology* 83: 265-270.

Davis, E.C., Franklin, J. B., Shaw, A. J. and Vilgalys, R. 2003. Endophytic Xylaria (Xylariaceae) among liverworts and angiosperms: Phylogenetics, distribution, and symbiosis. *American Journal of Botany* 90 (11): 1661-1667.

Dharmaputra, O. S., Soetarmi Tjitrosomo, H. S. and Abdul Latief, A. 1990. Antagonistic effect of four fungal isolates to *Ganoderma boninense*, the causal agent of basal stem rot of oil palm. *Biotropia* 3: 41-49.

Flood, J. 2006. A review of Fusarium wilt of oil palm caused by *Fusarium oxysporum* f. sp. *elaeidis. Phytopathology* 96: 660-662.

García, A., Rhoden, A. Filho, C. J. R., Nakamura, C. V. and Pamphile, J. A. 2012. Diversity of foliar endophytic fungi from the medicinal plant *Sapindus saponaria* L. and their localization by scanning electron microscopy. *Biological Research* 45: 139-148.

Gardes, M. and Bruns, T. D. 1993. ITS primers with enhanced specificity for basidiomycetes-application to the identification of mycorrhizae and rusts. *Molecular Ecology* 2: 113-118.

Gazis, R. and Chaverri, P. 2010. Diversity of fungal endophytes in leaves and stems of wild rubber trees (*Hevea brasiliensis*) in Peru. *Fungal Ecology* 3: 240-254.

Gond, S. K., Verma, V. C., Kumar, A., Kumar, V. and Kharwar, R. N. 2007. Study of endophytic fungal community from different parts of *Aegle marmelos* Correae (Rutaceae) from Varanasi (India). *World Journal of Microbiology and Biotechnology* 23: 1371-1375.

Guarro, J., Gené, J. and Stchigel, A. M. 1999. Developments in Fungal Taxonomy. *Clinical Microbiology Reviews* 12(3): 454-500.

Guo, L. D., Hyde, K. D. and Liew, E. C. Y. 2000. Identification of endophytic fungi from *Livistona chinensis* based on morphology and rDNA sequences. *New Phytology* 147: 617-630.

Gveroska, B. and Ziberoski, J. 2011. *Trichoderma harzianum* as a biocontrol agent against *Alternaria alternata* on tobacco. *Applied Technologies & Innovations* 2(7): 67-76.

Ha, T. N. 2010. Using *Trichoderma* species for biological control of plant pathogens in Vietnam. *Journal of International Society for Southeast Asian Agricultural Science* 16(1): 17-21.

Hallmann, J., Berg, G. and Schulz, B. 2006. Isolation procedures for endophytic microorganisms. In *Microbial root endophytes*, ed. B. Schulz, C. Boyle and T. Sieber, pp. 299-319. German: Springer-Verlag Berlin Heidelberg.

Harjono, S. and Widyastuti, S. M. 2001. Antifungal activity of purified endochitinase produced by biological agent *Trichoderma reesei* against *Ganoderma philippii*. *Pakistan Journal of Biological Science* 4: 1232-1234.

Hartley, C. W. S. 1977. *The Oil Palm* (*Elaeis guineensis* Jacq.).1st edn, London: Longman.

Hartley, C. W. S. 1988. *The Oil Palm* (*Elaeis guineensis* Jacq.). 3rd edn, London: Longman.

Ho, C. T. and Khairuddin, H. 1997. Usefulness of soil mounding treatments in prolonging productivity of prime-aged *Ganoderma* infected palms. *Planter* 73 (854): 239-244.

Ho, Y. W. and Khairuddin, H. 1995. Pathogenicity and histopathology of *Ganoderma boninense* on oil palm seedlings. *Journal of Bioscience* 6(2): 155-164.

Ho, Y. W. and Nawawi, A. 1985. *Ganoderma boninense* Pat. from basal stem rot of oil palm (*Elaeis guineensis*) in Peninsular Malaysia. *Pertanika*: 8425-428.

Huang, W.Y., Cai, Y. Z., Hyde, K. D., Corke, H. and Sun, M. 2008. Biodiversity of endophytic fungi associated with 29 traditional Chinese medicinal plant. *Fungal Diversity* 33: 61-75.

Hudson, P. S. 1972. *Fungi in Agricultural Soils*. Great Britain: Longman Group Limited.

Idris, A. S., Ariffin, D., Swinburne, T. R. and Watt, T. A. 2000. The identity of *Ganoderma* species responsible for BSR disease of oil palm in Malaysia – pathogenicity test. *MPOB Information Series No.* 103: 1-4.

Idris, A. S., Ismail, S., Ariffin, D. and Ahmad, H. 2004. Prolonging the productive life of *Ganoderma* infected palms with hexaconazole. *MPOB Information Series No*. 500: 1-4.

Jalgaonwala, R. E., Mohite, B. V. and Mahajan, R. T. 2010. Evaluation of endophytes for their antimicrobial activity from indigenous medicinal plants belonging to North Maharashtra region India. *International Journal on Pharmaceutical and Biomedical Research (IJPBR)* 1(5): 136-141.

Jeewon, R., Ittoo, J., Mahadeb, D., Jaufeerally-Fakim, Y., Wang, H. K. and Liu, A. R. 2013. DNA based identification and phylogenetic characterisation of endophytic and saprobic fungi from *Antidesma madagascariense*, a medical plant in Mauritius. *Journal of Mycology*, vol. 2013, Article ID 781914, 10 pages, 2013. doi.org/10.1155/2013/781914.

Johannesson, H., LæssØe, T., and Stenlid, J. 2000. Molecular and morphological investigation of *Daldinia* in northern Europe. *Mycological Research* 104 (3): 275-280.

Karnchanatat, A., Petsom, A., Sangvanich, P., Piaphukiew, J., Whalley, A. J. S., Reynolds, C. D. and Sihanonth, P. 2007. Purification and biochemical characterization of an extracellular β-glucosidase from the wood-decaying fungus *Daldinia eschscholzii* (Ehrenb.:Fr.) Rehm. *FEMS Microbiology Letters* 270: 162-170.

Kasmir, J., Senthilkumar, S. R., Britto, S. J. and Raj, L. J. M. 2011. Identification of fungal endophytes from Orchidaceae members based on nrITS (Internal Transcribed Spacer) region. *International Research Journal of Biotechnology* 2(6): 139-144.

Kim, H. Y., Choi, G. J., Lee, S. W., Lim, H. K., Jang, K. S., Son, S. W., Lee, S. O., Cho, K. Y., Sung, N. D. and Kim, J. C. 2007. Some fungal endophytes from vegetable crops and their anti-oomycete activities against tomato late blight. *Letter in Applied Microbiology* 44: 332-337.

Khan, A. L., Shinwari, Z. K., Kim, Y. H., Waqas, M., Hamayun, M., Kamran, M. and Lee, I. J. 2012. Role of endophytes *Chaetomium globosum* LK4 in growth of *Capsicum anuum* by production of gibberenllins and indole acetic acid. *Pakistan Journal of Botany* 44(5): 1601-1607.

Khan, R., Shahzad, S., Choudhary, M. I., Khan, S. A. and Ahmad, A. 2007. Biodiversity of the endophytic fungi isolated from *Calostropis procera* (Ait.) R. Br. *Pakistan Journal of Botany* 39(6): 2233-2239.

Khairuddin, H. 1990. *Basal Stem Rot of Oil Palm: Incidence, Etiology and Control*, Master Thesis, Universiti Pertanian Malaysia.

Khatiwora, E., Adsul, V. B., Kulkarni, M. M., Peshpande, N. R. and Kashalkar, R. V. 2010. Spectorscopic determination of total phenol and flavoid contents of *Ipmoea carnea*. *International Journal of ChemTech Research* 3: 1698-1701.

Kok, S. M., Goh, Y. K., Tung, H. J., Goh, K. J., Wong, W. C. and Goh, Y. K. 2013. *In vitro* growth of *Ganoderma boninense* isolates on novel palm extract medium and virulence on oil palm (*Elaeis guineensis*) seedlings. *Malaysian Journal of Microbiology* 9(1): 33-42.

Kumar, S. and Kaushik, N. 2013. Endophytic fungi isolated from oil-seed crop *Jatropha curcas* produces oil and exhibit antifungal activity. *PLoS ONE* 8(2): e56202.

Lacey, L. A. and Neven, L. G. 2006. The potential of the fungus, *Muscodor albus*, as a microbial control agent of potato tuber moth (Lepidoptera: Gelechiidae) in stored potatoes. *Journal of Invertebrate Pathology* 91: 195-198.

Laila, N., Umi Kalsom, Y., Shafiquzzaman, S., Jannatul, F. and Aminur Rahman, M. 2012a. Effect of media on growth and antagonist activity of selected *Trichoderma* strains against *Ganoderma*. *African Journal of Microbiology Research* 6(48): 7449-7453.

Laila, N., Tan, S. G., Umi Kalsom, Y., Ho, C. L. and Abdullah, F. 2012b. Biocontrol agent *Trichoderma harzianum* strain FA 1132 as an enhancer of oil palm growth. *Pertanika Journal of Tropical Agricultural Science* 35(1): 173-182.

Latiffah, Z. and Ho, Y. W. 2005. Morphological characteristic and somatic incompatibility of *Ganoderma* from infected oil palm from three inland estates. *Malaysian Journal of Microbiology* 1(2): 46-52.

Latiffah, Z., Harikrishna, K., Tan, S. G., Faridah, A. and Ho, Y. W. 2005. Random amplified polymorphic DNA (RAPD) and random amplified microsatellite (RAMS) of *Ganoderma* from infected oil palm and coconut stumps in Malaysia. *Asia Pacific Journal of Molecular Biology and Biotechnology* 13 (1): 23-24.

Lee, S. S., Alias, S. A., Jones, E. G. B., Zainuddin, N. and Chan, H. T. 2012. *Checklist of Fungi of Malaysia*. Forest Research Institute Malaysia.

Lim, T. K., Chung, G. F. and Ko, H. W. 1992. Basal stem rot of oil palm caused by *Ganoderma boninense*. *Plant Pathology Bulletin* 1: 147-152.

Lim, H. P. and Fong, Y. K. 2005. Research on basal stem rot (BSR) of ornamental palms caused by basidiospores from *Ganoderma boninense*. *Mycopathologia* 159: 171-179.

Mahadi, N., Mueller, M., Chia, Y. T., Kuek, C. and Nissom, P. M. Isolation of an endophytic fungus producing volatile anti *Ganoderma* compounds: potential biocontrol agent for *Ganoderma boninense*. Paper presented at the meeting of British Mycological Society-Fungal Interaction of the University Aicante, Spain. September, 2012.

Maciá-Vicente, J. G., Jansson, H. B., Abdullah, S. K., Descals, E., Salinas, J., and Lopez-Llorca, L. V. 2008. Fungal root endophytes from natural vegetation in Mediterranean environments with special reference to *Fusarium* spp. *FEMS Microbiology Ecology* 64: 90-105.

Mends, M. T., Yu, Eizadora, Strobel, G. A., Riyaz-Ul-Hassan, S., Booth, E., Geary, B., Sears, J., Taatjes, C. A. and Hadi, M. Z. 2012. An endophytic *Nodulisporium* sp. producing volatile organic compounds having bioactivity and fuel potential [Doi: 10.4172/2157-7463.1000117]. *Journal of Petroleum & Environmental Biotechnology* 3: 117.

Mercier, J. and Manker, D. C. 2005. Biocontrol of soil-borne diseases and plant growth enhancement in greenhouse soilless mix by the volatile-producing fungus *Muscodor albus*. *Crop Protection* 24: 355-362.

Mercier, J. and Jiménez, J. I. 2004. Control of fungal decay of apples and peaches by the biofumigant fungus *Muscodor albus*. *Postharvest Biology and Technology* 31: 1-8.

Mohd Basri, W., Norman, K., Idris, A. S., Ariffin, D., Sundram, S., Ramle, M. and Siti Ramlah, A. A. 2003. *Handbook of Pest and Disease of Oil Palm*. Bangi: Malaysian Palm Oil Board.

Mohd Nazif, S. 2011. *Effects of Arbuscular Mycorrhizal Fungi and Trichoderma harzianum on Growth and Disease Suppression in Oil Palm*, Master Thesis, Universiti Putra Malaysia.

Moncalvo, J. M. 2000. Systematics of *Ganoderma*. In *Ganoderma Diseases Perennial Crops*, ed. J. Flood, P.D. Bridge, and M. Holderness, pp. 23-45. Wallingford: CABI Publishing.

Myung, S. P., Ahn, J. Y., Choi, G. J., Choi, Y. H., Jang, K. Y. and Kim, J. C. 2010. Potential of the volatile-producing fungus *Nodulisporium* sp. CF016 for the control of postharvest diseases of apple. *Journal of Plant Pathology* 26(3): 253-259.

Naher, L., Yusuf, U. K., Ismail, A., Tan, S. G. and Mondal, M. M. A. 2013. Ecological status of *Ganoderma* and basal stem rot disease of oil palm (*Elaeis guineensis* Jacq.). *Australian Journal of Crop Science* 7(11): 1723-1727.

Nakadate, S., Nozawa, K., Sato, H., Horie, H., Fujii, Y., Nagai, M., Hosoe, T., Kawai, K. and Yaguchi, T. 2008. Antifungal cyclic desipeptide, eujavanicin A, isolated from *Eupenicillium javanicum*. *Journal of Natural Products* 71: 1640-1642.

Nazeeb, M., Barakah, S. S. and Loong, S. G. 2000. Potential of density oil palm plantings in diseased environment. *Planter* 76: 699-710.

Ng, I. S., Chen, P. T., Ju, Y. M. and Tsai, S. W. 2010. Novel cellulose screening and optimal production from the wood decaying Xylariaceae: *Daldinia* species. *Applied Biochemistry and Biotechnology* DOI 10.1007/s12010-010-9102.

Ng, K. P., Ngeow, Y. F., Yew, S. M., Hamimah, H., Soo-Hoo, T. S., Lee, K. W. and Yee, W. Y. 2012. Draft genone sequence of *Daldinia eschscholzii* isolated from blood culture. *Eukaryotic Cell* 11(5): 703.

Nilsson, R. H., Kristiansson, E., Ryberg, M. and Hallenberg, N. and Larsson, K. H. 2008. Intraspecific ITS variability in the kingdom fungi as expressed in the international sequence databases and its implications for molecular species identification. *Evolutionary Bioinformatics* 4: 193-201.

Novas, V. M., Iannone, L. J., Godeas, A. M. and Cabral, D. 2009. Positive association between mycorrhiza and forliar endophytes in *Poa bonariensis*, a native grass. *Mycological Progress* 8: 75-81.

Nur Ain Izzati, M. Z. and Abdullah, F. 2008. Disease suppression in *Ganoderma*-infected oil palm seedlings treated with *Trichoderma harzianum*. *Plant Protection Science* 44: 101-107.

Nuzul, A. I. 2013. Characteristic of Malaysian palm kernel and its products. *Journal of Oil Palm Research* 25(2): 245-252.

Ownley, B. H., Griffin, M. R., Klingeman, W. E., Gwinn, K. D., Moulton, K. and Pereira, R. M. 2008. *Beauveria bassiana*: Endophytic colonization and plant disease control. *Journal of Invertebrate Pathology* 98: 267-270.

Panchal, G. and Bridge, P.D. 2005. Following basal stem rot in young oil palm plantings. *Mycopathologia* 159: 123-127.

Pandi, M., Kumaran, R. S., Choi, Y. K., Kim, H. J. and Muthumary, J. 2011. Isolation and detection of taxol, an anticancer drug produced from *Lasiodiplodia theobromae*, an endophytic fungus of the medicinal plant *Morinda citrifolia*. *African Journal of Biotechnology* 10(8): 1428-1435.

Park, J. H., Choi, G. J., Jang, K. S., Lim, H. K., Kim, H. T., Cho, K. Y. and Kim, J. C. 2005. Antifungal activity against plant pathogenic fungi of chaetoviridin isolated from *Chaetomium globosum*. *FEMS Microbiology Letters* 252: 309-313.

Paterson, R. R. M. 2007. *Ganoderma disease* of oil palm- A white rot perspective necessary for integrated control. *Crop protection* 26: 1369-1376.

Pilotti, C. A. and Sanderson, F. R. 2001. BSR-unravelling the mystery: the Milne Bay situation. In*: Proceeding of the 2001 International Palm Oil Congress-Agriculture*, pp. 641-645. Kuala Lumpur: MPOB.

Pilotti, C. A. 2005. Stem rots of oil palm caused by *Ganoderma boninense*: Pathogen biology and epidemiology. *Mycopathologia* 159: 129-137.

Pimentel, I. C., Glienke-Blanco, C., Gabardo, J., Stuart, R. M., and Azevedo, J. L. 2006. Identification and colonization of endophytic fungi from soybean (*Glycine max* (L.) Merril) under different environment conditions. *Brazilian Archives of Biology and Technology* 49: 705-711.

Pinruan, U., Rungjindamai, N., Choeyklin, R., Lumyong, S., Hyde, K. D. and Jones, E. B. G. 2010. Occurrence and diversity of basidiomycetous endophytes from the oil palm, *Elaeis guineensis* in Thailand. *Fungal Diversity* 41: 71-88.

Piyaboon, O., Thunyamada, S., Numsiripongpan, W., Pattayanan, K., Wattanagetkul, M., Ophawatanasina, T., Tantithama, N. and Upala, W. 2013. Application of endophytic fungi from para rubber tree as high ability in inhibitors of against *Phytophthora botryosa*, the pathogen of leaf-fall disease in para rubber tree. *Journal of Agricultural Technology* 9(5): 1179-1187.

Pornsuriya, C., Lin, F.C., Kanokmedhakul, S. and Soytong, K. 2008. New record of *Chaetomium* species isolated from soil under pineapple plantation in Thailand. *Journal of Agricultural Technology* 4: 91-103.

Photita, W., Taylor, P. W. J., Ford, R., Hyde, K. D. and Lumyong, S. 2005. Morphological and molecular chariterization of *Colletotrichum* species from herbaceous plants in Thailand. *Fungal Diversity* 18: 117-133.

Purwadaria, T., Niwarna, N., Ketaren, P. P., Pradono, D. I. and Wisdyastuti, Y. 2003. Synergistic activity of enzymes produced by *Eupenicillium javanicum* & *Aspergillus niger* NRRL 337 on palm oil factory wastes. *Biotropia* 20: 1-10.

Qian, Y., Hua, C., Zhang, H. Y., Lin, Y., Pigang, L. and Hongxing, J. 2007. Study on bio-control related genes of *Trichoderma* sp. and *Chaetomium* spp. *KMITL Science and Technology Journal* 7: 8-15.

Qin, X. D., Dong, Z. J. and Liu, J. K. 2006. The new compounds from the ascomycete *Daldinia concentrica*. *Helvetica Chimica Acta* 89: 450-455.

Raeder, U. and Broda, P. 1985. Rapid preparation of DNA from filamentous fungi. *Letter in Applied Microbiology* 1:17-20.

Raper, K. B., Thom, C. and Fennell, D. I. 1968. *A manual of the Penicillia*. New York: Hafner Publishing Company, Inc.

Raviraja, N. S., Maria, G. L. and Sridhar, K. R. 2006. Antimicrobial evaluation of endophytic fungi inhabiting medicinal plants of the Western Ghats of India. *Engineering in Life Sciences* 5: 515-520.

Rees, R. W., Flood, J., Hasan, Y. and Cooper, R. M. 2007. Effects of inoculums potential, shading and soil temperature on root infection of oil palm seedlings by the basal stem rot pathogen *Ganoderma boninense*. *Plant Pathology* 56: 862-870.

Rees, R. W., Flood, J., Hasan, Y., Potter, U. and Cooper, R. M. 2009. Basal stem rot of oil palm (*Elaeis guineensis*); mode of root infection and lower stem invasion by *Ganoderma boninense*. *Plant Pathology* 58: 982-989.

Rezwana, K. 2007. *Isolation, Identification and Cultivation of Endophytic Fungi from Medicinal Plants for the Production and Characterization of Bioactive Fungal Metabolites*, PhD Thesis, Universiti of Karachi.

Rivera-Orduńa, F. N., Suarez-Sanchez, R. A., Flores-Bustamante, Z. R., Gracida-Rodriguez, J. N. and Flores-Cotera, L. B. 2011. Diversity of endophytic fungi of *Taxus globosa* (Mexican yew). *Fungal Diversity* 47: 65-74.

Riyaz-Ul-Hassan, S., Strobel, G., Geary, B. and Sears, J. 2013. An endophytic *Nodulisporium* sp. from Central America producing volatile organic compounds with both biological and fuel potential. *Journal of Microbiology and Biotechnology* 23(1): 29-35.

Rogers, J. D. 2000. Thoughts and musings on tropical Xylariaceae. *Mycological Research* 104 (12): 1412-1420.

Rogers, J. D. and Ju, Y. M. 2012. The Xylariaceae of the Hawaiian Islands. *North American Fungi* 7(9): 1-35.

Roslan, A. and Idris, A. S. 2012. Economic impact of *Ganoderma* incidence on Malaysian oil palm plantation-A case study in Johor. *Oil Palm Industry Economic Journal* 12: 24-30.

Rubini, M. R., Silva-Ribeiro, R. T., Pomella, A. W. V., Maki, C. S., Araújo, W. L., dos Santos, D. R. and 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.

Rungjindamai, N., Pinruan, U., Choeyklin, R., Hattori, T., and Jones, E. B. G. 2008. Molecular characterization of basidiomycetous endophytes isolated from leaves, rachis and petioles of the oil palm, *Elaeis guineensis*, in Thailand. *Fungal Diversity* 33: 139-161.

Santamaria, J. and Bayman, P. 2005. Fungal epiphytes and endophytes of coffee leaves (*Coffea arabiaca*). *Microbial Ecology* 50: 1-8.

Sapak, Z., Meon, S. and Ahmad Z. A. M. 2008. Effect of endophytic bacteria on growth and suppression of *Ganodema* infection in oil palm. *International Journal of Agriculture & Biology* 10: 127-32.

Sariah, M., Hussin, M. Z., Miller, R. N. G. and Holderness, M. 1994. Pathogenicity of *Ganoderma boninense* tested by inoculation of oil palm seedlings. *Plant Pathology* 43: 507-510.

Schulz, B., Boyle, C., Draeger, S., Rommert, A. K. and Krohn, K. 2002. Endophytic fungi: a source of novel biologically active secondary metabolites. *Mycological Research* 106(9): 996-1004.

Schulz, B. and Boyle, C. 2005. The endophytic continuum: Review. *Mycological Research* 109(6): 661-98.

Schoch, C. L., Seifert, K. A., Huhndorf, S., Robert, V., Spouge, J. L., Levesque, C. A., Chen, W. and Fungal Barcoding Consortium. 2011. *Proceedings of the National Academy of Science* 109 (16): 6241-6246.

Seena, S. and Sridhar, K. R. 2004. Endophytes fungal diversity of two sand dune wild legumes form the Southwest Coast of India. *Canadian Journal of Microbiology* 50: 1015-1021.

Seth, H. K. 1970. *A Monograph of The Genus Chaetomium*. German: Verlag Von J. Cramer.

Shamala, S. and Idris, A. S. 2009. *Trichoderma* as a biocontrol agent against *Ganoderma* in oil palm. *MPOB Information Series No.*422: 1-4.

Shamala, S., Chris, D., Sioban, O. and Idris, A. S. 2006. Preliminary studies on the development of monoclonal antibodies against mycelia of *Ganoderma boninense*, the causal pathogen of basal stem rot of oil palm. *Malaysian Journal of Microbiology* 2(1): 30-34.

Shamsilawani, A. B., Siti Ramlah, A. A., Nor Shalina, T. and Nor Erlina, K. 2009. Efficacy of entomopathogenic fungi *Paecilomyces* spp., in controlling the oil palm bagworm, *Pteroma pendula* (Joannis). *Journal of Oil Palm Research* 21: 693-699.

Siddiquee, S., Yusuf, U. K., Hossain, K. and Jahan, S. 2009. *In vitro* studies on the potential *Trichoderma harzianum* for antagonistic properties against *Ganoderma boninense*. *Journal of Food, Agriculture & Environment* 7: 970-976.

Singh, G. 1991. *Ganoderma*-the scourge of oil palm in coastal areas. *The Planter* 67: 421-444.

Soytong, K. and Quimio, T. H. 1989. Antagonism of *Chaetomium globosum* to the rice blast pathogen, *Pyricularia oryzae*. *Kasetsart Journal of Natural Science* 23: 198-203.

Stadler, M., LæssØe, T., Simpson, J. A. and Wollweber, H. 2004. A survey of *Daldinia* species with large ascospores. *Mycological Research* 108(9): 1025-1041.

Stimpson, K. M. S. and Rasmussen, A. N. Clearing The Old Stand and Some Preparation for Replanting Coastal Oil Palm. In *Advanced In Oil Palm Cultivation*. Proceedings of the International Oil Palm Conference, Kuala Lumpur, Malaysia, Nov. 16-18, 1972. Wastie, R. L. and Earp, D. A. (Ed.); Yau Seng Press: Kuala Lumpur, 1973.

Strobel, G. A. 2002. Microbial gifts from rain forests. *Canadian Journal of Plant Pathology* 24: 14-20.

Strobel, G. A., Dirkse, E., Sears, J. and Markworth, C. 2001. Volatile antimicrobials from *Muscodor albus*, a novel endophytic fungus. *Microbiology* 147: 2943-2950.

Sundram, S., Abdullah, F., Ahmad, Z. A. M. and Yusuf, U. K. 2008. Efficacy of single and mixed treatments of *Trichoderma harzianum* as biocontrol agents of *Ganoderma* basal stem rot in oil palm. *Journal of Oil Palm Research* 20: 470-483.

Sundram, S., Meon, S., Seman, I. A. and Othman, R. 2011. Symbiotic interaction of endophytic bacteria with Arbuscular mycorrhiza fungi and its antagonistic effect on *Ganoderma boninence*. *Journal of Microbiology* 49(4): 551-7.

Suryanarayanan, T. S., Venkatesan, G. and Murali, T. S. 2003. Endophytic fungal communities in leaves of tropical forest trees: diversity and distribution patterns. *Current Science* 85: 489-493.

Susanto, A., Sudharto, P. S. and Purba, R. Y. 2005. Enhancing biological control of basal stem rot disease (*Ganoderma boninense*) in oil palm plantations. *Mycopathologia* 159: 153-157.

Suwannarach, N., Kumla, J., Bussaban, B., Nuangmek, W., Matsui, K. and Lumyong, S. 2013. Biofumigation with the endophytic fungus *Nodulisporium* spp. CMU-UPE34 to control postharvest decay of citrus fruits. *Crop Protection* 45: 63-70.

Tagawa, M., Tamaki, H., Manome, A., Koyama, O. and Kamagata, Y. 2010. Isolation and characterization of antagonistic fungi against potato scab pathogens from potato field soils. *FEMS Microbiology Letters* 305:136-142.

Tang, A. M. C., Jeewon, R. and Hyde, K. D. 2009. A re-evaluation of the evolutionary relationships within the Xylariaceae based on ribosomal and protein-coding gene sequences. *Fungal Diversity* 34: 127-155.

Tarman, K., Palm, G. J., Porzel, A., Merzweiler, K., Arnorld, N., Wessjohann, L. A., Unterseher, M. and Lindequist, U. 2012. Helicascolide C, a new lactone from an Indonesian marine algicolous strain of *Daldinia eschscholzii* (Xylariaceae, Ascomycota). *Phytochemistry* 5: 83-86.

Tenguria, R. K., Khan, F. N. and Quereshi, S. 2011. Endophytes-Mines of pharmacological therapeutics. *World Journal of Science and Technology* 1 (5): 127-149.

Turner, P. D. 1981. *Oil Palm Diseases and Disorders*. Kuala Lumpur: Oxford Universiti Press.

Villa, N. O., Kageyama, K. and Suga, H. 2006. Phylogenetic relationships of *Phytium* and *Phytophthora* species based on ITS rDNA, cytochrome oxidase II and β-tubulin gene sequences. *Mycologia* 98(3): 410-422.

Whalley, A. J. S. 1996. The xylariaceous way of life. *Mycological Research* 100: 897-922.

White, T. J., Bruns, T. D., Lee, S. and Taylor, J. W. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In *PCR Protocol: A Guide to Methods and Application*, ed. Innes, M., Gelfand, D. H., Sninsky, J. J. and White, T. J., pp. 315-322. San Diego: Academic Press.

Wong, L. C., Bong, C. F. J. and Idris, A. S. 2012. *Ganoderma* species associated with basal stem rot disease of oil palm. *American Journal of Applied Science* 9(6): 879-885.

Wu, H., Yang, H. Y., You, X. L. and Li, Y. H. 2013. Diversity of endophytic fungi from roots of *Panax ginseng* and their saponin yield capacity. *Springer Plus* 2:107.

Yoo, J. J. and Eom, A. H. 2012. Molecular identification of endophytic fungi isolated from needle leaves of conifers in Bohyeon Mountain, Korea. *Mycobiology* 40 (4): 231-235.

Yung, C. L., Harrison, L. L. N. and Choo, Y. M. 2013. Physio-chemical properties of biodiesel produced from *Jatropha curcas* oil and palm oil. *Journal of Oil Palm Research* 25(2): 159-164.

Yuyama, K. T., Pereira, J., Maki, C. S. and Ishikawa, N. K. 2013. *Daldinia eschscholtzii* isolated from the Brazillian Amazon: taxonomic feature and mycelial growth conditions. *Acta Amazonica* 43: 1