UNIVERSITI PUTRA MALAYSIA

CHARACTERISATION OF STREPTOMYCES AND THEIR BIOCONTROL ACTIVITIES AGAINST RICE BLAST PATHOGEN *Pyricularia oryzae*

HAYMAN KAKA KHAN AWLA

FP 2016 51

UNIVERSITI PUTRA MALAYSIA
BERILMU BERBAKTI

CHARACTERISATION OF STREPTOMYCES AND THEIR BIOCONTROL ACTIVITIES AGAINST RICE BLAST PATHOGEN *Pyricularia oryzae*

By

HAYMAN KAKA KHAN AWLA

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

May 2016

DEDICTION

I Would Like To Dedicate My Thesis To

My Beloved Parents

My Lovely Wife

My Dearly Loved Two Kids

Ahmad

Tlova

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

CHARACTERISATION OF STREPTOMYCES AND THEIR BIOCONTROL ACTIVITIES AGAINST RICE BLAST PATHOGEN *Pyricularia oryzae*

By

HAYMAN KAKA KHAN AWLA

May 2016

Chairman : Associate Professor Wong Mui Yun, PhD
Faculty : Agriculture

Blast disease caused by the fungus *Pyricularia oryzae* is the most significant disease affecting rice cultivation and causing serious yield losses. To reduce the usage of chemicals, an alternative method for a sustainable control of the disease is necessary. *Streptomyces* have been known to produce antimicrobial compounds and are potential biocontrol agents. This study was carried out to isolate, identify and characterise *Streptomyces* isolates for *in vitro* screening against *P. oryzae*, to identify the antimicrobial compounds produced by selected *Streptomyces* isolates and their mechanisms of biocontrol, and to evaluate the efficacy of selected *Streptomyces* isolate against *P. oryzae* in the glasshouse. A total of 54 *Streptomyces* isolates were obtained from four sites in peninsula Malaysia including healthy and infected paddy fields. All the isolates were tested against *P. oryzae* by dual culture test on Potato Dextrose Agar (PDA) and 14 isolates showed growth inhibition of *P. oryzae*. The best two isolates with more than 80% Percentage of inhibition of radial growth (PIRG %) were selected for subsequent experiments. The isolates were identified as *Streptomyces sp.* based on the morphological, physiological and chemical characteristics and confirmed with 16S rRNA sequence analysis that was compared with related bacteria in GenBank database using MEGA 6.1. Isolates UPMRS4 (*Streptomyces* sp.) and UPM28 (*Streptomyces zaomyceticus*) were found to be the most effective *Streptomyces* against the pathogen with PIRG showing 98.3% and 86.3%, respectively. For extraction of bioactive compounds from UPMRS4, eight different solvents were used and the crude extract obtained from ethyl acetate was found to give the highest PIRG (88%). Bioactive volatile compounds from the ethyl acetate crude extract were identified using gas chromatography-mass spectrometry (GC-MS). Twenty-two volatile compounds were identified as major compounds in the isolated UPMRS4 that were possibly responsible for the antifungal activity. Four nonvolatile compounds from the same crude extract were identified using Liquid chromatography-Mass spectrometry MS (LC-MS MS) and the main compounds were N-Acetyl-D, L-phenylalanine, amicoumacin, fungichromin and rapamycin. For the glasshouse study, UPMRS4 was used as a seed coating for *in vivo* study with four treatments. The results showed significant disease suppression and enhancement of yield attributes compared to the untreated control. UPMRS4 isolate was able to reduce 80% of disease severity compared with other treatments and increase shoot height (15.13%), shoot dry weight (45.7%), leaf surface area (44.6%),

root length (48.9%), root dry weight (63.2%), number of tillers (42.2%), yield (36.9%), panicle length (15.4%) and the number of spikelets/panicle (29.3%) compared to the control plants at three months after inoculation. Defense-related gene expression in rice leaf samples with seed coating application in both inoculated and uninoculated with *P. oryzae* was evaluated using quantitative real-time PCR. Chitinase (*Cht-1*), β-1, 3-glucanase, *OsPRla, Oswrky45* and *OsJAMYB* genes were selected for the study during the three days. Rice plants inoculated with *Streptomyces* sp. UPMRS4 isolate demonstrated a higher abundance of defence gene expression compared with the non-treated controls. The outcomes indicate that UPMRS4 induced rice defence by enhancing the expression levels of OsPR1a, *Cht-1*, *Gns1*, *Oswrky45* (SA) and *OsJAMYB* (JA).

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

PENCIRIAN ASINGAN STREPTOMYCES DAN AKTIVITI BIOKAWALANNYA MELAWAN PATOGEN BLASTA PADI *Pyricularia oryzae*

Oleh

HAYMAN KAKA KHAN AWLA

Mei 2016

Pengerusi : Profesor Madya Wong Mui Yun, PhD
Fakulti : Pertanian

Penyakit blasta yang disebabkan oleh fungus *Pyricularia oryzae* merupakan penyakit paling utama yang menjejaskan penanaman padi dan mendatangkan kerugian hasil yang serius. Untuk mengurangkan penggunaan bahan kimia, kaedah alternatif untuk memperoleh kawalan yang mampan terhadap penyakit ini adalah perlu. *Streptomyces* telah diketahui dapat menghasilkan sebatian antimikrob dan berpotensi sebagai agen biokawalan. Kajian ini dijalankan untuk mengasing, mengenal pasti dan membuat pencirian terhadap asingan *Streptomyces* bagi penyaringan secara *in vitro* terhadap *P. oryzae*, untuk mengenal pasti sebatian antimikrob yang dihasilkan oleh asingan *Streptomyces* terpilih dan mekanisme biokawalannya, dan untuk menilai efikasi asingan *Streptomyces* terpilih melawan *P. oryzae* dalam rumah kaca. Sejumlah 54 asingan *Streptomyces* telah diperolehi dari empat tapak kajian di semenanjung Malaysia termasuklah padi sihat dan terjangkit. Kesemua asingan telah diuji terhadap *P. oryzae* secara ujian dwi kultur ke atas Agar Kentang Dektrosa (PDA) dan 14 asingan menunjukkan perencatan tumbesaran terhadap *P. oryzae*. Dua asingan terbaik dengan lebih daripada 80% peratus tumbesaran jejarian inhibition of radialgrowth (PIRG %) telah dipilih bagi eksperimen selanjutnya. Asingan tersebut telah dikenal pasti sebagai *Streptomyces sp.* berdasarkan ciri-ciri morfologi, fisiologi dan kimia serta disahkan dengan analisis jujukan 16S rRNA yang dibandingkan dengan bakteria berkait dalam pangkalan data GenBank menggunakan MEGA 6.1. Asingan UPMRS4 (*Streptomyces* sp.) dan UPM28 (*Streptomyces zaomyceticus*) telah dikenal pasti sebagai asingan *Streptomyces* yang paling efektif terhadap patogen tersebut dengan peratusan PIRG 98.3% dan 86.3%, masing-masingnya. Bagi pengekstrakan sebatian bioaktif dari UPMRS4, lapan pelarut berbeza telah digunakan dan ekstrak mentah yang diperolehi daripada etil asetat telah didapati memberikan peratusan PIRG tertinggi (88%). Sebatian bioaktif meruap daripada ekstrak mentah etil asetat telah dikenal pasti menggunakan kromatografi gas-spektrometri jisim (GC-MS). Dua puluh dua sebatian meruap telah dikenal pasti sebagai sebatian utama dalam UPMRS4 yang diasingkan, yang berkemungkinan bertanggung jawab terhadap aktiviti antifungus. Empat sebatian tidak meruap daripada ekstrak mentah yang sama telah dikenal pasti menggunakan kromatografi cecair-spektrometri jisim MS (LC-MS/MS) dan sebatian utama adalah N-Asetil-D, L-fenilalanine, amicoumacin, fungikromin and rapamycin. Bagi kajian rumah kaca, UPMRS4 telah digunakan sebagai penyalut benih bagi dua kajian *in vivo* dengan empat rawatan. Hasil menunjukkan menunjukkan perencatan penyakit yang ketara dan peningkatan sifat-sifat hasil berbanding sampel kawalan yang tidak dirawat. Asingan UPMRS4 telah berjaya mengurangi 80% keterukan penyakit berbanding dengan rawatan lain dan meningkatkan ketinggian pucuk (15.1%), berat kering pucuk (45.7%), luas permukaan daun (44.6%), panjang akar (48.9%), berat kering akar (63.2%), bilangan anak gagan (42.2%), hasil (36.9%), panjang panikel (15.4%) dan bilangan spikelet/panikel (29.3%) berbanding tumbuhan kawalan pada tempoh tiga bulan selepas inokulasi. Ekspresi gen terkait-pertahanan dalam sampel daun padi yang menggunakan salutan benih dalam kedua-dua *P. oryzae* yang terinokulasi dan tidak terinokulasi telah diuji menggunakan analisis kuantitatif PCR masa-nyata. Gen kitinase (*Cht-1*), β-1, 3-glukanase, *OsPRla,Oswrky45* dan *OsJAMYB* telah dipilih untuk dikaji selama tiga hari. Pokok padi yang terinokulasi dengan asingan *Streptomyces* sp. UPMRS4 menunjukkan kelimpahan ekspresi gen pertahanan yang lebih tinggi berbanding sampel kawalan yang tidak dirawat. Dapatan kajian menunjukkan UPMRS4 mengaruh sistem pertahanan padi dengan meningkatkan aras ekspresi *OsPR1a*, *Cht-1*, *Gns1*, *Oswrky45* (SA) dan *OsJAMYB* (JA).

ACKNOWLEDGEMENTS

In the mane of Allah, the Most Gracious and the Most Merciful

Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis. I first want to thank my supervisor and committee chair, Assoc. Prof. Dr. Wong Mui Yun. You have acquainted me with an interesting field of research and took the time to guide and to exhortat me through this entire process. I cannot thank you enough for your quietness and consolation amid my time here in this graduate project. I would like to further extend my gratitude to my committee members, Assoc. Prof. Dr. Jugah Kadir and Assoc. Prof. Dr. Radziah Othman, for giving astute suggestions all through my process. Furthermore, I want to thank the both Departments of Plant Protection, and Soil Management in the Faculty of Agriculture, and all the staff members and students for welcoming me as a researcher.

To my lovely wife, thank you for the patience and for encouraging me to finish my study. I am particularly grateful to my parents, my brothers and my sisters, thank you for continually supporting and advising me to proceed with my instruction. I would not have possessed the capacity to limb out looking for new undertakings without every one of you. To my friend and associates in the institute of Tropical Agriculture, Post-Doc. Mohammad Faseleh Jahromi, thank you for the directions, advices and research facility support.

Thanks to the Ministry of Higher Education and Scientific Research in Erbil, Iraqi Kurdistan Region, and Khabat Technical Institute for their financial supporting during the period of my PhD study. Finally, most significantly I am much obliged go to the Malaysian government and the kind hearted individuals at Universiti Putra Malaysia, for money related backing of graduate exploration assistantship and providing for me this chance to study in this prestigious and presumed organization.

Much thanks to you all

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Avr	Pathogen avirulence
Bar	A unit of pressure
BCAs	Biocontrol agents
CFU	Colony Forming Unit
cfu/ml	Colony forming unit per milliliter
CRD	Completely randomized design
DHP	Di-potassium hydrogen phosphate
DMSO	Dimethyl sulfoxide
DNA	Deoxyribonucleic acid
DNase	Deoxyribonuclease
DNTPs	Deoxynucleoside triphosphates
DW	Dry weight
EDTA	Ethylenediaminetetra acetic acid
Fwd_name	Forward name
Fwd_seq	Forward sequence
GC-MS	Gas chromatography mass spectrometry
GL	Gelatin liquefaction
Ha	Hectare
HPLC	High performance liquid chromatography
HR	Hypersensitivity reaction
IAA	Indole 3-acetic acid
ISR	Induced systemic resistance
ITS	Internal transcribed spacer regions
Kb	Kilo base
M	Molar
M. WT.	Molecular weight
MeOH	Methanol
Mg	Milligram
MIC	Minimum inhibitory concentration
Mm	Milli molar
$NaCO_3$	Sodium carbonate
NaOH	Sodium hydroxide
NCBI	National centre of biotechnology information
Ng	Nanogram
Nm	Nanometer
UPMP.o	Pyricularia oryzea
PCR	Polymerase chain reaction
PDA	Potato dextrose agar
Ph	Logarithm of hydrogen ion activity
PSB	phosphate solubilizing bacteria
PSM	phosphate solubilizing microorganisms
QTLs	Quantitative Trait loci
R	Resistance
rDNA	Ribosomal deoxyribonucleic acid
Rev_name	Reverse name
Rev_seq	Reverse sequence
RNA	Ribonucleic acid

Rpm	Revolving per minute
SDS	Sodium dodecyl sulphate
SEM	Scanning electron microscopy
Tris-HCl	hydroxymethyl-hydrochloride
TSB	trypticase soya broth
u/µl	Unit per microliter
units/ml	Units per milliliter
UPMRS	University Putra Malaysia RrhizoStreptomyces
v/v	Volume per volume
Ver.	Version
w/v	Weight per volume

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the world's most important crops and it is consumed as a staple as well as primary source of energy and protein (Zhang *et al.*, 2007). The major rice producer countries are China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Philippines, Brazil, and Japan (IRRI, 2008; FAO, 2013). Rice provides nutrition for six billion people worldwide (Maclean *et al.*, 2002). Asia, is home to 60 % of the world's population and where 90 % of the world's rice is grown. More than 3 billion Asians get 35–75 % of their calories from rice and its products (Khush, 2005).

In Malaysia, rice is a major crop besides oil palm, rubber, and cocoa grown by the private and public sectors. Approximately 72% of Malaysia's rice is grown in eight granary areas that produce two crops annually. In Malaysia rice is mainly grown as wet paddy and only small parts in east Malaysia are under dry land paddy cultivation (Papademetriou, 2001).

The production of rice faces many threats such as pests and diseases. Rice blast disease, caused by the fungus *Pyricularia oryzae*, ranks among the most significant diseases that affect rice cultivation because it is widespread in most of the rice growing areas and seriously affects the quantity and quality of yield (Hayasaka *et al.*, 2008). The disease is found in more than 85 countries (Hajano *et al.* 2011) and under the right environmental conditions it can be very damaging (Scardaci *et al.*, 1997). Losses in yield and harvest of the world rice crop have averaged 10-30% annually (Tongen *et al.*, 2006), and this affects significantly the cost of rice production. The disease can infect all above ground parts of the rice plant. Direct and indirect rice yield losses are due to leaf and panicle blast respectively (Silva *et al.*, 2009).

There are many difficulties in finding a solution for rice blast disease, although some control methods have been identified to be effective such as fungicide application, managing planting time as well as resistant cultivar usage. However, applying fungicides is not a preferred option due to cost implications as well as the fact that it is not friendly to the environment. Furthermore, the spread of the disease can be very rapid and using resistant varieties is at best only for the short term. (Baldwin *et al.*, 2004).

Biological control using bio-agents is an excellent alternative to chemicals and has been proven successful for controlling plant diseases in many countries. Various fungi from the genus *Aspergillus, Gliocladium*, *Paecilomyces, and Trichoderma* and bacteria from the genus *Bacillus, Pseudomonas, Serratia, Erwinia, Rhizobium* and *Paenibacillus* are good examples. Among them, actinobacteria is a phylum of Gram-positive bacteria, which are important candidates for biological control and have been successfully used in rice diseases management worldwide. The beneficial effects of actinomycetales have been attributed to the production of antibiotics, antifungals, metabolites, siderophores, lytic enzymes, hydrogen cyanide (HCN), phosphate solubilization, and induction of systemic resistance against different pathogens (Podile and Kishore, 2006).

Streptomyces is a largest genus of rhizobacteria known to be a rare source of bioactive metabolites which are able to produce vital compounds for medicine and agriculture (Prabavathy *et al.*, 2006) after undergoing various biological processes. *Streptomyces* are able to successfully control soil-borne plant pathogenic fungi by hydrolyzing their cell walls. Actinobacteria are being used currently as agents for the biological control of major pathogenic microorganisms in plants (Keiser *et al.*, 2000; Shahidi *et al.*, 2004).

To our best knowledge, until now no indigenous *Streptomyces* species against *Pyricularia oryzae* on rice have been documented in Malaysia. Therefore, this study was designed to isolate antagonistic actinomycetales from rice plant rhizosphere samples collected from different rice growing regions of Peninsular Malaysia. It was hypothesized that these *Streptomyces* antagonists will be effective for biocontrol against *P. oryzae* causing blast disease in rice.

The objectives of this research are:

1) To isolate, identify and characterise *Streptomyces* isolates from healthy rice fields and their biocontrol activity against *P. oryzae.*
2) To identify the antimicrobial compounds produced by selected *Streptomyces* isolates and their mechanism of biocontrol.
3) To evaluate the efficacy of selected *Streptomyces* isolate against rice blast disease under glasshouse conditions.

REFERENCES

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

Akinbile, C. O., El-Latif, K. A., Abdullah, R., and Yusoff, M. S. (2011). Rice production and water use efficiency for self-sufficiency in Malaysia: A review. Trends in Applied Sciences Research, 6(10):1127.

Alam, S., Khalil, S., Ayub, N., and Rashid, M. (2002). In vitro solubilization of inorganic phosphate by phosphate solubilizing microorganisms (PSM) from maize rhizosphere. International Journal of Agricultural and Biology, 4:454-458.

Aldesuquy HS, Mansour FA, Abo-Hamed SA (1998) Effect of the culture filtra^tes of *Streptomyces* on growth and productivity of wheat plants. Folia Microbiol 43:465–470.

Alexander, M. (1977). Introduction to soil microbiology (No. Ed. 2). John Wiley and Sons. 467 pp.

Ardakani, S. S., Heydari, A., Tayebi, L., and Mohammadi, M. (2010). Promotion of cotton seedlings growth characteristics by development and use of new bioformulations. International Journal of Botany. 6(2): 95-100

Asaga, k. (1987). Cultivar resistance. In Yamanaka, S. and Yamaguchi, T. (eds). Rice Blast Disease, Yokendo: Tokyo. 216-249.

Ashrafuzzaman, M., Hossen, F. A., Ismail, M. R., Hoque, A., Islam, M. Z., Shahidullah, S. M., and Meon, S. (2009). Efficiency of plant growth-promoting rhizobacteria (PGPR) for the enhancement of rice growth. African Journal of Biotechnology. 8, (7).

Azizi, P., Rafii, M. Y., Mahmood, M., Abdullah, S. N., Hanafi, M. M., Nejat, N., Latif, M.A., and Sahebi, M. (2015). Differential Gene Expression Reflects Morphological Characteristics and Physiological Processes in Rice Immunity against Blast Pathogen *Magnaporthe oryzae*. PLoS ONE 10(5): e0126188.

Azumi, M., Ogawa, K. I., Fujita, T., Takeshita, M., Yoshida, R., Furumai, T., and Igarashi, Y. (2008). Bacilosarcins A and B, novel bioactive isocoumarins with unusual heterocyclic cores from the marine-derived bacterium *Bacillus subtilis*. Tetrahedron, 64(27):6420-6425.

Baker, H., Sidorowicz, A., Sehgal, S. N., and Vézina, C. (1978). Rapamycin (AY-22,989), a new antifungal antibiotic. III. In vitro and in vivo evaluation. The Journal of antibiotics, 31(6):539-545.

Baldwin, F. L., Bernhardt, A. D. J., Carroll, M. B., Bureau, A. F. and Glover, M. K. (2004). Pest Management Strategic Plan for Midsouth Rice (Arkansas, Louisiana, Mississippi) August 30, 2004 Advisory Committee Members for Pest Management Strategic Plan for Midsouth Rice Arkansas.

Bashan, Y. and De-Bashan, L. E. (2010). Chapter two-how the plant growth-promoting bacterium Azospirillum promotes plant growth a critical assessment. Advances in agronomy, 108: 77-136.

Bastidas, R. J., Shertz, C. A., Lee, S. C., Heitman, J., and Cardenas, M. E. (2012). Rapamycin exerts antifungal activity in vitro and in vivo against *Mucor circinelloides* via FKBP12-dependent inhibition of Tor. Eukaryotic cell, 11(3): 270-281.

Becker, D. M., Kinkel, L. L., and Schottel, J. L. (1997). Evidence for interspecies communication and its potential role in pathogen suppression in a naturally occurring disease suppressive soil. Canadian journal of microbiology, 43(10):985-990.

Bentley, S.D., Chater, K.F., Cerdeno-Tarraga, A.M., Challis, G.L., Thomson, N.R., James, K.D., Harris, D.E., Quail, M.A., Kieser, H., Harper, D. and Bateman, A., (2002). Complete genome sequence of the model actinomycete *Streptomyces coelicolor* A3 (2).Nature, 417(6885): 141-147.

Berdy, J. (2005). Bioactive microbial metabolites. The Journal of antibiotics, 58(1):1-26.

Bhattacharyya, P. N., and Jha, D. K. (2012). Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. World Journal of Microbiology and Biotechnology, 28(4):1327-1350.

Bird, M. I., Hope, G. and Taylor, D. (2004). Populating PEP II: the dispersal of humans and agriculture through Austral-Asia and Oceania. Quaternary International. 118: 145-163.

Bonman, J.M. (1992). Durable resistance to rice blast disease environmental influences. Euphytica, 63:115-123.

Boukaew, S. and Prasertsan, P. (2014). Factors affecting antifungal activity of Streptomyces philanthi RM-1-138 against *Rhizoctonia solani*. World Journal of Microbiology and Biotechnology, 30(1):323-329.

Bryan, G.T., Wu, K.S., Farrall, L., Jia, Y., Hershey, H.P., McAdams, S.A., Faulk, K.N., Donaldson, G.K., Tarchini, R. and Valent, B. (2000). A single amino acid difference distinguishes resistant and susceptible alleles of the rice blast resistance gene Pi-ta. The Plant Cell Online, 12(11):2033.

Buyer JS, Sikora LJ, Chaney RL (1989) A new growth medium for the study of siderophore mediated interactions. Biology and Fertility of Soils 8,(2): 97-101.

Campbell, C. L.; Madden, L. V. (1990). Introduction to plant disease epidemiology.. xvii + 532 pp.

Cappuccino, J. G., and Sherman, N. (2008). Microbiology: a laboratory manual Pearson Benjamin Cummings. 9: 569.

Castillo, U.F., Strobel, G.A., Mullenberg, K., Condron, M.M., Teplow, D.B., Folgiano, V., Gallo, M., Ferracane, R., Mannina, L., Viel, S. and Codde, M. (2006). Munumbicins E-4 and E-5: novel broad-spectrum antibiotics from *Streptomyces* NRRL 3052. Federation of European Microbiological Societies. Microbiology letters, 255(2):296-300.

Chaiharn, M., and Lumyong, S. (2009). Phosphate solubilization potential and stress tolerance of rhizobacteria from rice soil in Northern Thailand. World Journal of Microbiology and biotechnology, 25(2):305-314.

Chandra, A., Saxena, R., Dubey, A., and Saxena, P. (2007). Change in phenylalanine ammonia lyase activity and isozyme patterns of polyphenol oxidase and peroxidase by salicylic acid leading to enhance resistance in cowpea against *Rhizoctonia solani*. Acta Physiologiae Plantarum, 29(4): 361-367.

Chen, H. L., Chen, B. T., Zhang, D. P., Xie, Y. F., and Zhang, Q. (2001). Pathotypes of *Pyricularia grisea* in rice fields of central and southern China. Plant Disease, 85(8):843-850.

Chen, Z., Zheng, Z., Huang, J., Lai, Z., and Fan, B. (2009). Biosynthesis of salicylic acid in plants. Plant signaling and behavior. 4(6):493-496.

Cleyet-Marcel, J.C., Larcher, M., Bertrand, H., Rapior, S., Pinochet, X. (2001) Plant growth enhancement by rhizobacteria. In J-F Morot-Gaudry, ed, Nitrogen Assimilation by Plants, Physiological, Biochemical and Molecular Aspects. Science Publishers, Inc., Enfeld, NH, pp 185–197.

Cook, A. E., and Meyers, P. R. (2003). Rapid identification of filamentous actinomycetes to the genus level using genus-specific 16S rRNA gene restriction fragment patterns. International journal of systematic and evolutionary microbiology, 53(6):1907-1915.

Cook, R. J., and Baker, K. F. (1983). The nature and practice of biological control of plant pathogens. American Phytopathological Society. 539 pp.

Coombs, J. T., and Franco, C. M. (2003). Visualization of an endophytic *Streptomyces* species in wheat seed. Applied and environmental microbiology, 69 (7):4260-4262.

Couch, B. C., and Kohn, L. M. (2002). A multilocus gene genealogy concordant with host preference indicates segregation of a new species, *Magnaporthe oryzae*, from *M. grisea*. Mycologia, 94:683-693.

Couillerot, O., Loqman, S., Toribio, A., Hubert, J., Gandner, L., Nuzillard, J. M. and Renault, J. H. (2014). Purification of antibiotics from the biocontrol agent *Streptomyces anulatus* S37 by centrifugal partition chromatography.Journal of Chromatography B, 944: 30-34.

Counce, P. A., Keisling, T. C. and Mitchell, A. J. (2000). A uniform, objective, and adaptive system for expressing rice development. Crop Science, 40(2): 436-443.

Crowley, D. E., and Kraemer, S. M. (2007). Function of siderophores in the plant rhizosphere. The rhizosphere: biochemistry and organic substances at the soil–plant interface, 2nd edn. CRC, Boca Raton, 173-200 pp.

Cruz, M. C., Cavallo, L. M., Görlach, J. M., Cox, G., Perfect, J. R., Cardenas, M. E., and Heitman, J. (1999). Rapamycin antifungal action is mediated via conserved complexes with FKBP12 and TOR kinase homologs in Cryptococcus neoformans. Molecular and cellular biology, 19(6):4101-4112.

Davelos, A. L., Xiao, K., Samac, D. A., Martin, A. P., and Kinkel, L. L. (2004). Spatial variation in *Streptomyces* genetic composition and diversity in a prairie soil. Microbial ecology, 48(4):601-612.

De Vleesschauwer, D., Djavaheri, M., Bakker, P. A., and Höfte, M. (2008). *Pseudomonas fluorescens* WCS374r-induced systemic resistance in rice against *Magnaporthe oryzae* is based on pseudobactin-mediated priming for a salicylic acid-repressible multifaceted defense response. Plant Physiology, 148 (4):1996-2012.

Demain, A. L., and Sanchez, S. (2009). Microbial drug discovery: 80 years of progress. The Journal of antibiotics, 62(1): 5-16.

Deshpande, N., Choubey, P., and Agashe, M. (2014). Studies on optimization of growth parameters for L-asparaginase production by *Streptomyces ginsengisoli*. The Scientific World Journal, 2014.

Dey, R., Pal, K. K., Bhatt, D. M., and Chauhan, S. M. (2004). Growth promotion and yield enhancement of peanut (*Arachis hypogaea* L.) by application of plant growth-promoting rhizobacteria. Microbiological research, 159(4): 371-394.

Dey, U., Harlapur, S.I., Dhutraj, D.N., Suryawanshi, A.P., Jagtap, G.P., Apet, K.T., Badgujar, S.L., Gholve, V.M., Kamble, H.N., Kuldhar, D.P. and Wagh, S.S. (2013). Effect of fungicides, botanicals, bioagents and Indigenous Technology Knowledge (ITK's) on germination of urediniospores of Puccinia sorghi in vitro. African Journal of Agricultural Research, 8(39): 4960-4971.

Diby, P., Anandaraj, M., Kumar, A., and Sarma, Y. R. (2005). Antagonistic mechanisms of fluorescent pseudomonads against Phytophthora capsici in black pepper (Piper nigrum L.). Journal of Spices and Aromatic Crops Vol. 14 (2): 122–129.

Dimkpa, C. O., Merten, D., Svatoš, A., Büchel, G., and Kothe, E. (2009). Siderophores mediate reduced and increased uptake of cadmium by Streptomyces tendae F4 and sunflower (Helianthus annuus), respectively.Journal of applied microbiology, 107(5):1687-1696.

Distasio, J. A., Salazar, A. M., Nadji, M., and Durden, D. L. (1982). Glutaminase-free asparaginase from vibrio succinogenes: An antilymphoma enzyme lacking hepatotoxicity. International Journal of Cancer, 30(3):343-347.

Du, Z. W., Cong, H. C., and Yao, Z. (2001). Identification of putative downstream genes of Oct-4 by suppression-subtractive hybridization.Biochemical and biophysical research communications, 282(3): 701-706.

Ebbole, D. J. (2007). *Magnaporthe* as a model for understanding host-pathogen interactions. Annual. Review. of Phytopathology, 45, 437-456.

Ehsanfar, S. and Modarres-Sanavy, S. A. (2004). Crop protection by seed coating. Communications in agricultural and applied biological sciences, 70(3), 225-229.

El-Abyad, M. S., El-Sayed, M. A., El-Shanshoury, A. R., and El-Sabbagh, S. M. (1993). Towards the biological control of fungal and bacterial diseases of tomato using antagonistic *Streptomyces* spp. Plant and soil, 149(2):185-195.

Elango, V., Manjukarunambika, K., Ponmurugan, P. and Marimuthu, S. (2015). Evaluation of *Streptomyces* spp. for effective management of *Poria hypolateritia* causing red root-rot disease in tea plants. Biological Control, 89: 75-83.

El-Mehalawy, A. A., Abd-Allah, N. A., Mohammed, R. M., and Abu-Shady, M. R. (2005). Actinomycetes antagonizing plant and human pathogenic fungi, II. Factors affecting antifungal production and chemical characterization ofthe active components. International Journal of Agriculture and Biology (Pakistan).

El-Tarabily, K. A., and Sivasithamparam, K. (2006). Non-streptomycete actinomycetes as biocontrol agents of soil-borne fungal plant pathogens and as plant growth promoters. Soil Biology and Biochemistry, 38(7), 1505-1520.

Emmert, E. A., and Handelsman, J. (1999). Biocontrol of plant disease: a (Gram-) positive perspective. FEMS Microbiology letters, 171(1): 1-9.

Esitken, A., Pirlak, L., Turan, M., and Sahin, F. (2006). Effects of floral and foliar application of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrition of sweet cherry. Scientia Horticulturae, 110(4), 324-327.

Estrada-De Los Santos, P., Bustillos-Cristales, R., and Caballero-Mellado, J. (2001). Burkholderia, a genus rich in plant-associated nitrogen fixers with wide environmental and geographic distribution. Applied and environmental microbiology, 67(6): 2790-2798.

Faheem, M., Raza, W., Zhong, W., Nan, Z., Shen, Q. and Xu, Y. (2015). Evaluation of the biocontrol potential of *Streptomyces goshikiensis* YCXU against Fusarium oxysporum f. sp. niveum. Biological Control, 81: 101-110.

FAO. (2011). (Food and Agriculture Organization of the United Nations). Agricultural statistics. Downloaded from http://www.faostat.org.

FAO. (2013) (Food and Agriculture Organization of the United Nations). Agricultural statistics. Downloaded from http://www.faostat.org.

Federle, M. J., and Bassler, B. L. (2003). Interspecies communication in bacteria. Journal of Clinical Investigation, 112(9): 1291.

Fujita, K., Arase, S., Hiratsuka, H., Honda, Y., and Nozu, M. (1994). The role of toxin (s) produced by germinating spores of *Pyricularia oryzae* in pathogenesis. Journal of Phytopathology, 142(3): 245-252.

Ganesh, N.R., Gangadhara, N.B., Basavaraja, N.T., and Krishna, N.R. (2012). Fungicidal management of leaf blast disease in rice. Global Journal of Biochemistry and Biotechnology, 1 (1): 18-21.

Gealy, D. R., Mitten, D. H., and Rutger, J. N. (2003). Gene flow between red rice (*Oryza sativa*) and herbicide-resistant rice (*O. sativa*): implications for weed management 1. Weed technology, 17(3): 627-645.

Getachew, G., Tesfaye, A., and Kassahun, T. (2014). Morphological, physiological and biochemical studies on *Pyricularia grisea* isolates causing blast disease on finger millet in Ethiopia. Journal of Applied Bioscience, 74: 6059-6071.

Ghazanfar, M. U., Wakil, W., and Sahi, S. T. (2009). Influence of various fungicides on the management of rice blast disease. Mycopath, 7(1): 29-34.

Gilbert, M. J., Soanes, D. M. and Talbot, N. J. (2004). Functional genomic analysis of the rice blast fungus *Magnaporthe grisea*. Applied Mycology and Biotechnology, 4: 331-352.

Glick, B. R. (2012). Plant growth-promoting bacteria: mechanisms and applications. Scientifica. http://dx.doi.org/10.6064/2012/963401.

Golshani, F., Fakheri, B. A., Behshad, E., and Vashvaei, R. M. (2015, January). PRs proteins and their Mechanism in Plants. Biological Forum – An International Journal 7(1): 477-495.

Gomez-Gomez, L. and Boller, T. (2002). Flagellin perception: a paradigm for innate immunity. Trends in Plant Science, 7(6): 251-256.

Gooday, G. W., Zhu, W. Y., and O'Donnell, R. W. (1992). What are the roles of chitinases in the growing fungus?. Federation of European Microbiological Societies Microbiology Letters, 100(1-3):387-391.

Gopalakrishnan, S., Pande, S., Sharma, M., Humayun, P., Kiran, B.K., Sandeep, D., Vidya, M.S., Deepthi, K. and Rupela, O. (2011). Evaluation of actinomycete isolates obtained from herbal vermicompost for the biological control of Fusarium wilt of chickpea. Crop Protection, 30 (8):1070-1078.

Gopalakrishnan, S., Vadlamudi, S., Bandikinda, P., Sathya, A., Vijayabharathi, R., Rupela, O., Kudapa, H., Katta, K. and Varshney, R.K. (2014). Evaluation of *Streptomyces* strains isolated from herbal vermicompost for their plant growth-promotion traits in rice. Microbiological research, 169(1): 40-48.

Guerre, P. (2015). Ergot Alkaloids Produced by Endophytic Fungi of the Genus Epichloë. Toxins, 7(3): 773-790.

Guleria, S., Aggarwal, R., Thind, T. S., and Sharma, T. R. (2007). Morphological and pathological variability in rice isolates of *Rhizoctonia solani* and molecular analysis of their genetic variability. Journal of phytopathology, 155(11-12): 654-661.

Hajano, J. U., Pathan, M. A., Rajput, Q. A., and Lodhi, M. A. (2011). Rice blast-mycoflora, symptomatology and pathogenicity. International Journal for Agro Veterinary and Medical Sciences, 5(1): 53-63.

Hamdali, H., Hafidi, M., Virolle, M. J., and Ouhdouch, Y. (2008). Rock phosphate-solubilizing Actinomycetes: screening for plant growth-promoting activities.World Journal of Microbiology and Biotechnology, 24(11): 2565-2575.

Hammond-Kosack, K.E. and Parker, J.E. (2003). Deciphering plant-pathogen communication: fresh perspectives for molecular resistance breeding. Current Opinion in Biotechnology, 14(2), 177-193.

Han, J. S., Cheng, J. H., Yoon, T. M., Song, J., Rajkarnikar, A., Kim, W. G. and Suh, J. W. (2005). Biological control agent of common scab disease by antagonistic strain *Bacillus* sp. sunhua. Journal of applied microbiology,99(1):213-221.

Haq, I. M., Adnan, M. F., Jamil, F. F., and Rehman, A. (2002). Screening of rice germplasm against *Pyricularia oryzae* and evaluation of various fungitoxicants for control of disease. Pakistan Journal of Phytopathology. 14(1): 32-5.

Harman, G. E. (1991). Seed treatments for biological control of plant disease. Crop Protection, 10(3), 166-171.

Harrison, P. H., Noguchi, H., and Vederas, J. C. (1986). Biosynthesis of polyene antibiotics: intact incorporation of carbon-13 labeled octanoate into fungichromin by *Streptomyces cellulosae*. Journal of the American Chemical Society, 108(13): 3833-3834.

Hasegawa S, Meguro A, Shimizu M, Nishimura T, Toyoda K, Shiraishi T, Kunoh H (2008) Two bioassay methods to evaluate root-accelerating activity of *Streptomyces* sp. MBR52 metabolites. Actinomycetologica 22:42–45.

Hashimoto, M., Taguchi, T., Nishida, S., Ueno, K., Koizumi, K., Aburada, M., and Ichinose, K. (2007). Isolation of 8′-phosphate ester derivatives of amicoumacins: structure-activity relationship of hydroxy amino acid moiety. The Journal of antibiotics, 60(12):752-756.

Hashioka, Y. (1973). Notes on *Pyricularia* II. Four species and one variety parasitic to Cyperaceae, Gramineae and Commelinaceae. Transactions of the Mycological Society of Japan, 14: 256-265.

Hassen, A., Belguith, K., Jedidi, N., Cherif, A., Cherif, M., and Boudabous, A. (2001). Microbial characterization during composting of municipal solid waste. Bioresource technology, 80(3):217-225.

Hayasaka, T., Fujii, H., and Ishiguro, K. (2008). The role of silicon in preventing appressorial penetration by the rice blast fungus. Phytopathology, 98(9): 1038-1044.

Hayat, R., Ali, S., Amara, U., Khalid, R., and Ahmed, I. (2010). Soil beneficial bacteria and their role in plant growth promotion: a review. Annals of Microbiology, 60(4): 579-598.

Hill, J. E., Williams, J. F., Mutters, R. G., and Greer, C. A. (2006). The California rice cropping system: agronomic and natural resource issues for long-term sustainability. Paddy and water environment, 4(1): 13-19.

Hinsinger, P. (2001). Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. Plant and soil, 237(2), 173-195.

Hirata, K., Kusaba, M., Chuma, I., Osue, J., Nakayashiki, H., Mayama, SH., and Tosa, Y. (2007). Speciation in *Pyricularia* inferred from multilocus phylogenetic analysis. Mycological Research, 111: 799-808.

Holt, J.G., Krieg, N.R., Sneath, P.H.A., Staley, J.T. and Williams, S.T. (1984). Bergeys Manual of Determinative Bacteriology. Baltimore, London: USA: Williams and Wilkins.

Hop, D.V., Phuong Hoa, P.T., Quang, N.D., Ton, P.H., Ha, T.H., Hung, N.V., Van, N.T., Hai, T.V., Kim Quy, N.T., Anh Dao, N.T. And Thi Thom, A.V., (2014). Biological Control of *Xanthomonas Oryzae* pv. *Oryzae* Causing Rice Bacterial Blight Disease by *Streptomyces toxytricini* VN08-A-12, Isolated from Soil and Leaf-litter Samples in Vietnam. Biocontrol science, 19(3): 103-111.

Hossain, M. A., and Rahman, A. (2011). Chemical composition of bioactive compounds by GC-MS screening and antifungal properties of the crude extracts of cabbage samples. Asian Journal of Biotechnology, 3(1): 68-76.

Howles, P., Lawrence, G., Finnegan, J., McFadden, H., Ayliffe, M., Dodds, P., and Ellis, J. (2005). Autoactive alleles of the flax L6 rust resistance gene induce non-race-specific rust resistance associated with the hypersensitive response. Molecular Plant-Microbe Interactions, 18(6): 570-582.

Hu, X. F., Ying, F. X., He, Y. B., Gao, Y. Y., Chen, H. M., and Chen, J. S. (2008). Characterization of *Pectobacterium carotovorum* subsp. carotovorum causing soft-rot disease on Pinellia ternata in China. European journal of plant pathology, 120(3): 305-310.

Huang H. C., Wang H. F., Yih K. H., Chang L. Z., Chang T. M. (2012). Dual bioactivities of essential oil extracted from the leaves of Artemisia argyi as an antimelanogenic versus antioxidant agent and chemical composition analysis by GC/MS. Int. J. Mol. Sci. 13, 14679–14697.

Hulbert, S.H., Webb, C.A., Smith, S.M. and Sun, Q. (2001). Resistance gene complexes: evolution and utilization. Annual Review of Phytopathology, 39(1); 285-312.

Hwang, M.S.H., Morgan, R.L., Sarkar, S.F., Wang, P.W. and Guttman, D.S. (2005). Phylogenetic characterization of virulence and resistance phenotypes of *Pseudomonas syringae*. Applied and Environmental Microbiology, 71(9):5182.

Inui, H., Yamaguchi, Y., and Hirano, S. (1997). Elicitor actions of N-acetylchitooligosaccharides and laminarioligosaccharides for chitinase and L-phenylalanine ammonia-lyase induction in rice suspension culture.Bioscience, biotechnology, and biochemistry, 61(6): 975-978.

IRRI. (2002). Standard evaluation system for rice (SES): Los Banos, Philippines.

IRRI. (2008). International Rice Research Institute: IRRI World Rice Statistics (WRS), Facts and Figures: 1960-2010.

Jamal-u-Ddin, H., Lodhi, A.M., Pathan, M.A., Khanzada, M.A., and Shah, G.S (2012). In-vitro evaluation of fungicides, plant extracts and bio-control agents against rice blast pathogen *Magnaporthe oryzae* Couch. Pakistan Journal of Botany. 44(5): 1775-1778.

Jeffrey, L. S. H., Sahilah, A. M., Son, R., and Tosiah, S. (2007). Isolation and screening of actinomycetes from Malaysian soil for their enzymatic and antimicrobial activities. Journal of Tropical Agriculture and Food Science, 35(1):159.

Ji, G. H., Wei, L. F., He, Y. Q., Wu, Y. P., and Bai, X. H. (2008). Biological control of rice bacterial blight by Lysobacter antibioticus strain 13-1. Biological control, 45(3): 288-296.

Jia, Y., McAdams, S. A., Bryan, G. T., Hershey, H. P., and Valent, B. (2000). Direct interaction of resistance gene and avirulence gene products confers rice blast resistance. The EMBO Journal, 19(15): 4004-4014.

Kamala, T. and Indra Devi, S. (2012). Biocontrol properties of indigenous Trichoderma isolates from North-East India against *Fusarium oxysoprum* and *Rhizoctonia solani*. African Journal of Biotechnology 11(34): 8491-8499.

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

Kanzaki, H., Nirasawa, S., Saitoh, H., Ito, M., Nishihara, M., Terauchi, R., and Nakamura, I. (2002). Overexpression of the wasabi defensin gene confers enhanced resistance to blast fungus (*Magnaporthe grisea*) in transgenic rice.Theoretical and Applied Genetics, 105(6-7): 809-814.

Karpagam, T., and Nagalakshmi, P. K. (2014). Isolation and characterization of phosphate solubilizing microbes from agricultural soil. International Journal of Current Microbiology and Applied Sciences, 3(3): 601-614.

Karthik, N., Binod, P. and Pandey, A. (2015). Purification and characterisation of an acidic and antifungal chitinase produced by a *Streptomyces* sp. Bioresource technology, 188: 195-201.

Kato, H. (2001). Rice blast disease. Pesticide outlook, 12(1): 23-25.

Kato, H., Yamamoto, M., Yamaguchi-Ozaki, T., Kadouchi, H., Iwamoto, Y., Nakayashiki, H., Tosa, Y., Mayama, S., and Mori, N. (2000). Pathogenicity, mating ability and DNA restriction fragment length polymorphisms of Pyricularia populations isolated from Gramineae, Bambusideae and Zingiberaceae plants. Journal of General Plant Pathology, 66: 30-47.

Kavitha, A., Vijayalakshmi, M., Sudhakar, P., and Narasimha, G. (2010). Screening of Actinomycete strains for the production of antifungal metabolites. African Journal of Microbiology Research, 4(1): 027-032.

Khamna, S., Yokota, A., and Lumyong, S. (2009). Actinomycetes isolated from medicinal plant rhizosphere soils: diversity and screening of antifungal compounds, indole-3-acetic acid and siderophore production. World Journal of Microbiology and Biotechnology, 25(4): 649-655.

Khan, M.S., Zaidi, A., Wani, P.A. and Oves, M. (2009). Role of plant growth promoting rhizobacteria in the remediation of metal contaminated soils. Environmental Chemestry Letters 7(1): 1-19.

Khush, G.S. (2005). "What it will take to feed 5.0 billion rice consumers in 2030." Plant Molecular Biology, 59(1): 1-6.

Kidoglu, F., Gül, A., Ozaktan, H., and Tüzel, Y. (2007). Effect of rhizobacteria on plant growth of different vegetables. In International Symposium on High Technology for Greenhouse System Management: Greensys. 801:1471-1478.

Kim, Y. S., Oh, J. Y., Hwang, B. K., and Kim, K. D. (2008). Variation in sensitivity of *Magnaporthe oryzae* isolates from Korea to edifenphos and iprobenfos. Crop protection, 27(11): 1464-1470.

Kinkel, L. L., Schlatter, D. C., Bakker, M. G., and Arenz, B. E. (2012). *Streptomyces* competition and co-evolution in relation to plant disease suppression. Research in microbiology, 163(8): 490-499.

Kloeppe, J. W., Rodriguez-Kabana, R., Zehnder, A. W., Murphy, J. F., Sikora, E., aand Fernandez, C. (1999). Plant root-bacterial interactions in biological control of soilborne diseases and potential extension to systemic and foliar diseases. Australasian Plant Pathology, 28(1): 21-26.

Koide, Y., Kobayashi, N., Xu, D. and Fukuta, Y. (2009). Resistance genes and selection DNA markers for blast disease in rice (*Oryza sativa* L.). JapanAgricultural Research Quarterly, 43, 255-280.

Koizumi, S. (2007). Durability of resistance to rice blast disease. A differential system for blast resistance for stable rice production environment. Japan International Research Center for Agricultural Sciences working report, 53:1–10.

Kumar, R., and Lown, J. W. (2003). Design, synthesis and in vitro cytotoxicity studies of novel pyrrolo [2, 1][1, 4] benzodiazepine-glycosylated pyrrole and imidazole polyamide conjugates. Organic & biomolecular chemistry, 1(19), 3327-3342.

Kurth, F., Mailänder, S., Bönn, M., Feldhahn, L., Herrmann, S., Große, I. and Tarkka, M. T. (2014). Streptomyces-induced resistance against oak powdery mildew involves host plant responses in defense, photosynthesis, and secondary metabolism pathways. Molecular Plant-Microbe Interactions, 27(9): 891-900.

Labeda, D. P. (2011). Multilocus sequence analysis of phytopathogenic species of the genus *Streptomyces*. International journal of systematic and evolutionary microbiology, 61(10): 2525-2531.

Lama, A., Pané-Farré, J., Chon, T., Wiersma, A. M., Sit, C. S., Vederas, J. C. and Nakano, M. M. (2012). Response of methicillin-resistant Staphylococcus aureus to amicoumacin A. PloS one, 7(3): e34037.

Lee, M. W., Qi, M., and Yang, Y. (2001). A novel jasmonic acid-inducible rice myb gene associates with fungal infection and host cell death. Molecular plant-microbe interactions, 14(4): 527-535.

Lelliott, R. A., and Stead, D. E. (1987). Methods for the diagnosis of bacterial diseases of plants. Blackwell Scientific Publications.

Li, Qili, Yinhui Jiang, Ping Ning, Lu Zheng, Junbin Huang, Guoqing Li, Daohong Jiang, and Tom Hsiang. (2011). Suppression of *Magnaporthe oryzae* by culture filtrates of *Streptomyces globisporus* JK-1. Biological control, 58(2):139-148.

Li, Y., Sun, Z., Zhuang, X., Xu, L., Chen, S., and Li, M. (2003). Research progress on microbial herbicides. Crop Protection, 22(2):247-252.

Li, Y., Xu, Y., Liu, L., Han, Z., Lai, P. Y., Guo, X. and Qian, P. Y. (2012). Five new amicoumacins isolated from a marine-derived bacterium *Bacillus subtilis*. Marine drugs, 10(2):319-328.

Lima, J.L. (2003). Seleção de actinomicetos para o controle biológico de *Ralstonia solanacearum* e promoção de crescimento de mudas de tomateiro. Bahia, Brazil, 70p. (M.Sc. Dissertation. Programa de Pós-Graduação em Ciências Agrárias. UFBA).

Liu, D., Anderson, N. A., and Kinkel, L. L. (1995). Biological control of potato scab in the field with antagonistic *Streptomyces scabies*. Phytopathology,85(7): 827-831.

Livak, K. J., and Schmittgen, T. D. (2001). Analysis of relative gene expression data using real-time quantitative PCR and the 2− ΔΔCT method.methods, 25(4): 402-408.

Lo, C. W., Lai, N. S., Cheah, H. Y., Wong, N. K. I., and Ho, C. C. (2002). Actinomycetes isolated from soil samples from the Crocker Range Sabah.ASEAN Review on Biodiversity and Environmental Conservation.

Loria, R., Bukhalid, R. A., Fry, B. A., and King, R. R. (1997). Plant pathogenicity in the genus Streptomyces. Plant Disease, 81(8): 836-846.

Lynd, L. R., Weimer, P. J., Van Zyl, W. H., and Pretorius, I. S. (2002). Microbial cellulose utilization: fundamentals and biotechnology. Microbiology and molecular biology reviews, 66(3): 506-577.

Maclean, J., Dawe, D., Hardy, B. and Hettel, G. (2002). Rice almanac. International Rice Research Institute, West Africa Rice Development Association. International Center for Tropical Agriculture, Food and Agriculture Organization. CAB International, Wallingford, UK.

Madden, L. V., Hughes, G., and Van Den Bosch, F. (2007). The study of plant disease epidemics). St. Paul, MN: American Phytopathological Society.632(3): 33.

Madhaiyan, Munusamy, Selvaraj Poonguzhali, Murugaiyan Senthilkumar, Sundaram Seshadri, Heekyung Chung, Y. A. N. G. Jinchul, Subbiah Sundaram, And S. A. Tongmin. (2004). Growth promotion and induction of systemic resistance in rice cultivar Co-47 (Oryza sativa L.) by *Methylobacterium* spp. Botanical Bulletin of Academia Sinica, 45.

Malinowski, D. P., Belesky, D. P., and Lewis, G. C. (2005). Abiotic stresses in endophytic grasses. Neotyphodium in cool-season grasses. 187-199.

Manidipa, R., Dutta, S. G., and Venkata, R. C. (2013). Pseudomonads: Potential Biocontrol agents of Rice Diseases. Research Journal of Agriculture and Forestry Sciences- ISSN, 2320, 6063.

Mansouri, M. D., and Darouiche, R. O. (2008). In-vitro activity and in-vivo efficacy of catheters impregnated with chloroxylenol and thymol against uropathogens. Clinical Microbiology and Infection, 14(2): 190-192.

Mao, W., Lewis, J. A., Hebbar, P. K. and Lumsden, R. D. (1997). Seed treatment with a fungal or a bacterial antagonist for reducing corn damping-off caused by species of Pythium and Fusarium. Plant Disease, 81(5), 450-454.

Mastretta, C., Taghavi, S., van der Lelie, D., Mengoni, A., Galardi, F., Gonnelli, C. and Vangronsveld, J. (2009). Endophytic bacteria from seeds of Nicotiana tabacum can reduce cadmium phytotoxicity. International Journal of Phytoremediation, 11(3), 251-267.

Maurhofer, M., KEEL, C., Haas, D., and Défago, G. (1995). Influence of plant species on disease suppression by *Pseudomonas fluorescens* strain CHAO with enhanced antibiotic production. Plant Pathology, 44(1): 40-50.

McCouch, S., Nelson, R.J., Tohme, J. and Zeigler ,R.S. (1994). Mapping of blast resistance genes in rice. Rice Blast Disease. R.S., Zeigler, S.A., Leong and P.S., Teng, Wallingtonford. UK: The Centre for Agriculture and Bioscience International. 167-186.

McDonald, B.A. and Linde, C. (2002). Pathogen population genetics, evolutionary potential, and durable resistance. Annual Review of Phytopathology, 40(1): 349-379.

Melo, I. S., Santos, S. N., Rosa, L. H., Parma, M. M., Silva, L. J., Queiroz, S. C., and Pellizari, V. H. (2014). Isolation and biological activities of an endophytic Mortierella alpina strain from the Antarctic moss Schistidium antarctici. Extremophiles, 18(1): 15-23.

Meng, X., Yu, J., Yu, M., Yin, X., and Liu, Y. (2015). Dry flowable formulations of antagonistic *Bacillus subtilis* strain T429 by spray drying to control rice blast disease. Biological Control, 85: 46-51.

Meyers, B.C., Kozik, A., Griego, A., Kuang, H., and Michelmore, R.W. (2003). Genome-wide analysis of NBS-LRR–encoding genes in Arabidopsis. The Plant Cell Online, 15(4): 809.

Mirza, M. S., Mehnaz, S., Normand, P., Prigent-Combaret, C., Moënne-Loccoz, Y., Bally, R., and Malik, K. A. (2006). Molecular characterization and PCR detection of a nitrogen-fixing Pseudomonas strain promoting rice growth. Biology and Fertility of Soils, 43(2): 163-170.

Mishra, M., Kumar, U., Mishra, P. K., and Prakash, V. (2010). Efficiency of plant growth promoting rhizobacteria for the enhancement of Cicer arietinum L. growth and germination under salinity. Advanced Biomedical Research, 4(2): 92-96.

Monaghan, P., Fardis, M., Revill, W. P., and Bell, A. (2005). Antimalarial effects of macrolactones related to FK520 (ascomycin) are independent of the immunosuppressive properties of the compounds. Journal of Infectious Diseases, 191(8): 1342-1349.

Montealegre, J. R., Reyes, R., Pérez, L. M., Herrera, R., Silva, P., and Besoain, X. (2003). Selection of bioantagonistic bacteria to be used in biological control of *Rhizoctonia solani* in tomato. Electronic Journal of Biotechnology, 6(2): 115-127.

Morakchi, H., Ayari, A., Taok, M., Kirane, D., and Cochet, N. (2009). Characterization of Streptomyces strain SLO-105 isolated from Lake Oubeira sediments in North-East of Algeria. African Journal of Biotechnology. 8(22).

Morath, S. U., Hung, R., and Bennett, J. W. (2012). Fungal volatile organic compounds: a review with emphasis on their biotechnological potential. Fungal Biology Reviews, 26(2): 73-83.

Motta, A. S., Cladera-Olivera, F., and Brandelli, A. (2004). Screening for antimicrobial activity among bacteria isolated from the Amazon basin.Brazilian Journal of Microbiology, 35(4): 307-310.

Murashima, K., Kosugi, A., and Doi, R. H. (2002). Synergistic effects on crystalline cellulose degradation between cellulosomal cellulases from Clostridium cellulovorans. Journal of bacteriology, 184(18): 5088-5095.

Nan, Z. B., and Li, C. J. (2000). Neotyphodium in native grasses in China and observations on endophyte / host interactions. In Proceedings of the 4th international Neotyphodium-grass interactions symposium. 41-50.

Nautiyal, C. S. (1999). An efficient microbiological growth medium for screening phosphate solubilizing microorganisms. Federation of European Microbiological Societies; microbiology Letters, 170(1): 265-270.

Ndowora, T. C. R., Kinkel, L. L., Jones, R. K., and Anderson, N. A. (1996). Fatty acid analysis of pathogenic and suppressive strains of *Streptomyces* species isolated in Minnesota. Phytopathology, 86(2):138-143.

Neeraja, C., Anil, K., Purushotham, P., Suma, K., Sarma, P. V. S. R. N., Moerschbacher, B. M., and Podile, A. R. (2010). Biotechnological approaches to develop bacterial chitinases as a bioshield against fungal diseases of plants.Critical Reviews in Biotechnology, 30(3): 231-241.

Netam, R. S., Bahadur, A. N., Tiwari, U., and Tiwari, R. K. S. (2011). Efficacy of plant extracts for the control of (*Pyricularia grisea*) blast of rice under field condition of Bastar, Chattisgarh. Journal of Agricultural Science and Technology. 2(2): 269-271.

Nicol, J. M., Turner, S. J., Coyne, D. L., Den Nijs, L., Hockland, S. and Maafi, Z. T. (2011). Current nematode threats to world agriculture. In Genomics and molecular genetics of plant-nematode interactions. Springer Netherlands, 21-43.

Nimnoi, P., Pongsilp, N., and Lumyong, S. (2010). Endophytic actinomycetes isolated from Aquilaria crassna Pierre ex Lec and screening of plant growth promoters production. World Journal of Microbiology and Biotechnology. 26(2):193-203.

Ningthoujam, D., Sanasam, S., and Nimaichand, S. (2009). A *Streptomyces sindenensis* strain LS1-128 exhibiting broad spectrum antimicrobial activity. Research Journal of Biological Sciences. 4: 1085-1091.

Noguchi, H., Harrison, P. H., Arai, K., Nakashima, T. T., Trimble, L. A., and Vederas, J. C. (1988). Biosynthesis and full NMR assignment of fungichromin, a polyene antibiotic from Streptomyces cellulose. Journal of the American Chemical Society. 110(9):2938-2945.

Noori, M.S.S. and Saud, H.M. (2012). Potential Plant Growth-Promoting Activity of *Pseudomonas* sp. Isolated from Paddy Soil in Malaysia as Biocontrol Agent. Journal of Plant Pathology and Microbiology 3:120.

Oh, B.T., Hur, H., Lee, K.J., Shanthi, K., Soh, B.Y., Lee, W.J., Myung, H. and Kamala-Kannan, S (2011). Suppression of Phytophthora blight on pepper (*Capsicum annuum* L.) by bacilli isolated from brackish environment. Biocontrol Science and Technology. 21(11): 1297-1311.

Oleszek W., Marston A., editors. (eds.) (2000). Saponins in food, feedstuffs and medicinal plants, in Proceedings of the Phytochemical Society of Europe, 45:1–95.

Oliveira, A. L. M., Urquiaga, S., and Baldani, J. I. (2003). Processos e mecanismos envolvidos *na influência de microrganismos* sobre o crescimento vegetal. Embrapa Agrobiologia. Documentos, 161.

Olubunmi, A., Gabriel, O. A., Stephen, A. O., and Scott, F. O. (2009). Antioxidant and antimicrobial activity of cuticular wax from Kigelia africana. Fabad Journal of Pharmaceutical Sciences, 34(4): 193-198.

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

Pandey, S., Gauchan, D., Malabayabas, M., Bool-Emrick, M. and Hardy, B. (2012). Patterns of adoption of improved rice varities and farm level impacts in stress-prone rainfed areas in South Asia. International Rice Research Institute.

Panhwar, Q. A., Othman, R., Rahman, Z. A., Meon, S., and Ismail, M. R. (2014). Isolation and characterization of phosphate-solubilizing bacteria from aerobic rice. African Journal of Biotechnology, 11(11): 2711-2719.

Papademetriou, M. K. (Ed.). (2001). Crop diversification in the Asia-Pacific region. FAO Regional Office for Asia and the Pacific.

Paramageetham, C. and Prasada Babu, G. (2012). Antagonistic Activity of Fluorescent *Pseudomonads* against a Polyphagous Soil Born Plant Pathogen-Sclerotium rolfsii. 1: 436:10.4172/scientificreports.436.

Parthasarathi, S., Sathya, S., Bupesh, G., Samy, R. D., Mohan, M. R., Kumar, G. S. and Balakrishnan, K. (2012). Isolation and characterization of antimicrobial compound from marine *Streptomyces hygroscopicus* BDUS 49. World Journal of Fish and Marine Sciences. 4(3):268-277.

Patel, J. B., Tenover, F. C., Turnidge, J. D., and Jorgensen, J. H. (2011). Susceptibility test methods: dilution and disk diffusion methods. Manual of Clinical Microbiology, 1122-1143.

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

Peng, X., Hu, Y., Tang, X., Zhou, P., Deng, X., Wang, H., and Guo, Z. (2012). Constitutive expression of rice WRKY30 gene increases the endogenous jasmonic acid accumulation, PR gene expression and resistance to fungal pathogens in rice. Planta. 236(5): 1485-1498.

Perini, V.M., Castro, H., Santos, G., Aguiar, R.S., Leao, E.U and Seixas, P.T.L (2011). Evaluation of the preventive and curative effect of the essential oil of citronella grass in the control of *Pyricularia grisea*. Journal of Biotechnology and Biodiversity. 2(2): 23.

Pham, V.D., Nguyen, B.S., Tran, Thi Ngoc Bich., Hoang dinh Dinh., Pham Van Kim., H.J.L Jorgensen and Smedegaard-Petersen. (2000). Induction of systemic acquired resistance in rice against blast (*Pyricularia grisea* Cav.) by di-potassium hydrogen phosphate.

Phillipson J. D. (2007). Phytochemistry and pharmacognosy. Phytochemistry 68: 2960–2972.

Pieterse, C. M. J., Wees, S. V., Ton, J., Pelt, J. V., and Loon, L. C. (2002). Signalling in Rhizobacteria-Induced Systemic Resistance in Arabidopsis thaliana. Plant Biology, 4(5): 535-544.

Pinchuk, I. V., Bressollier, P., Sorokulova, I. B., Verneuil, B., and Urdaci, M. C. (2002). Amicoumacin antibiotic production and genetic diversity of *Bacillus subtilis* strains isolated from different habitats. Research in Microbiology.153(5): 269-276.

Pinchuk, I. V., Bressollier, P., Verneuil, B., Fenet, B., Sorokulova, I. B., Mégraud, F., and Urdaci, M. C. (2001). In Vitro Anti-Helicobacter pyloriActivity of the Probiotic Strain Bacillus subtilis 3 is Due to Secretion of Antibiotics. Antimicrobial agents and chemotherapy. 45(11): 3156-3161.

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

Polikanov, Y. S., Osterman, I. A., Szal, T., Tashlitsky, V. N., Serebryakova, M. V., Kusochek, P. and Konevega, A. L. (2014). Amicoumacin A inhibits translation by stabilizing mRNA interaction with the ribosome. Molecular cell. 56 (4):531-540.

Ponmurugan, P., and Gopi, C. (2006). Distribution pattern and screening of phosphate solubilizing bacteria isolated from different food and forage crops. Journal of Agronomy. 5(4): 600-604.

Postma, J., Scheper, R. W. A., and Schilder, M. T. (2010). Effect of successive cauliflower plantings and *Rhizoctonia solani* AG 2-1 inoculations on disease suppressiveness of a suppressive and a conducive soil. Soil Biology and Biochemistry. 42(5):804-812.

Pozo, M. J., Van Loon, L. C. and Pieterse, C. M. (2004). Boosting plant defence by beneficial soil microorganisms. In 16th workshop of Marie Curie Fellows: Research training in progress (pp. 158-161). European Commission-Directorate-General for research.

Prabavathy, V. R., Mathivanan, N., and Murugesan, K. (2006). Control of blast and sheath blight diseases of rice using antifungal metabolites produced by *Streptomyces* sp. PM5. Biological Control, 39(3):313-319.

Prabhu, A. S., Filippi, M. C., and Zimmermann, F. J. P. (2003). Cultivar response to fungicide application in relation to rice blast control, productivity and sustainability. Pesquisa Agropecuária Brasileira. 38(1): 11-17.

Prasad, S. S., and Gupta, P. K. (2012). Compatibility of new insecticides and fungicides against stem borer and leaf blast on semi-deep water rice. Crop Research Hisar, 43(1): 2.

Qiu D, Xiao J, Xie W, Cheng H, Li X, Wang S (2009) Exploring transcriptional signaling mediated by OsWRKY13, a potential regulator of multiple physiological processes in rice. BioMed Central Plant Biology. 9 (74):1-14.

Quintana-Jones, T. A. (2011). Evaluation of Drip Applications and Foliar Sprays of the Biocontrol Product Actinovate on Powdery Mildew and Other Fungal Diseases of Tomato (Doctoral dissertation, California Polytechnic State University, San Luis Obispo).

Rajan, B. M., and Kannabiran, K. (2014). Extraction and Identification of Antibacterial Secondary Metabolites from Marine *Streptomyces* sp. VITBRK2. International journal of molecular and cellular medicine. 3(3):130.

Rajkumar, M., Ae, N., Prasad, M. N. V., and Freitas, H. (2010). Potential of siderophore-producing bacteria for improving heavy metal phytoextraction.Trends in Biotechnology. 28(3): 142-149.

Rashad, F. M., Fathy, H. M., El-Zayat, A. S., and Elghonaimy, A. M. (2015). Isolation and characterization of multifunctional Streptomyces species with antimicrobial, nematicidal and phytohormone activities from marine environments in Egypt. Microbiological research. 175: 34-47.

Recio, E., Colinas, Á., Rumbero, Á., Aparicio, J. F. and Martín, J. F. (2004). PI factor, a novel type quorum-sensing inducer elicits pimaricin production in

Streptomyces natalensis. Journal of Biological Chemistry. 279(40): 41586-41593.

Ryu, C. M., Farag, M. A., Hu, C. H., Reddy, M. S., Kloepper, J. W., and Paré, P. W. (2004). Bacterial volatiles induce systemic resistance in Arabidopsis. Plant Physiology, 134(3): 1017-1026.

Sabaratnam, S. and Traquair, J. A. (2002). Formulation of a *Streptomyces* biocontrol agent for the suppression of Rhizoctonia damping-off in tomato transplants. Biological Control, 23(3): 245-253.

Saccardo, P. A. (1880). Fungorum extra-europaeorum Pugillus. Michelia, 2(6), 138.

Sambrook J, Fritsch Ef, Maniatis T (1989) Molecular cloning: A laboratory manual, 2nd ed. 3. Cold Spring Harbor (New York): Cold Spring Harbor Laboratory Press.

Sanim, B. (2011). Management of Water Resources in Supporting Independent and Sovereign State. KIPNAS X in Jakarta in cooperation with Indonesian Institute of Sciences (LIPI) and the Ministry of National Education and Culture on the date. 8-10.

Saraf, M., Thakkar, A., Pandya, U., Joshi, M. and Parikh, J. (2013). Potential of plant growth promoting microorganisms as biofertilizers and biopesticides and it's exploitation in sustainable agriculture. Journal of Microbiology and Biotechnology Research. 3(5): 54-62.

Sarkar, A., Islam, T., Biswas, G., Alam, S., Hossain, M., and Talukder, N. (2012). Screening for phosphate solubilizing bacteria inhabiting the rhizoplane of rice grown in acidic soil in Bangladesh. Acta microbiologica et immunologica Hungarica. 59(2): 199-213.

Sarker, A., Talukder, N. M., and Islam, M. T. (2014). Phosphate solubilizing bacteria promote growth and enhance nutrient uptake by wheat. Plant Science Today. 1(2): 86-93.

Scardaci, S. C., Webster, R. K., Greer, C. A., Hill, J. E., William, J. F., Mutters, R. G., Brandon, D. M., McKenzie, K. S., and Oster, J. J. (1997). Rice Blast: A New Disease in California. Agronomy Fact Sheet Series 2. Department of Agronomy and Range Science, University of California, Davis.

Seebold Jr, K. W., Datnoff, L. E., Correa-Victoria, F. J., Kucharek, T. A., and Snyder, G. H. (2004). Effects of silicon and fungicides on the control of leaf and neck blast in upland rice. Plant Disease. 88(3): 253-258.

Selvakumar, P., Viveka, S., Prakash, S., Jasminebeaula, S. and Uloganathan, R. (2012). Antimicrobial activity of extracellularly synthesized silver nanoparticles from marine derived Streptomyces rochei. International Journal of Pharma and Bio Sciences. 3:188-197.

Sesma, A., and Osbourn, A. E. (2004). The rice leaf blast pathogen undergoes developmental processes typical of root-infecting fungi. Nature. 431(7008): 582-586.

Shahaya Mary, R. and Dhanaseeli, M. (2012). Biocontrol Potential of Selected Actinomycete and its Metabolites against *Rhizoctonia solani*. Indian Journal of Natural Sciences. 2(12): 965-972.

Shahidi Bonjar GH, Fooladi MH, Mahdavi MJ, Shahghasi A. (2004). Broadspectrim, a Novel Antibacterial from *Streptomyces* sp. Biotechnology. 3: 126-130.

Shanthakumar, S. P., Duraisamy, P., Vishwanath, G., Selvanesan, B. C., Ramaraj, V., and David, B. V. (2015). Broad spectrum antimicrobial compounds from the bacterium *Exiguobacterium mexicanum* MSSRFS9.Microbiological research. 178: 59-65.

Sharma,R.C., Chaudhary, N.K., Ojha, B.R., Joshi, B.K., Pandey, M.P. and Tiwary , A.K. (2005). Genetic diversity and performance of Masuli and its substitute rice cultivars. Journal of the Institute of Agriculture and Animal Science: 26:21-30.

Shih, H. D., Liu, Y. C., Hsu, F. L., Mulabagal, V., Dodda, R., and Huang, J. W. (2003). Fungichromin: a substance from *Streptomyces padanus* with inhibitory effects on *Rhizoctonia solani*. Journal of agricultural and food chemistry. 51(1): 95-99.

Shimizu, M., Nakagawa, Y., Yukio, S. A. T. O., Furumai, T., Igarashi, Y., Onaka, H., ... and Kunoh, H. (2000). Studies on endophytic actinomycetes (I) Streptomyces sp. isolated from Rhododendron and its antifungal activity. Journal of General Plant Pathology, *66*(4): 360-366.

Shimizu, M., Yazawa, S., and Ushijima, Y. (2009). A promising strain of endophytic Streptomyces sp. for biological control of cucumber anthracnose. Journal of general plant pathology, *75*(1): 27-36.

Shimono M, Sugano S, Nakayama A, Jiang CJ, Ono K, Toki S, Takatsuji H (2007) Rice WRKY45 plays a crucial role in benzothiadiazole-inducible blast resistance. Plant Cell 19: 2064–2076.

Shimono, M., Koga, H., Akagi, A.Y.A., Hayashi, N., Goto, S., Sawada, M., Kurihara, T., Matsushita, A., Sugano, S., JIANG, C.J. and Kaku, H. (2012). Rice WRKY45 plays important roles in fungal and bacterial disease resistance. Molecular Plant Pathology. 13(1): 83-94.

Shipp, M. (2005). Rice crop timeline for the southern states of Arkansas, Louisiana, and Mississippi. NSF Center for Integrated Pest Management, Raleigh, NC, USA.

Silva, G. B., Prabhu, A. S., Filippi, M. C. C., Trindade, M. G., Araujo, L. G., and Zambolim, L. (2009). Genetic and phenotypic diversity of *Magnaporthe oryzae* from leaves and panicles of rice in commercial fields in the State of Goiás, Brazil. Tropical Plant Pathology, 34(2): 071-076.

Singh, L. S., Mazumder, S., and Bora, T. C. (2009). Optimisation of process parameters for growth and bioactive metabolite produced by a salt-tolerant and alkaliphilic actinomycete, *Streptomyces tanashiensis* strain A2D. Journal de Mycologie Médicale/Journal of Medical Mycology, 19(4): 225-233.

Singh, L. S., Sharma, H., and Talukdar, N. C. (2014). Production of potent antimicrobial agent by actinomycete, *Streptomyces sannanensis* strain SU118 isolated from phoomdi in Loktak Lake of Manipur, India. BioMed Central *microbiology*. 14(1):1.

Singh, R. J. (Ed.). (2006). Genetic Resources, Chromosome Engineering, and Crop Improvement: Chemical Rubber Company (CRC) Press. Vegetable Crops (3).

Singh, R., Singh, L. S., Prasad, D., Kureel, R. S., Sengar, R., and Singh, A. (2010). Relationship of susceptibility and growth stages of plant for development of epidemic of sheath blight in rice. Journal of Applied and Natural Science, 2(2), 230-233.

Skamnioti, P., and Gurr, S. J. (2009). Against the grain: safeguarding rice from rice blast disease. Trends in Biotechnology. 27(3): 141-150.

Snyder, L. R., and Dolan, J. W. (2007). High-performance gradient elution: the practical application of the linear-solvent-strength model. Journal of the American Chemical Society,129 (27): 8669-8670.

Son, T. T. N., Diep, C. N., and Giang, T. T. M. (2006). Effect of bradyrhizobia and phosphate solubilizing bacteria application on Soybean in rotational system in the Mekong delta. Omonrice, 14: 48-57.

Spaepen, S., and Vanderleyden, J. (2011). Auxin and plant-microbe interactions. Cold Spring Harbor perspectives in biology. 3(4): 1438.

Stein, T. (2005). *Bacillus subtilis* antibiotics: structures, syntheses and specific functions. Molecular microbiology. 56(4):845-857.

Swamy, H. N., Sannaulla, S., and Kumar, M. D. (2009). Evaluation of new fungicides against rice blast in Cauvery delta. Karnataka Journal of Agricultural Sciences. 22(2): 450-451.

Szkop, M., and Bielawski, W. (2013). A simple method for simultaneous RP-HPLC determination of indolic compounds related to bacterial biosynthesis of indole-3-acetic acid. Antonie van Leeuwenhoek. 103(3): 683-691.

Talbot, N. J. (2003). On the trail of a cereal killer: exploring the biology of *Magnaporthe grisea*. Annual Reviews in Microbiology. 57(1): 177-202.

Tamura, K., Stecher, G., Peterson, D., Filipski, A., and Kumar, S. (2013). MEGA6: molecular evolutionary genetics analysis version 6.0. Molecular biology and evolution. 30(12): 2725-2729.

TeBeest, D.O., Guerber, C., and Ditmore, M. (2007). Rice blast, from http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/pages/RiceBlast.aspx

Teng, P.S., (1994).The epidemiological basis for blast management. In: Zeigler RS, Leong, S.A, Teng ,P.S, editors. Rice blast disease. Wallingford, Oxon (United Kingdom): CAB International, Los Baños (Philippines): International Rice Research Institute. 409-434.

Tewari, S. N. (2008). Strategic approach for management of rice blast through eco-friendly botanical products. CRRI Research Bulletin1, Central Rice Research Institute, Indian Council of Agricultural Research, Cuttack, India, 84.

Tirmali, A. M., and Patil, B. K. (2000). Evaluation of new fungicidal formulations for the control of blast disease of rice. Journal of Maharashtra Agricultural Universities. 25(2): 223-224.

Tirmali, A. M., Latake, S. B., and Bendre, N. J. (2001). Evaluations of new fungicides for control of blast disease of rice. Journal of Maharashtra Agricultural Universities. 26(1-3): 197-198.

Tirmali, A. M., Narute, T. K., and Bhalerao, V. K. (2011). Management of neck blast disease of rice through new fungicides. Journal of Plant Disease Sciences 6(2): 193-194.

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

Tokala, Ranjeet K., Janice L. Strap, Carina M. Jung, Don L. Crawford, Michelle Hamby Salove, Lee A. Deobald, J. Franklin Bailey, and M. J. Morra. (2002). Novel plant-microbe rhizosphere interaction involving *Streptomyces lydicus* WYEC108 and the pea plant (*Pisum sativum*). Applied and Environmental Microbiology. 68(5): 2161-2171.

Tongen, A., Goriely, A., and Tabor, M. (2006). Biomechanical model for appressorial design in *Magnaporthe grisea*. Journal of Theoretical Biology. 240(1): 1-8.

Tripathi, S. K., and Jain, A. K. (2005). Evaluation of Bio-Pesticides and Fungicides for Leaf Blast and Seed Discoluration of Rice. Plant protection bulletin-new Delhi. 57(1/2): 20.

Upadhyaya, S., Behera, J., and Tewari, S. N. (2012). Integrated management of foliar blast through ecofriendly formulated product, Oscext-e developed from Ocimum sanctum ethanolic extract. Archives of Phytopathology and Plant Protection. 45(19): 2290-2300.

USDA. (1998). Crop Profile for Rice in California, from http://www.ipmcenters.org/cropprofiles/docs/carice.pdf.

Vakil, R., Knilans, K., Andes, D., and Kwon, G. S. (2008). Combination antifungal therapy involving amphotericin B, rapamycin and 5-fluorocytosine using PEG-phospholipid micelles. Pharmaceutical research. 25(9): 2056-2064.

Valent, B., and Chumley, F. G. (1991). Molecular genetic analysis of the rice blast fungus, *Magnaporthe grisea*. Annual review of phytopathology. 29(1): 443-467.

Varma, C.K.Y. and Santhakumari, P. (2012). Management of rice blast through new fungicidal formulations. Indian Phytopathol. 65(1): 87-88.

Velho-Pereira, S., and Kamat, N. M. (2011). Antimicrobial screening of actinobacteria using a modified cross-streak method. Indian journal of pharmaceutical sciences. 73(2):223.

Vijaya, M. (2002). Field Evaluation of Fungicides against Blast Disease of Rice. Indian Journal of Plant Protection. 30(2): 205-206.

Villas-Boas S. G., Mas S., Akesson M., Smedsgaard J., Nielsen J. (2005). Mass spectrometry in metabolome analysis. Mass Spectrometry in Metabolome Analysis. 24: 613–646.

Wahyudi, A. T., and Astuti, R. I. (2010). Screening of *Pseudomonas* sp. isolated from rhizosphere of soybean plant as plant growth promoter and biocontrol agent. American Journal of Agricultural and Biological Science. 6:134.

Wan, M., Li, G., Zhang, J., Jiang, D., and Huang, H. C. (2008). Effect of volatile substances of *Streptomyces platensis* F-1 on control of plant fungal diseases. Biological Control. 46(3): 552-559.

Wang Y., Chang L., Zhao X., Meng X., Liu Y. (2012). Gas chromatography-mass spectrometry analysis on compounds in volatile oils extracted from yuan zhi (*Radix polygalae*) and shi chang pu (*Acorus tatarinowii*) by supercritical CO2. Journal of Traditional Chines Medicin. 32(3): 459–464.

Wang, G. L., and Valent, B. (Eds.). (2009). Advances in genetics, genomics and control of rice blast disease. Springer Science and Business Media.417.

Wang, J., Wang, W., Wang, L., Zhang, G., Fan, K., Tan, H., and Yang, K. (2011). A novel role of 'pseudo'γ-butyrolactone receptors in controlling γ-butyrolactone biosynthesis in *Streptomyces*. Molecular microbiology, 82(1), 236-250.

Wang, Y., Brown, H. N., Crowley, D. E., and Szaniszlo, P. J. (1993). Evidence for direct utilization of a siderophore, ferrioxamine B, in axenically grown cucumber. Plant Cell and Environment. 16(5): 579-585.

Wang, Z.X., Yano, M., Yamanouchi, U., Iwamoto, M., Monna, L., Hayasaka, H., Katayose, Y. and Sasaki, T. (1999). The Pib gene for rice blast resistance belongs to the nucleotide binding and leucine rich repeat class of plant disease resistance genes. The Plant Journal. 19(1): 55-64.

Wei, G., Kloepper, J. W., and Tuzun, S. (1991). Induction of systemic resistance of cucumber to Colletotrichum orbiculare by select strains of plant growth-promoting rhizobacteria. Phytopathology. 81(11):1508-1512.

Wu Q, Hou MM, Li LY, Liu LJ, Hou YX, Liu GZ (2011) Induction of pathogenesis-related proteins in rice bacterial blight resistant gene Xa21-mediated interactions with *Xanthomonas oryzae* pv. oryzae. Journal of Plant Pathology. 39(2):455–459.

Wu, J. Y., Huang, J. W., Shih, H. D., Lin, W. C., and Liu, Y. C. (2008). Optimization of cultivation conditions for fungichromin production from Streptomyces padanus PMS-702. Journal of the Chinese Institute of Chemical Engineers. 39(1):67-73.

Xiong, Z. Q., Zhang, Z. P., Li, J. H., Wei, S. J., and Tu, G. Q. (2012). Characterization of *Streptomyces padanus* JAU4234, a producer of actinomycin X2, fungichromin, and a new polyene macrolide antibiotic. Applied and environmental microbiology. 78(2): 589-592.

Yao, M., Tweddell, R., and Desilets, H. (2002). Effect of two vesicular-arbuscular mycorrhizal fungi on the growth of micropropagated potato plantlets and on the extent of disease caused by *Rhizoctonia solani*. Mycorrhiza. 12(5): 235-242.

Yu, X., Liu, X., Zhu, T. H., Liu, G. H., and Mao, C. (2011). Isolation and characterization of phosphate-solubilizing bacteria from walnut and their effect on growth and phosphorus mobilization. Biology and Fertility of Soils. 47(4):437-446.

Zaidi, A., Khan, M., Ahemad, M., and Oves, M. (2009). Plant growth promotion by phosphate solubilizing bacteria. Acta microbiologica et immunologica Hungarica. 56(3): 263-284.

Zarandi, M. E., Bonjar, G. S., Dehkaei, F. P., Moosavi, S. A., Farokhi, P. R., & Aghighi, S. (2009). Biological control of rice blast (*Magnaporthe oryzae*) by use of *Streptomyces sindeneusis* isolate 263 in greenhouse. American Journal of Applied Sciences. 6(1): 194-199.

Zhang, T.W., Wei, Z., Qi, O.Z., Wen, L.C., Jun, Z.J., Kun, W.Z. and Li., W. (2007). Analyses of temporal development and yield losses due to sheath blight of rice (*Rhizoctonia solani* AG-11A). Agricultural Sciences in China. 6(9): 1074-1081.

Zhang, X., Li, C., and Nan, Z. (2012). Effects of cadmium stress on seed germination and seedling growth of Elymus dahuricus infected with the *Neotyphodium endophyte*. Science China Life Sciences. 55(9):793-799.

BIODATA OF STUDENT

Hayman Kaka khan Awla was born in Erbil, Iraq. He received his BCs (Bachelor of Science) from Faculty of Agriculture, plant protection department, at Salahaddin University, Erbil, Iraq in July 2003. After obtaining MSc (Master of Science) at the same college in February 2008 in Plant Pathology, He cooperated as an invitee lecture in agriculture group, Salahaddin University and institute of Agriculture Khabat for a period of 4 years. He has been a full time PhD student since September 2013 in Universiti Putra Malaysia (UPM).

Throughout his studying life, he has published journal articles, research projects, and seminar proceeding and workshops.

LIST OF PUBLICATIONS

Awla, H. K., Kadir, J., Othman, R., Rashid, T. S., and Wong, M. Y. (2016). Bioactive Compounds Produced by Streptomyces sp. Isolate UPMRS4 and Antifungal Activity against Pyricularia oryzae. American Journal of Plant Sciences, 7(07), 1077.

Awla, H. K., Kadir, J., Othman, R., Rashid, T. S., and Wong, M. Y. (2016).Characterization of *streptomyces* sp. and their antagonistic activities against *pyricularia oryzae* causing rice blast in Malaysia. Submited to the Journal of Anomal and Plant Sciences (JAPS).

Hayman kakakhan Awla, Jugah Kadir, Radziah Othman and, Wong Mui Yun· Characterization of *Streptomyces* sp. and its antagonistic activity against *Pyricularia oryzae* causing rice blast. Poster presented in the 2nd International Conference on Crop Improvement (ICCI 2015). Engineering Auditorium, Faculty of Engineering, Universiti Putra Malaysia, 2-3 December 2015.