UNIVERSITI PUTRA MALAYSIA

CHARACTERIZATION OF STREPTOMYCES AMBOFACIENS S2 AND ELUCIDATION OF ITS ANTI-FUNGAL COMPOUNDS FOR BIOCONTROL OF CHILLI ANTHRACNOSE

JEFFREY LIM SENG HENG

FBSB 2014 19

CHARACTERIZATION OF *STREPTOMYCES AMBOFACIENS* S2 AND ELUCIDATION OF ITS ANTI-FUNGAL COMPOUNDS FOR BIOCONTROL OF CHILLI ANTHRACNOSE

By

JEFFREY LIM SENG HENG

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

November 2013

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

CHARACTERIZATION OF *STREPTOMYCES AMBOFACIENS* S2 AND ELUCIDATION OF ITS ANTI-FUNGAL COMPOUNDS FOR BIOCONTROL OF CHILLI ANTHRACNOSE

By

JEFFREY LIM SENG HENG

November 2013

Chairman: **Associate Professor Umi Kalsom Md. Shah, PhD**
Faculty: **Biotechnology and Biomolecular Sciences**

Red chilli is one of the most important diets for Malaysian. However chili plants are susceptible to attacks by few diseases such as anthracnose and Chili Mozaic Virus (CMV). Anthracnose is being considered as the major disease due to the ability of the fungi to attack both pre and post harvest chili fruits. With the high impact of anthracnose on chilli fruits the use of chemical pesticides has been frequent and uncontrolled. The high usage of chemical pesticides has caused damage not only to the environment but also human health. Biological control has been suggested as an alternative to counter the effect of chemical pesticides. Actinomycetes especially those from the genus of streptomycetes have been well known as a potential biological control agent for most of the plant pathogens. This study was conducted with the aim to investigate the characteristics of *Streptomyces ambofacines* S2 and to isolate antifungal compounds produced towards anthracnose for use as a biopesticide.

Colletotrichum capsici and *Colletotrichum gleosporioides* were isolated form infected chilli fruits using surface sterilization method. The fungi were later identified by targeting its internal transcribed spacer region (ITS). Molecular method confirmed that both *C. capsici* and *C. gleosporioides* were isolated.

A total of 513 isolates of actinomycetes were isolated from 5 different soil samples from both Peninsular Malaysia and Sabah and Sarawak using soil dilution method. The antifungal activity was detected using disc diffusion method. Through disc diffusion testing, 6 potential isolates of *Streptomyces* spp. were chosen for further studies (morphology study, molecular identification and carbon sources utilization analysis). However, only *Streptomyces ambofaciens* S2 was chosen for cultural condition optimization and bioactive compound isolation due to the highest inhibition zone exhibited towards *C. capsici* (15 mm) and *C. gleosporioides* (16 mm).

Metabolomic study conducted showed that *Streptomyces* spp. with antifungal producing abilities tend to produce more valine, isoleucine, leucine, asparagines, succinic acid and fructose, while non antifungal producing Streptomyces spp. produces more fatty acid, lactic acid, β glucose and gallic acid. Differences in the metabolite constituents have enable the used of metabolomic to characterize antifungal producing *Streptomyces* spp. from non antifungal producing *Streptomyces* spp.

The impact of media composition and cultural conditions were conducted for *S. ambofaciens* S2 using shake flask fermentation. It was observed that *S. ambofaciens* S2 produced the highest antifungal compound when chitin and peptone were used as the carbon and nitrogen sources respectively, 0.2% NaCl, 3 days incubation time, 6 days seed age and initial pH 8 for the broth. An increased of 33% in the inhibition zone was noted when *S. ambofaciens* S2 was grown using this condition. Chitinase activity was observed to be the highest when the culture was incubated for 7 days with the activity of 0.192 U/ml. Specific activity at day 7 was recorded as 1.28 U/mg. Formulation of an oil based liquid biopesticide using 20% glycerol added to the Chitin Peptone Media showed that *S. ambofaciens* S2 extract was able to give an effectiveness of 80% when tested *in vivo* for controlling chilli anthracnose.

Isolation of the bioactive compounds, indicated that the active compounds were eluted when 1:1 (hexane : ethyl acetate) was used. This active fraction was then subjected to purification using high pressure liquid chromatography (HPLC). The compound was white in colour when it was dried. Under liquid chromatography mass spectrocopy (LCMS) analysis, the compound was observed with the mass of 777.11 m/z. The compound was categorized under the group of polyenes.

Results from this study demonstrated *Streptomyces ambofaciens* S2 could be used as an alternative pesticide for controlling anthracnose in chilli fruits. In addition, metabolomic method could be used as a new way of fast characterization of different species of streptomycetes.

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

PENCIRIAN STREPTOMYCES AMBOFACINES S2 DAN PENERANGAN KOMPOUN ANTIKULAT UNTUK KAWALAN BIOLOGI TERHADAP ANTRAKNOS CILI

Oleh

JEFFREY LIM SENG HENG

November 2013

Pengerusi: **Profesor Madya Umi Kalsom Md. Shah, PhD**
Fakulti: **Bioteknologi dan Sains Biomolekul**

Cili merah merupakan satu diet makanan yang penting untuk warga Malaysia. Walaubagaimanapun, pokok cili adalah tidak rintang terhadap serangan penyakit seperti antraknos dan penyakit mozek virus (CMV). Serangan antraknos adalah dianggap sebagai salah satu penyakit yang serius kerana kulat itu dapat menyerang buah cili sebelum dan selepas tuai. Di sebabkan oleh impak tinggi antraknos terhadap buah cili, penggunaan pestisida telah menjadi kerap dan tidak terkawal. Penggunaan pestisida kimia yang tinggi telah menyebabkan kerosakkan pada alam sekitar dan juga kesihatan manusia. Kawalan biologi telah di sarankan sebagai satu langkah alternatif untuk memerangi kesan pestisida kimia. Bakteria yang dikenali sebagai aktinomiset terutamanya genus *Streptomiset* adalah dikenalpasti sebagai agen kawalan biologi semulajadi untuk kebanyakan penyakit tumbuhan. Kajian ini telah dijalankan bagi pencirian *Streptomiset ambofaciens* S2 dan penyaringan kompaun antikulat terhadap antraknos bagi penggunaan sebagai biopestisida.

Colletotrichum capsici dan *Colletotrichum gleosporioides* telah di pencilkan daripada buah cili yang dijangkiti penyakit antraknos menggunakan kaedah pensterilan permukaan. Kulat yang diperolehi kemudianya dikenalpasti dengan mensasarkan kawasan "internal transcribed spacer". Kaedah molecular mengesahkan bahawa kedua-dua *C. capsici* dan *C. gleosporioides* telah dipencilkan.

Sejumlah 513 isolat aktinomiset telah diperolehi daripada 5 sampel tanah yang diambil daripada Semenanjung Malaysia dan juga Sabah dan Sarawak dengan menggunakan teknik pencairan tanah bersiri. Aktiviti antikulat dikesan melalui penggunaan teknik "disc diffusion". Melalui teknik ini, 6 isolat *Streptomiset* spp. berpotensi telah dipilih untuk kajian lebih mendalam (moforlogi, pengenalpastian secara molekular dan analisis penggunaan bahan karbon). Bagaimanapun hanya *Streptomyces ambofaciens* S2 yang dipilih untuk dikaji pengoptimuman kondisi kultur dan pemencilan kompoun bioaktif kerana penghasilan zon perencat yang paling besar terhadap *C. capsici* (15 mm) dan *C. gleosporioides* (16 mm).

Kajian metabolomik yang dijalankan terhadap *Streptomiset* spp. yang menghasilkan antikulat menunjukkan lebih banyak valina, iso leusina, leusina, asparagina, asid suksinik and fruktos dihasilkan manakala *Streptomiset* spp. yang tidak menghasilkan antikulat menunjukkan penghasilan asid lemak, asid laktik, β-glukos dan asid galik yang lebih banyak. Perbezaan metabolit ini telah membolehkan keupayaan streptomiset untuk menghasilkan aktiviti antikulat terhadap antraknos.

Impak komposisi media dan kondisi kultur telah dijalankan bagi *S. ambofaciens* S2 dengan menjalankan fermentasi menggunakan kelalang kon. Daripada kajian ini, didapati bahawa *S. ambofaciens* S2 menghasilkan aktiviti antikulat pada tahap tertinggi apabila kitin dan pepton digunakan sebagai bahan karbon dan nitrogen, 0.2% NaCl, tempoh pengeraman selama 3 hari, umur sel 6 hari dan pH awalan 8. Penggunaan kondisi ini membolehkan peningkatan zon perencat sebanyak 33%. Aktiviti kitin didapati berada pada tahap tertinggi pada hari ke-7 pengeraman dengan aktivitinya dicatatkan pada 0.192 U/ml. Aktiviti khusus enzim yang diperolehi pada hari ke-7 adalah 1.28 U/mg. Formulasi minyak biopestisid cecair yang dihasilkan daripada ekstrak *S. ambofaciens* S2 dengan campuran 20% gliserol kepada "Chitin Peptone Media" menunjukkan keberkesanan sebanyak 80.0% pada cili yang diuji terhadap antraknos.

Penyaringan bahan bioaktif menunjukkan kompoun aktif diperolehi dengan penggunaan 1:1 (hexane : etil acetat). Kompoun aktif ini seterusnya dibersihkan dengan menggunakan kromatografi cecair prestasi tinggi (HPLC). Penggunaan kromatografi cecair spektrometri jisim (LCMS), memberikan jisim kompoun pada 777.11 m/z. Kompoun bioaktif ini di kelaskan pada kelas "polyenes".

Keputusan daripada kajian ini menunjukkan *Streptomyces ambofaciens* S2 boleh digunakan sebagai pestisid alternatif untuk antraknos buah cili. Tambahna daripada ini, kajian metabolomik boleh digunakan sebagai satu cara baru untuk pencirian spesis streptomiset yang berlainan.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my sincere gratitude to Associate Professor Dr. Umi Kalsom Md Shah for her willingness to allow me to pursuit my PhD's project under her supervision. I would also like to thank her all of her support, patience, invaluable advice and guidance throughout the duration of my study.

My deepest thanks to my committee members Prof. Dr. Khozirah Shaari and Dr. Nor' Ain Abd. Rahman for their constructive ideas. My special thanks to Prof Dr. Khozirah for allowing me to work in Natural Product Laboratories, Institute of Biology Sciences. I would also like to thank Malaysia Agricultural of Research and Development Institute (MARDI) for granting me the scholarship for my PhD study.

My thanks to all my friends and laboratory officers Mr. Salahuddin, Mr. Azizul and Mrs. Zurina of Natural Product Laboratory for their helps and co-operations throughout my work at the laboratory. My sincere thanks to my colleague Mrs. Halizah Hamzah from MARDI for helping me preparing and maintaining the cultures throughout the whole project. My thank also to members of Microbiology Laboratory, Management and Utilisation of Biological Resources, Strategic Resource Research Centre, MARDI for all the help given during my PhD tenure.

Finally, I would like express my heartfelt thanks to my family members for their love, understanding, patients and support during my study.

I certify that a Thesis Examination Committee has met on 27th November 2014 to conduct the final examination of Jeffrey Lim Seng Heng on his thesis entitled "**CHARACTERIZATION OF *STREPTOMYCES AMBOFACIENS* S2 AND ELUCIDATION OF ITS ANTIFUNGAL COMPOUNDS FOR BIOCONTROL OF CHILLI ANTHRACNOSE**" 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 Doctor of Philosophy.

Members of the Examination Committee were as follows:

Noorjahan Banu bt Mohamed Alitheen, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Chairman)

Sariah Meon, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Arbakariya b Ariff, PhD
Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Internal Examiner)

Saisamorn Lumyong, PhD
Faculty of Science
Chiang Mai University
Thailand
(External Examiner)

_____

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

Date: 21 January 2014

This thesis submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Phylosophy. The member of the Supervisory Committee were as follow:

Umi Kalsom Md. Shah, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
University Putra Malaysia
(Chairman)

Khozirah Shaari, PhD
Professor
Faculty of Science
University Putra Malaysia
(Member)

Nor `Ain Abdul Rahman, PhD
Senior Lecturer
Faculty of Biotechnology and Biomolecular Sciences
University Putra Malaysia
(Member)

_____
BUJANG BIN KIM HUAT , PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rue 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Univesiti Putra Malaysia (Research)2012.

Signature:_____ Date: 27th November 2013

Name and Matric No.: Jeffrey Lim Seng Heng (GS25716)

Declaration by Members of Supervisory Committee

This is to confirm that:

- The research conducted and the writing of this thesis was under our supervision;
- Supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____

Name of
Chairman
of Supervisory
Committee: Associate Professor
Dr.Umi Kalsom Md. Shah

Signature: _____

Name of
Member of
of Supervisory
Committee: Professor Dr. Khozirah
Shaari

Signature: _____

Name of
Member
of Supervisory
Committee: Dr. Nor' Ain Abdul Rahman

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

α	Alpha
β	Beta
μl	microlitter
C	Carbon
Ca	Calsium
$Ca(NO_3)_2$. $4H_2O$	Calsium Nitrate-4 hydrate
$CaCO_3$	Calsium Carbonate
cfu	Colony Forming Unit
cm	Centimeter
D	Dextro
dH_2O	Distilled water
DNA	Deoxyribonucleic Acid
$FeSO_4$. $7H_2O$	Ferrous Sulphate-7 hydrate
FTIR	Fourier Transformed Infrared
g	Gram
G + C	Guanine + Cytosine
H	Hydrogen
h	Hour
HCl	Hydrochloric Acid
HPLC	High Performance Liquid Chromatography
KCl	Kalium Chloride
KH_2PO_4	Kalium dihydrogen phosphate
KNO_3	Kalium Nitrate
L	Levo
L	Litter
LCMS	Liquid Chromatography Mass Spectroscopy
M	Molarity
mg	Milligram
ml	Mililiter
mm	milimeter
$MgSO_4$. $7H_2O$	Magnesium Sulphate-7 hydrate
min	Minute
m/z	Mass to charge ratio
Na_2HPO_4	*di*-natrium hydrogen phosphate
Na_2HPO_4. $12H_2O$	*di*-natrium hydrogen phosphate-12 hydrate
NaCl	Natrium Chloride
$(NH_4)_2$	*di*-ammonium
NMR	Nuclear Magnetic Resonance
OPLS	Orthogonal Partial Least Square
PCA	Principle Component Analysis
PCR	Polymerase Chain Reaction
pH	Potential of hydrogen

ppm	Part per million
sec	Second
SEM	Scanning Electron Microscope
spp.	Species
w/v	Weight per volume
v/v	Volume per volume
%	Percentage
^{o}C	Degree Celsius

CHAPTER 1

INTRODUCTION

Red chilli or scientifically known as *Capsicum annumm* has been a part of Malaysian daily meal diet. The use of red chilli fruits include for the making of sambal (a kind of spicy chilli sauce make from dried red chilli and onion) and curry rendang (a Malay delicacy prepared from curry and chicken or beef). According to FAO report, 2012, area cultivated with chilli in Malaysia in the year 2000 was estimated to be around 2,200 ha with estimated yield of 113,636.36 Hg/Ha (FAOSTAT, 2012). This number increased to 2,594 ha in the year 2010 with the total estimated yield of 134,244.41 Hg/Ha (FAOSTAT, 2012). This has showed an increased of approximately 15 % of the total cultivated area and hence indicating the importance of the crop.

Like any other plants, chilli has two most prevalence diseases namely the chilli mosaic virus (CMV) and anthracnose (Than *et. al*., 2008a; Isaac, 1992). Both diseases have been reported to cause yield loss and reduce in the marketablity of the chilli fruits (Iqbal *et al*., 2012; Suwan *et al*., 2012). Anthracnose is considered to be more severe due to the fact that anthracnose could infect the chilli fruits both pre and post harvest. According to Than *et al*. (2008a), anthracnose disease can infect the whole chilli plant itself. Typical symptoms of anthracnose were leaf tip die-back, stem die-back, foliar blight, leaf spot, leaf lesion and for fruit there would be sunken necrotic tissues, with concentric rings of acervuli that are often wet. Chemical methods used to prevent the occurrence of anthracnose disease might cause health hazard to the consumers. Due to that biological control methods would be considered the best practice (Pal and Gardener, 2006).

Actinomycetes are Gram-positive bacteria which have been long known for its special morphological criteria (Abou-Elela and Ghanem, 2005). Actinomycetes are the only bacteria with the capacity to form branches of ramifying network of filaments which is also known as mycelium. Apart from the mycelium, actinomycetes also produce abundant asexual spores known as conidia. These conidia gave the actinomycetes colonies their ‘powdery” look on the agar media plate. Due to this special characteristic actinomycetes are also called pseudo-bacteria. The name actinomycetes come from two Latin words, actinis which means ‘ray’ and myces which means fungus (Hopwood, 2007).

Actinomycetes are classified as bacteria due to several factors such as the present of peptidoglycan in their cell wall, their sensitivity towards lysozyme that will degrade the polysaccharide backbone of the peptidoglycan and their sensitivity towards antibacterial but not antifungal antibiotics. Actinomycetes can be differentiated into different genera based on their morphological, physical and chemical criteria (George *et al*., 2010).

Malaysia which had been known as one of the world mega diversity country has the potential of obtaining novel microorganisms with new bioactive compounds (Jeffrey, 2008). Actinomycetes had been known to be most abundant in soil compared to water and air (Kumar *et al*., 2010; Jeffrey, 2008; Thangapandian *et al*., 2007). The ability of microorganisms to produce bioactive compounds have been related to their environmental stresses. These stresses caused the microorganisms to produce enzymes that could help them to combat the stresses. There are 2 kinds of enzymes system produced by the microorganism; intracellular and extracellular. Extracellular enzymes or exoenzymes are more easily isolated as no rapture of bacterial cells were needed. This has helped the manufacturers to reduce their production cost due to easy recovery of enzymes from the bacterial cells (Asad *et al*., 2011).

Isolation of bioactive compounds from actinomycetes had been well documented by researchers worldwide (Kumar *et al*., 2010; Ramesh and Mathivanan, 2009; Jeffrey, 2008; Thangapandian *et al*., 2007). The most distinguished genera of actinomycetes that had been widely isolated for their secondary metabolites activities are Streptomycetes. *Streptomyces* spp. are easily found in soil and they contributed to the soil microbial communities in many way such as degradation of polysaccharides present in the soil for easily uptake of nutrients by plants and other microorganisms and secretion of bioactive compounds to inhibit the growth of certain microorganisms. The first isolated antibiotic from actinomycetes was streptomycin an antibiotic isolated from *Streptomyces griseus* (Waksman *et al*., 1946). Streptomycetes had been well known to secrete majority antifungal compounds from the group of polyene and macrolides.

The ability of microorganisms to produce their metabolites would depend on their ability to modulate their metabolic composition according to their environment. By understanding the metabolites produced, researchers are able to study the unique cellular process of certain microorganisms which may be influence by physiological and also environmental signals (Jensen *et al*., 2006). Fingerprinting these chemical constituents that present in the microorganism may helps to further understand the microorganism antibiotic pathway.

With the increasing demand for chilli and the effect of chemical pesticides towards human health, this research was done to identify a biocontrol agent that could be used as an alternative for the current practices for chilli planters. In the current practice, chemical pesticides have been used heavily to control pest and disease in chilli, this has caused contamination to the environment (Sharma and Parihar, 2010). The use of chemical pesticides do not just caused contamination but also creating a more resistance and mutated microorganisms that needs higher dosage of the chemical substances. The use of natural occurring enemies or biological control could help to minimize the impact of the chemical pesticides in agriculture (Pal and Gardener, 2006). Utilization of antagonistic microorganisms has been found in postharvest of various fruits and vegetables (Fravel, 2005). The used of biological control agents in post harvest have been reported to be very efficacious for controlling anthracnose on chilli (Chanchaichaovivat *et al*., 2007). The

main objective of this study was to reduce the used of the chemical pesticides by obtaining a biological based pesticide for controlling anthracnose in chilli.

In this study, we isolated streptomycetes from the soil samples collected and then proceed with study on the impact of cultural condition on the potential strepyomycetes. The antifungal compound obtained from the potential actinomycetes were then isolated and characterized. Metabolomic study was performed to determine the metabolites responsible for antifungal production (Appendix 1.1). It is hyphothesized that secondary metabolite produce by selected streptomycetes were an extracellular compound and this compound inhibited the growth of *Colletotrichum gloeosporioides* through the mode of antibiosis.

The specific objectives of this study were:-

1) To isolate, screen and characterize streptomyces with the ability to produce antifungal activity.
2) To characterize metabolites presents for both antifungal and non antifungal producing *Streptomyces* spp. using metabolomic study.
3) To investigate the impact of medium composition (carbon, nitrogen, NaCl) and cultivation conditions (pH, seed age, agitation, temperature) on the production of antifungal activity by *Streptomyces ambofaciens* S2.
4) To characterize the antifungal compounds produced by *Streptomyces ambofaciens* S2.

REFERENCES

Abou-Elela, G. M. and Ghanem, N. B. (2005). Phenotypic characterization and numerical taxonomy of some actinomycetes strains isolated from Burullos Lake. *Egyptian Journal of Aquatic Research*. 31(2): 125-144.

Abdul Wahid, O. A. (2001). Occurance of *Colletotrichum* anthracnose disease of guava fruit in Egypt. *International Journal of Pest Management*. 47: 147-152.

Agnolet, S., Jaroszewski, J. W., Verpoorte, R. and Staerk, D. (2010). 1H NMR based metabolomics combined with HPLC-PDA-MS-SPE-NMR for investigation of standardized *Ginkgo biloba* preparations. *Metabolomics*. 6: 292-302.

Agrios, G. N. (2005). *Plant Pathology*, 5th edition. San Diego, Academic Press.

Ahmed, A. A. (2007). Production of antimicrobial agent by *Streptomyces violachromogenes. Saudi Journal of Biological Sciences*. 14(1):7-16.

Akinbode, O. A. and Ikotun, T. (2011). Potentials of two *Trichoderma* species as antagonistic agents against *Colletotrichum destructivum* of cowpea. *African Journal of Microbiology Research*. 5(5): 551-554.

Albareda, M., Rodri-guez-Navarro, D. N., Camacho, M. and Temprano, F. J. (2008). Alternative to peat as a carrier for *Rhizobia* inoculants: Solid and liquid formulation. *Soil Biology and Biochemistry*. 40: 2771-2779.

Alexander, S. A and Waldenmaier, C. M. (2002). Management of anthracnose in bell pepper. Fungicide and nematicide test. New Fungicide and nematicide data committee of the American Phytopathogical Society. Retrieved from http://apsjournals.apsnet.org/doi/abs/10.1094/PDIS.2004.88.11.1198

Al-Askar, A. A., Abdul Hair, W. M. and Rashad, Y. M. (2011). *In vitro* antifungal activity of *Streptomyces spororaveus* RDS28 against some pathogenic fungi. *African Journal of Agricultural Research*. 6(2): 2835-2842.

Alharbi, S. A., Chinnathambi, A., Murugan, A. M. and Wainwright, M. (2012). Antibacterial activity of actinomycetes isolated from terrestrial soil of Saudi Arabia. *Journal of Food, Agriculture & Environmental*. 10(2): 1093-1097.

Altieri, C., Bevilacqua, A., Cardillo, D. and Sinigaglia, M. (2008). Antifungal activity of fatty acids and their monoglcerides against *Fusarium* spp. in a laboratory medium. *International Journal of Food and Science Technology*. 44: 242-245.

Altschul, S. F., Jenkins, A., Kristiansen, B. E and FrØholm, C. O. (1990). Basic local alignment search tool. *Journal of Molecular Biology*. 215: 403-410.

Amano, S., Miyadoh, S. and Shomura, T. (2012). *Streptomyces griseus* M-1027. *Digital Atlas of Actinomycetes*. Retrieved from http://www.nih.go.jp/saj/DigitalAtlas/subwin.cgi? Section=7&fig=1

Anastasiadi, M., Zira, A., Magiatis, P., Haroutounian, S. A., Skaltsounis, A. L and Mikros, E. (2009).1H NMR-Based Metabonomics for the Classification of Greek Wines According to Variety, Region, and Vintage. Comparison with HPLC Data. *Journal of Agriculture and Food Chemistry*. 57(23): 11067-11074.

Anitha, A. And Rabeeth, M. (2010). Degradation of fungal cell walls of phytopathogenic fungi by lytic enzyme of *Steptomyces griseus*. *African Journal of Plant Science*. 4(3): 061-066.

Anitha, A. and Rebeeth, M. (2009). *In vitro* antifungal activity of *Streptomyces griseus* against phytopathogenic fungi of tomato field. *Academic Journal of Plant Science*. 2(2): 119-123.

Arasu, M. V., Asha, K. R. T., Duraipandiyan, V., Ignacimuthu, I. and Agastian, P. (2012). Characterization and phylogenetic analysis of novel polyene type antimicrobial metabolite producing actinomycetes from marine sediments: Bay of Bengal India. *Asian Pacific Journal of Tropical Biomedicine*. 2(10): 803-810.

Arasu, M. V., Duraipandiyan, V., Agastian, P and Ignacimuthu, S. (2009). *In vitro* antimicrobial activity of *Streptomyces* spp. ERI-3 isolated from Western Ghats rock soil (India). *Journal of Medical Mycology*. 19(1): 22-28.

Arifuzzaman, M., Khatun, M. R. and Rahman, H. (2010). Isolation and screening of actinomycetes from Sundarbans soil for antibacterial activity. *African Journal of Biotechnology*. 9(29): 4615-4619.

Arroyo, M., Torres-Guzmán, R., de la Mata, I., Castillón, M. P and Acebal, C. (2000). Activation and stabilization of Penicillin V acylase from *Streptomyces avendulae* in the presence of glycerol and glycols. *Biotechnology Progress*. 16(3): 368-371.

Asad, W., Asif, M. and Rasool, S. A. (2011). Extracellualr enzyme production by indigenous thermophilic bacteria: partial purification and characterization of α-amylase by Bacillus sp. WA21. *Pakistan Journal of Botany*. 43(2): 1045-1052.

Atta, H. M., (2009). An antifungal agent produced by *Streptomyces olivacescleroticus*, AZ-SH514. *World Applied Sciences*. 6(11): 1495-1505.

Atta, H. M., Bahobail, A. S. and El-Sehrawi, M. H. (2011). Studies on isolation, classification and phylogenetic characterization of antifungal substance produced by *Streptomyces albidoflavous*-143. *New York Science Journal*. 4(3): 40-53.

Azizan, K. A., Baharum, S. N., Ressom, H. W. and Noor, N. M. (2012). GC-MS analysis and PLS-DA validation of the trimethyl silyl-derivatization techniques. *America Journal of Applied Science*. 9(7): 1124-1136.

Baharlouei, A., Sharifi-Sirchi, G. R. and Shahidi Bonjar, G. H. (2010). Identification of an antifungal chitinase from a potential biocontrol agent, *Streptomyces plicatus* strain 101, and its new antagonistic spectrum of activity, *The Philippine Agricultural Scientist.* 93(4): 439-445.

Bailey, J. A. (1987). Phytoalexins: A genetic view of their significance. *In: P. R.* Day and G. J. Jellis. *Genetics and Plant Pathogenesis* (pp. 13-26). Oxford: Blackwell Publishers.

Bailey, J. A. and Jeger, M. J. (1992). *Colletotrichum: Biology, pathology and control*. (pp. 388). Wallingford: Commonwealth Mycological Institute.

Bajad, S. and Shulaev, V. (2011). LC-MS-Based Metabolomics. In T. O. Metz. *Metabolic Profiling, Methods and Protocols* (pp. 213-228). Springer Science and Business Media.

Baniasadi, F., Shahidi Bonjar, G. H., Baghizadeh, A., Karimi Nik, A., Jorjandi, M., Aghighi, S. and Rashid Farokhi, P. (2009). Biologial control of *Sclerotinia sclerotiorum*, causal agent of sunflower head and stem rot disease, by use of soil borne actinomycetes isolates. *American Journal of Agricultural and Biological Sciences*, 4: 146-151.

Barry, S. M. and Challis, G. L. (2009). Recent advances in siderophore biosynthesis. C*urrent opinion in Chemical Biology*. 13(2): 205-215.

Basavaraj, N. K, Chandrashekhara, S., Shamarez, A. M., Goudanavar, P. S. and Manvi, F. V. (2010). Isolation and morphological characterization of antibiotic producing actinomycetes. *Tropical Journal of Pharmaceutical Research*. 9(3): 231-236.

Baudoin, E., Benizri, E. and Guckert, A. (2001). Metabolic fingerprint of microbial communities from distinct maize rhizosphere compartments. *European Journal of Soil Biology*. 37(2): 85-93.

Bazilah, A. B. I., Sariah, M., Zainal Abidin, M. A. and Yasmeen, S. (2011). Effect of carrier and temperature on theviability of *Burkhoderia* sp. (UPMB3) and *Pseudomonas* sp. (UPMP3) during storage. *International Journal of Agriculture and Biology*. 13: 198-202.

Benko, R. and Highley, T. L. (1990). Biological control of wood attacking fungi using bacteria. In G. C. Llewellyn and C. E. O'Rear. *Biodeterioration Research 3*. (pp. 327-332). New York: Plenem Press.

Bèrdy, J. (2005). Bioactive microbial metabolites. *Journal of Antibiotics*, 58: 1-26.

Bibb, M. J. (2005). Regulation of secondary metabolism from streptomycetes. *Current Opinion in Microbiology*, 8: 208-215.

BIOLOG Inc. (2010). Gen III: Instruction of use. Retrieved from http://www.biolog.com.

Boonratkwang, C., Chamswarng, C., Intanoo, W. and Juntharasri, V. (2007). Effect of secondary metabolites from *Trichoderma harzianum* strain PM9 on growth inhibition of *Colletotrichum gloeosporioides* and chilli anthracnose control. *Proceeding of the 8th National Plant Protection Conference*. (pp. 323-336). Naresuan University, Phisanulok, Thailand.

Bosland, P. W. and Votava, E. J. (2003). *Pepper: Vegetable and Spice Capsicums*. CAB International, England.

Britton, G. and Hornero-Méndez, D. (1997). Carotenoids and Colour in Fruits and Vegetablee. In F. A. Tomás-Barberán and R. J. Robins. *Phytochemistry of fruits and Vegetables* (pp. 11-28). Oxford, England: Clarendon Press.

Bruheim, P., Borgos, S. E. F., Tsan, P., Sletta, H., Ellingsen, T. E., Lancelin, J. M. and Zotchev, S. B. (2004). Chemical Diversity of Polyene Macrolides Produced by *Streptomyces noursei* ATCC 11455 and Recombinant Strain ERD44 with Genetically Altered Polyketide Synthase NysC. *Antimicrobial Agents and Chemotherapy*. 48(11): 4120-4129.

Bundy, J.G., Willey, T.L., Castell, R.S. Ellar, D.J. and Brindle, K.M. (2005). Discrimination of pathogenic clinical isolates and laboratory strains of *Bacillus ereus* by NMR-based metabolomic profiling, *FEMS Microbiology Letter*. 242: 127–136.

Bunterngsook, B., Kanokratana, P., Thongaram, T., Tanapongpipat, S., Uengwetwanit, T., Rachdawong, S., Vichitsoonthonkul., T. and Eurwilaichitr, L. (2010). Identification and characterization of lipolytic enzymes from a peat swampforest soil metagenome. *Biosciences, Biotechnology and Biochemistry*. 74(9):1848-1854.

Cannon, P. F., Bridge, P. D. and Monte, E. (2000). Linking the past, present and future of *Colletotrichum* systematic. In D. Prusky, S. Freeman and M. Dickman. *Colletotrichum: Host specificity, pathology and host-pathogen interaction* (pp. 1-20). St. Paul, Minnesota: APS Pres.

Cano, J., Guarro, J. and Gene, J. (2004). Molecular and morphological identification of *Colletotrichum* species of clinical interest. *Journal of Clinical Microbiology* 42: 2450-2454.

Challis, G. L. and Hopwood, D. A. (2003). Synergy and contingency as driving forces for the evolution of multiple secondary metabolite production by *Streptomyces* species. *Proceedings of the National Academy of Sciences*. 100(2): 14555-14561.

Chandra Nayaka, S., Udaya Shankar, A. C., Niranjana, S. R., Prakash, H. S. and Mortensen, C. N. (2009). *Anthracnose disease of chilli pepper. Technical Bulletin* (pp. 1-12). Asian Seed Health Centre: University of Mysore, India.

Chang, T. S., Tseng, M., Ding, H. Y. and Shou-Ku Tai, S. (2008). Isolation and characterization of *Streptomyces hiroshimensis* strain TI-C3 with anti-tyrosinase activity. *Journal of Cosmetic Science*. 59(1): 33-40.

Champness, W. (2000). Actinomycete development, antibiotic production, and phylogeny: questions and challenges, In *Prokaryotic Development* Y. V. Brun and L. J. Shimkets. (pp. 11-31). Washington, DC: ASM Press.

Chanchaichaovivat, A., Ruenwongsa, P. and Panijpan, B. (2007). Screening and identification of yeast strains from fruits and vegetables: Potential for biological control of postharvest chilli anthracnose (*Colletotrichum capsici*). *Biological control*. 42: 326-335.

Chellapandi, P., Sivaramakrishnan, S. and Viswanathan, M. B. (2010). System Biotechnology: an emerging trend in metabolic engineering of industrial microorganisms. *Journal of Computer Science & Systems Biology*. 3(2): 043-049.

Chellapandi, P. and Jani, H. M. (2008). Production of endoglucanase by the native strains of Streptomyces isolates in submerged fermentation. *Brazilian Journal of Microbiology*. 39(1):122-127.

Cheol Nam, P., Lee, J. M., Lee, D. and Kim, B. S. (2008). Antifungal activity of valinomycin, a peptide antibiotic produced by *Streptomyces* sp. Strain M10 antagonistic to *Botrytis cinerea*. *Journal of Microbiology and Biotechnology*. 18(5): 880-884.

Chen, X., Tang, L., Li, S., Liao, L., Zhang, J. and Mao, Z. (2011). Optimization of medium for enhancement of ε-Poly_L-Lysine production of *Streptomyces* sp. M-Z18 with glycerol as carbon source. *Bioresource Technology*. 102(2): 1727-1732.

Christopher, J. A., Cherie, H. B., Benjamin, J. D., Judie, M. F., Megan, N. C., Grainger, M. M. H and Melanie, J. S. (2008). Isolation by HPLC and characterization of the bioactive fraction of New Zealand manuka (Leptospermum scoparium) honey. *Carbohydrate Research*. 343:651-659.

Clermont, N., Legault, G., Lerat, S. and Beaulieu, C. (2012). Effect of biopolymers on geldanamycin production and biocontrol ability of *Streptomyces melanosporofaciens* strain EF-76. *Canadian Journal of Plant Pathology*. 32(4): 481-489.

Conn, H. J. and Conn, J. E. (1941). Value of pigmentation in classifying actinomycetes. *Journal of Bacteriology*. 42(6): 791-799.

da Silva, I. R., Martins, M. K., Carvalho, C. M., de Azevedo, J. L. and de Lima, R. E. (2012). The effect of varying culture conditions on the production of antibiotics by *Streptomyces* spp. isolated from the Amazonian soil. *Fermentation Technology*. Doi:10.4172/2167-7972.1000105.

Dastager, S. G., Dayanand, A., Li, W. J., Kim, C. J., Lee, J. C., Parl, D. J., Tian, X. P. and Razluddin, Q. S. (2008). Proteolytic activity from an alkali-thermotolerant *Streptomyces gulbargensis* sp. nov. *Current Microbiology*. 57:638-642.

Demain, A. L. (1974). How do antibiotic-producing micro-organisms avoid suiside? *Annals New York Academic Science*. 235: 601-612.

Dekker, J. and Ark, P. A. (1959). Protection of antibiotic pimaricin from oxidation and ultraviolet light by chlorophyllin and other compounds. *Antibiotics and Chemotherapy*. *9*: 327-332.

Derewacz, D.K., Goodwin, CR., McNees, CR., McLean, JA and Bachmann, BO. (2013). Antimicrobial drug resistance affects broad changes in metabolomic phenotype in addition to secondary metabolism. *PNAS*. 110(6):2336-2341.

Dhanasekaran, D., Thajuddin, N. and Panineerselvam, A. (2008). An antifungal compound: 4' Phenyl-1-napthyl-phenyl acetamide from *Streptomyces* sp. DPTB16. *Facta Universitatis. Series: Medicine and Biology*. 15(1): 7-12.

Dodd, J. C., Estrada, A and Jeger, M. J. (1992). Pidemiology of *Colletotrichum gloeosporioides* in the tropics. In J. A. Bailey and M. J. Jeger. *Colletotrichum: Biology, pathology and control* (pp. 308-325). Wallingford: CAB International.

Doumbou, C. L., Hamby Salove, M. K., Crawford, D. L. and Beaulieu, C. (2001). Actinomycetes, promising tools to control plant disease and to promote plant growth. *Phytoprotection*. 82: 85-102.

Du, M., Schardl., C. L., Vaillancourt, L. J. (2005). Using mating-type gene sequences for improved phylogenetic resolution of *Colletotrichum* species complexes. *Mycologia*. 97(3): 641-658.

Edwards, U., Rogall, T., Blocker, H., Emde, M. and Bottger, E.C. (1989). Isolation and direct complete nucleotide determination of entire genes. Characterization of a gene coding for 16S ribosomal RNA. *Nucleic Acids Research*. 17: 7843-7853.

El-Naggar, M. Y., El-Assar, S. A. and Abdul-Fawad, S. M. (2006). Meroparamycin production by newly isolated *Streptomyces* sp. strain MAR01: Taxonomy, Fermentation, Purification and Structural Elucidation. *The Journal of Microbiology*. 44(4): 432-438.

El-Tarabily, K. A. (2006). Rhizosphere-competent isolates of streptomycete and non-streptomycete actinomycetes capable of producing cell-wall-degrading enzymes to control *Pythium aphanidermatum* damping-off disease of cucumber. *Canadian Journal of Botany*. 84: 211-222.

El-Tarabily, K. A., Soliman, M. H., Nassar, A. H., Al-Hassani, H. A., Sivasithamparam, K., McKenna, F. and Hardy, G. E. St. J. (2000). Biological control of *Sclerotinia minor* using a chitinolytic bacterium and actinomycetes. *Plant Pathology*. 49(5): 573-583.

Fatma, Y. B. A. B., Pianelli, K., Martine, D. N., Aline, L. M., Catherine, D., Mickael, M., Marie-Helene, A., Dominique, R., Christophe, R., Annick, M., Sodak, B. and Cecile, C. (2012). ^{1}H-NMR metabolomics: Profiling method for a rapid and efficient screening of transgenic plants. *African Journal of Biotechnology*, 11(52): 11386-11399.

FAOSTAT. (2012). Retrieved from http://faostat3.fao.org/home/index.html.

Faraq, M. A., Porzel, A. and Wessjohann, L A. (2012). Comparative metabolite profiling and fingerprinting of medicinal licorice roots using a multiplex approach of GC-MS, LC-MS and 1D NMR techniques. *Phytochemistry*. 76: 60-72.

Feng, W. H., Mao, X. M., Liu, Z. H., Li, Y. Q. (2011). The ECF sigma factor SigT regulated actinorhodin production in responcse to nitrogen stree in *Streptomyces coelicolor*. *Applied Microbiology and Biotechnology*. 92: 1009-1021.

Fernie, A. R., Trethewey, R. N., Krotzky, A. J., Willmitzer, L. (2004). Innovation metabolite profiling: from diagnostics to systems biology. *Nature Reviews Molecular Cell Biology*. 5:763-769.

Fiedler, H. P., and Krastel, P., Muller, J., Gebhardt, K. and Zeeck, A. (2001). Enterobactin: the characteristic catecholate siderophoren of *Enterobacteriaceae* is produced by *Streptomyces* species. *FEMS Microbiology Letters*. 196: 147-151.

Firn, R. D. and Jones, C. G. (2000). The evolution of secondary metabolism – a unifying model. *Molecular Microbiology*. 37: 989-994.

Flärdh, K. and Buttner, M. J. (2009). *Streptomyces morphogenetics*: dissecting differentiation in a filamentous bacterium. *Nature Reviews Microbiology*. 7: 36-49.

Fravel, D. R. (2005). Commercialization and implementation of biocontrol. *Annual Review of Phytopathology*. 43: 337-359.

Fravel, D. R., Connick Jr, W. J. and Lewis, J. A. (1998). Formulation of microorganisms to control plant diseases. In H. D. Burges. *Formulation of microbial biopesticides. Beneficial microorganisms, nematodes and seed treatments* (pp. 5-7). Netherland: Kluwer Academic Publishers.

Freeman, S., Minz, D., Kolesnik, I., Barbul, O., Zveibil, A., Maymon, M., Nitzani, Y., Kirshner, B., Rav-David, D., Bilu, A., Dag, A., Shafir, S. and Elad, Y. (2004). *Trichoderma* biocontrol of *Colletotrichum acutatum* and *Botrytis cinerea* and survival in strawberry. *European Journal of Plant Pathology*. 110: 361–370.

Gall, G. L., Colquhoun, I. J. and Defernez, M. (2004). Metabolite profiling using 1H NMR spectroscopy for quality assessment of green tea, *Camellia sinensis* (L.). *Journal of Agricultural and Food Chemistry*. 52(4):692-700.

Gao, H., Liu, M., Liu, J., Dai, H., Zhou, X., Liu, X., Zhuo, Y., Zhang, W. and Zhang, L. (2008). Medium optimization for the production of avermectin B1 a by *Streptomyces avermitilis* 14-12A using response surface methology. *Bioresource Technology*. 100(7):4012-4016.

Gebreel, H.M., El-Mehalawy, A. A., El-Kholy, I. M., Rifaat, H. M. and Humid, A. A. (2008). Antimicrobial activities of certain bacteria isolated from Egyptian soil against pathogenic fungi. *Research Journal of Agriculture and Biological Sciences*. 4(4): 331-339.

George, M., George, G. and Mohamed, H. (2010). Diversity and antibacterial activity of actinomycetes from wetland soil. *The South Pacific Journal of Natural and Applied Sciences*. 28: 52-57.

Goodfellow, M., William, S. T. and Modarski, M. (1988). *Actinomycetes in Biotechnology*. London: Academic Press.

Gorajana, A., Poluri, E. and Zeeck, A. (2010). Cytotoxic compounds from a marine actinomycetes, *Streptomyces albovinaceus* var. *baredar* AUBN $_{10}$/2. *African Journal of Biotechnology*. 9(42): 7197-7202.

Grivet, J. P. and Delort, A. M. (2009). NMR for microbiology: *In vivo* and *In situ* applications. *Progress in Nuclear Magnetic Resonance Spectroscopy*. 54: 1–53.

Gupte, T. E. and Naik, S. R. (2005). Isolation, taxonomic and fermentation studies on a new strain of *Streptomyces arenae var ukrainiana* producing a tetraene antibiotic. *World Journal of Microbiology & Biotechnology*. 15: 545-552.

Gyuranecz, M., Erdelyi, K., Fodor, L., Szepe, B., Fuleki, M., Szoke, I., Denes, B. and Makrai, L. (2010). Characterization of *Francisella tularensis* strains, comparing their carbon source utilization. *Zoonoses Public Health*. 57(6): 417-422.

Haeder, S., Wirth, R., Herz, H. and Spiteller, D. (2009). Candicidin-producing Streptomyces support leaf-cutting ants to protect their fungus garden against the pathogenic fungus Escovopsis. *Proceedings of the National Academy of Sciences*. 106(12): 4742-4746.

Haggag, W. M., Mohamed, E. M and El Azzazy, A. M. (2011). Optimization and production of antifungal hydrolysis enzymes by *Streptomyces aureofaciens* against *Colletotrichum gloeosporioides* of mango. *Agriculture Sciences*. 2(2): 146-157.

Han, Y., Yang, B. J., Zhang, F. L., Miao, X. L. and Li, Z. Y. (2009). Characterization of antifungal chitinase from marine *Streptomyces* sp. DA11 associated with South China Sea Sponge *Craniella australiensis*. *Marine Biotechnology*. 11:132-140.

Henis, Y. and Alexander, M. (1968). Differentiation of Streptomyces strains by gas chromatography. *Antonie Van Leeuwenhoek.* 34(2): 159-164.

Heuer, H., Krsek, M., Baker, P., Smalla, K., Wellington, E. M. H. (1997). Analysis of Actinomycete Communities by Specific Amplification of Genes Encoding 16S rRNA and Gel-Electrophoretic Separation in Denaturing Gradients. *Applied and Environmental Microbiology*. 63(8): 3233-3241.

Holt, J. A., Krieg, N. R. And Sneath, P. H. A. (1994). *Bergey's manual of determinative bacteriology*. Baltimore, MD: Williams & Wilkins.

Hoster, F., Schmitz, J. E. and Daniel, R. (2005). Enrichment of chitinolytic microorganisms: isolation and characterization of a chitinase exhibiting antifungal activity against phytopathogenic fungi from a novel *Streptomyces* strain. *Applied Microbiology and Biotechnology*. 66(4): 434-442.

Hopwood, D. (2007). An introduction to the actinobacteria. *Microbiology Today*. May 2007. Retrieved from http://www.sgm.ac.uk/pubs/micro_today/pdf/050701.pdf. (2012)

Horna, D. H., Gómez, C., Olano, C., Palomino-Schätzlein, M., Pineda-Lucena, A., Carbajo, R. J., Braña, A. F., Méndez, C., Salas, J. A. (2011). Biosynthesis of the RNA Polymerase Inhibitor Streptolydigin in *Streptomyces lydicus*: Tailoring Modification of 3-Methyl-Aspartate. *Journal of Bacteriology*. 193(10): 2647-2651.

Hornero-Méndez, D., Costa-Garcia, J. and Minguez-Mosquera, M. I. (2002). Chracterization of carotenoids high-producing *Capsicum annuum* cultivars selected for paprika production. *Journal of Agricultural and Food Chemistry*. 50(20): 5711-5716.

Hotta, K., Takahashi, A., Saito, N., Okami, Y. and Umezawa, H. (1983). Multiple resistance to aminoglycoside antibiotics. *Journal of Antibiotics*. 36: 1748-1754.

Hrug, D., Zurek, G., Revermann, O., Elicer, G. V. and Muller, R. (2008). Discovering the hidden secondary metabolome of *Myxococcus Xanthus*: a study of intraspecific diversity. *Applied and Environmental Microbiology*. *74*(10): 3058-3068.

Hyde, K. D., Cai, L., McKenzei, E. H. C., Yang, Y. L., Zhang, J. Z. and Prihastuti, H. (2009). *Colletotrichum*: a catalogue of confusion. *Fungal Diversity*. 39: 1-17.

Ikeda, K., Saito, H., Sato, S. I., Fujinaga, M., Chino, S., Oyamada, S. and Shoumura, S. (2004). Correlation between production of antifungal metabolites by *Streptomyces* sp. 39L40C and di\sease suppressive effect to mulberry twig blight. *Journal of Insect Biotechnology and Sericology*. 73: 95-100.

Intra, B., Mungsuntisuk, I., Nihira, T., Igarasi, Y. and Watanalai, P. (2011). Identification of actinomycetes from plant rhizospheric soil with inhibitory against *Colletotrichum* spp., the causative agent of anthracnose disease. *BMC Research Notes*. 4: 98-105.

Intanoo, W. and Chamswarng, C. (2007). Effect of antagonistic bacterial formulation for control of anthracnose on chilli fruits. *Proceeding of the 8th National Plant Protection Conference* (pp. 309-322). Naresuan University, Phisanulok, Thailand.

Isacc, S. (1992). *Fungal-plant interactions*. London: Chapman and Hall.

Islam, M. R., Yong, T. J., Yeon, J. R., Chi, H. S. and Yong, S. L. (2009). Ioslation, identification and optimal culture conditions of *Streptomyces albidoflavus* C247 producing antifungal agents against *Rhizoctonia solani* AG2-2. *Mycobiology*. 37(2): 114-120.

Ismet, A., Rizwana, H., Al-Othman, M. R. and Bakir, M. A. (2012). Studies of actinomycetes for biological control of *Colletotrichum musae* pathogen during post harvest anthracnose of banana. *African Journal of Microbiology Research*. 6(17): 3879-3886.

Iqbal, S., Ashfaq, M., Shah, H., Inam-Ul-Haq, M. and Ud-Din, A. (2012). Prevalence and distribution of Cucumber Mosaic Virus (CMV) in major chilli growing areas of Pakistan. *Pakistan Journal of Botany*. 44(5): 1749-1754.

Iwai, Y., Kimura, K. and Takahashi, Y. (1980). Om-173, new nanaomycin-type antibiotics produced by a strain of streptomyces. Taxonomy, production, isolation and biological properties. *Journal of Antibiotics*. 36(10): 1268-1274.

Jain, P. K. and Jain, P. C. (2007). Isolation, characterization and antifungal activity of *Streptomyces sampsonii* GS1322. *Indian Journal of Experimental Biology*. 45: 203-206.

Jayasree, D., Sandhya Kumari, T. D., Kavi Kishor, P. B., Vijaya Lakshmi, M., Lakshmi Narasu, M. (2009). Optimization of production protocol of alkaline protease by *Streptomyces pulvereceus*. *International Journal of Research and Industry - Science and Technology*. 1(2): 79-82.

Jeffrey, L. S. H. (2008). Isolation, characterization and identification of actinomycetes from agriculture soils at Semongok , Sarawak. *African Journal of Biotechnology*. 7(20): 3700-3705.

Jensen., P. R., Philip, G. W., Oh, D. C., Zeigler, L. and Fenical, W. (2006). Species-specific secondary metabolite productionin marine actinomycetes of the genus *Salinispora*. *Applied and Environmental Mircobiology*. 73(4): 1146-1152.

Jensen, S. E. and Paradkar, A. S. (1999). Biosynthesis and molecular genetics of clavulnalic acid. *Antonie Van Leeuwenhoek*. 75: 125-133.

Jones, K. A. and Burges, H. D. (1998). Formulation of bacteria, viruses and protozoa to control insects. In H. D. Burges. *Formulation of microbial biopesticides. Beneficial microorganisms, nematodes and seed treatments* (pp. 5-7). Netherland: Kluwer Academic Publishers.

Jonsbu, E., Ellingsen, T. E. and Nielsen, T. (2000). Effects of nitrogen sources on cell growth and production of nystatin by *Streptomyces noursei*. *Journal of Antibiotics*. 53: 1354-1362.

Joo, J.G. (2005). Purification and characterization of an extracellular chitinase from the antifungal biocontrol agent *Streptomyces halstedii*. *Biotechnology Letters*. 27(19): 1483-1486.

Kafur, A and Khan A. B. (2011). Influence of cultural parameter on antimicrobial activity of endophytic *Strepomyces* sp. Cr 12 isolated from *Catharanthes roseus* leaves. *International Journal of Drug Delivery*. 3: 425-431

Kamenik, Z., Hadacek, Z., Mareckova, M., Ulanova, D. and Kopecky, J. (2010). Ultra high-performance liquid chromatography fingerprinting method for chemical screening of metabolites in cultivation broth. *Journal of Chromatography A*. 1217: 8016-8025.

Kanini, G. S., Katsifas, E. A., Savvides, A. L. and Karagouni, A. D. (2013). *Streptomyces rochei* ACTA1551, an indigenous Greek isolate studied as a potential biocontrol agent against *Fusarium oxysporum* f.sp. lycopersici. *BioMed Research International*. http://dx.doi.org/10.1155/2013/387230.

Karimi, E., Sadeghi, A., Dehaji, P. A., Dalvand, Y., Omidvari, M and Nezhad, M. K. (2012). Biocontrol activity of salt tolerant Streptomyces isolates against phtopathogens causing root rot of sugar beet. *Biocontrol Science and Technology*. 22(3): 333-349.

Katsifas, E. A., Koraki, T. G. and Karagouni, A. D. (2000). Determination of metabolic activity of streptomyces in soil microorganisms. *Journal of Applied Microbiology*. 89: 178-184.

Kavitha, A., Vijayalakshmi, M., Sudhakar, P. and Narasimha, G. (2010). Screening of actinomycetes strains for the production of antifungal metabolite. *African Journal of Microbiology Research*. 4(1): 27-32.

Kavitha, A. And Vijayalakshmi, M. (2009). Cultural parameters affecting the production of bioactive metabolites by *Norcadia levis* MK-VL_113. *Journal of Applied Siences Research*. 5(12): 2138-2147.

Kefialew, Y and Ayalew, A. (2008). Postharvest biological control of anthracnose (*Colletotrichum gloeosporioides*) on mango (*Mangifera indica*). *Postharvest Biology and Technology*. 50: 8-11.

Khavazi, K. A., Rejali, F. A., Seguin, P. B. and Miransari, M. C. (2007). Effectes of carrier, sterilisation method and incubation on survival of *Bradyrhizobium japonicum* in soyabean (*Glycine max* L.) inoculants. *Enzyme and Microbial Technology*. 41: 780-784.

Khrisnan, P., Kruger, N. J. and Ratcliffe, R. G. (2005). Metabolite fingerprinting and profiling in plants using NMR. *Journal of Experimental Botany*. 56(410): 255-265.

Kim, B. S., Park, K. S. and Lee, W. S. (1987). Search for resistance to two *Colletotrichum* species in pepper (*Capsicum* spp.). *Journal of Korean Society and Horticulture Science*. 28: 207-213.

Kim B. S. and Hwang, B.K. (2003). Fungicides. In D. K. Arora. *Fungal biotechnology in agricultural, food and environmental application* (123-133). New York: Marcel Decker.

Kim, B. W., Kwon, H. J., Park, H. Y., Nam, S. W., Park, J. P. and Yun, J. W. (2000). Production of a novel transfructosylating enzyme from *Bacillus macerans* EG-6. *Bioprocess Engineering*. 23: 11-16.

Kim, D. G., Moon, K., Kim, S. H., Park, S., Park, S. Y., Lee, S. K., Oh, K. B., Sin, J. and Oh, D. C. (2012). Bahamaolides A and B, antifungal polyene polyol macrolides from the marine actinomycetes *Streptomyces* sp. *Journal of Natural Products*. 75(5): 959-967.

Kim, H. K., Choi, Y. H.and Verpoorte, R. (2010). NMR based metabolomic analysis of plants. *Nature Protocol*. 3: 1001-1012.

Kim J. D., Han, J. W., Hwang, I. C., Lee, D and Kim, B. S. (2012). Identifiaction and biocontrol efficacy of *Streptomyces miharaensis* producing filipin III against Fusarium wilt. *Journal of Basic Microbiology*. 52: 150-159.

Kim, K. J., Yang, Y. J. and Kim J. G. (2003). Purification and characterization of chitinase from *Streptomyces* sp. M-20. *Journal of Biochemistry and Molecular Biology*. 36(2): 185-189.

Kim, K. K., Yoon, J. B., Park, H. G., Park, E. W. and Kim, Y. H. (2004). Structural modification and programmed cell death of chilli pepper fruits related to resistance responses to *Colletotrichum gloeosporioides* infection. *Genetics and Resistance*. 94: 1295-1304.

Kim, Y. P., Tomoda, H., Iizima, K, Fukuda, T., Matsumoto, A., Takahashi, Y and Omura, S. (2003). Takanawaenes, Novel antigungal antibiotics produced by *Streptomyces* sp. K99-5278. I. Taxonomy, Fermentation, Isolation and biological properties. *Journal of Antibiotics*. 56(5): 448-453.

Kitani, S., Miyamoto, K. T., Takamatsu, S., Herawati, E., Iguchi, H., Nishitomi, K., Uchida, M., Nagamitsu, T., Omura, S., Ikeda, H and Nihira, T. (2011).Avenolide, a *Streptomyces* hormone controlling antibiotic production in *Streptomyces avermitilis*. *Proceedings of the National Academy of Sciences*. 108(39): 16410-16415.

Kitouni, M., Boudemagh, A., Oulmi, L., Reghioua, S., Boughachiche, F., Zerizer, H., Hamdiken, H., Couble, A., Mouniee, D., Boulahrouf, A. And Boiron, P. (2005). Isolation of actinopmycetes producing bioactive substances from water, soil and tree bark samples of the north-east of Algeria. *Journal de Mycologie Médicale*. 15: 45-51.

Koga, D., Mitsutomi, M., Kono, M. and Matsumiya, M. (1999). Biochemistry of chitinases. In P. Jollès. and R. A. A. Muzzarelli. *Chitin and chitinases* (pp. 111-123). Berlin: Birkhäuser Verlag.

Kokosková, B. and Mráz, I. (2005). Reliability of diagnostic techniques for *Erwinia amylovora*, the causative agent of fire blight disease. *Folia Microbiology (Praha)*. 50(3): 217-21.

Kol, S., Merlo, E., Scheltema, R. A., de Vries, M., Vonk, R. J., Kikkert, N. A., Dijkhuizen, L., Breitling, R and Tanako, E. (2010). Metabolomic characterization of the salt stress response in *Streptomyces coelicolor*. *Applied and Environmental Microbiology*. 76(8): 2574-2581.

Kumar, N., Singh, R. K., Mishra, S. K., Singh, A. K., Pachouri, U. C. (2010). Isolation and screening of soil actinomycetes as source of antibiotics active against bacteria. *International Journal of Microbiology Research.* 2(2): 12-16.

Larsson, J. (2010). *Streptomyces sporulation genes and regulators involved in bacterial cell differentiation*. PhD Thesis. Lund University.

Lam, K. S. (2006). Discovery of novel metabolites from marine actinomycetes. *Current Opinion in Microbiology*. 9: 245-251.

Lane, D. J. (1991). 16S/23S rRNA sequencing. In: Nucleic Acid Techniques in Bacterial Systematics (Eds. Stackebrandt, E. and Goodfellow, M.), pp. 115–148. John Wiley & Sons, NewYork.

Laureti, L., Song, L., Huang, S., Corre, C., Leblond, P., Challis, L. and Aigle, B. (2011). Identification of a bioactive 51-membered macrolide complex by activation of a silent polyketide synthase in *Streptomyces ambofaciens*. *Proceedings of the National Academy of Sciences*. 108(15): 6258-6263.

Lee, J. Y. and Hwang, B. K. (2002). Diversity of antifungal actinomycetes in various vegetative soils of Korea. *Canadian Journal of Microbiology*. 48: 407-417.

Lee, Y. J., Kitani, S. and Nihira, T. (2010). Null mutation analysis of an *afsA*-family gene, *barX*, that is involved in biosynthesis of the *γ*-butyrolactone autoregulator in *Streptomyces virginiae*. *Microbiology*. 156(1): 206-210.

Lenné, J. M. and Parbery, D. G. (1976). Phylloshere antagonists and appressoria formation in Colletotrichum gloeosporioides. *Transaction of the British Mycological Society*. 66:334-336.

Lersen, T. O., Smedsgaard, J., Nielsen, K. F., Hansen, M. E. and Frisvad, J. C. (2005). Phenotypic taxonomy and metabolite profiling in microbial drug discovery. *Natural Product Report*. 22: 672-695.

Lewis, I. M. L. and Miller, S. A. (2003). Evaluation of fungicides and a biocontrol agents for the control of anthracnose on green pepper fruit, 2002. Nematicide test report. *New Fungicide and Netaticide Data Committee of the American Phytopathological Society*. (Online publication) Doi:10.1094/FN58.

Li, J., Zhao, G. Z., Qin, S., Huang, H. Y., Zhu, W. Y., Xu, L. H. and Li, W. J. (2009). *Saccharopolyspora tripterygii* nov., an endophytic actinomycete isolated from the stem of *Tripterygium hypoglaucum. International Journal of Systematic and Evolutionary Microbiology*. 59: 3040-3044.

Li, Z. L., Wang, Y. H., Chu, J., Zhuang, Y. P and Zhang, S. L. (2009). Effect of branched-chain amino acids, valine, isoleucine and leucine on the biosynthesis of Bitespiramycin 4”-o-Acylspiramycins. *Brazillian Journal of Microbiology*. 40: 734-746.

Liang, J. L., Xu, Z. N., Liu, T. F., Lin, J. P. and Cen, P. L. (2008). Effects of cultivation conditions on the production of natamycin with *Streptomyces gilvosporeus* LK-196. *Enzyme and Microbial Technology*. 42(2): 145-150.

Lindon, J. C., Holmes, E. and Nicholson, J. K. (2001). Pattern recognition methods and applications in biomedical magnetic resonance, *Progress in Nuclear Magnetic Resonance Spectroscopy*. 39: 1–40.

Liras, R. (1999). Biosynthesis and molecular genetics of cephamycins. Cephamycins produced by actinomycetes. *Antonie Van Leeuwenhoek*. 75: 109-124.

Lo, C.T. (1998). General mechanisms of action of microbial biocontrol agents. *Plant Pathology Bulletin*. 7: 155-166.

Lo, C. T., Nelson, E. B. and Harman, G. E. (1998). Ecological studies of transformed *Trichoderma harzianum* strain 1295-22 in the rhizosphere and on the phylloplane of creeping bentgrass. *Phytopathology*. 88: 129-136.

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*. (Online Publication). http://www.arbec.com.my/pdf/art21julysep02.pdf

Lorito, M., Hayes, C. K., Zoina, A., Scala, F., Del-Sorbo, G., Woo, S. L. and Harman, G. E. (1994). Potential of genes and genes products from *Trichoderma* spp. and *Gliocladium* spp. for the development of biological pesticides. *Molecular Biotechnology*. 2: 209-217.

Lowry, O. H., Rosenbrough, J. N., Farr, A. L. and Randall, R. J. (1951). Protein measurement with folin-phenol reagent. *Journal of Biology Chemistry*. 193: 265-275.

Malina, A. and Shai, Y. (2005). Conjugation of fatty acid with different lenght modulates the antibacterial and antifungal activity of a cationic biological inactive peptide. *Biochemical Journal*. 390: 695-702.

Maloy, O. C. (1993). Plant disease control: Principle and practice. (pp.346). New York: John Wiley & Sons, Inc.

Manandhar, J. B., Hartman, G. L. and Wang, T.C. (1995). Conidial germination and appressorial formation of *Colletotrichum capsici* and *Colletotrichum gloeosporioides* isolates from pepper. *Plant Disease*. 79: 361-366.

Mangamuri, U. K., Muvva, V., Poda, S. and Kamma, S. (2012). Isolation, identification and molecular characterization of rare actinomycetes from mangrove ecosystem of Nizampatnam. *Malaysian Journal of Microbiology*. 8(2): 83-91.

Manivasagan, P., Gnanam, S., Sivakumar, K., Thangaradjou, T., Vijayalakshmi, S. and Balasubramaniam, T. (2009). Antimicrobial and cytotoxic activities of an actinobacteria (*Streptomyces* sp. PM-32) isolated from an offshore sediments of the bay of Bengal in Tamailnadu. *Advances in Biological Research*. 3(5-6): 231-236.

Marin, A., Ferreres, F., Tomás Barberan, F. A. And Gil, M. (2004). Characterization and quantization of antioxidant constituents of sweet pepper (*Capsicum annunm* L.). *Journal of Agricultural and Food Chemistry*. 52(12): 3861-3869.

McNabb, A., Shuttleworth, R., Behme, R. and Colby, W. D. (1997). Fatty acid characterization of rapid growing pathogenic aerobic actinomycetes as a means of identification. *Journal of Clinical Microbiology*. 35: 1361-1368.

Meiklejohn, J. (1950). Numbers of bacteria and actinomycetes in a Kenya soil. *Journal of Soil Science*. 8: 240–247.

Mitsuiki, S., Sakai, M., Moriyama, Y., Goto, M and Furukawa, K. (2002). Purification and some properties of keratinolytic enzyme from an alkaliphilic *Norcardiopsis* sp. TOA-1. *Bioscience Biotechnology and Biochemistry*. 66: 164-167.

Miyamoto, K. T., Kitani, S., Komatsu, M., Ikeda, H. and Nihira, T. (2011). The autoregulator receptor homologue AvaR3 plays a regulatory role in antibiotic production, mycelial aggregation and colony development of *Streptomyces avermitilis*. *Microbiology*, 157(8): 2266-2275.

Mukherjee, G and Sen, S. K. (2006). Purification, characterization and antifungal activity of chitinase from *Streptomyces venezuelae* P_{10}. *Current Microbiology*. 53: 265-269.

Nachtigall, J., Schneider, K., Bruntner, C., Bull, A. T., Goodfellow, M., Zinecker, H., Imhoff, J. F., Nicholson, G., Irran, E., Süssmuth, R. D., Fiedler, H. P. (2011). Benzoxacystol, a benzoxazine-type enzyme inhibitor from the deep-sea strain *Streptomyces* sp. NTK 935. *Journal of Antibiotics*. 64(6): 453-457.

Nagpure, A. and Gupta, R. K. (2012). Purification and characterization of an extracellular chitinase from antagonistic *Streptomyces violaceusniger*. *Journal of Basic Microbiology*. Doi:10.1002/jobm.201100648.

Nakouti, I., Sihanonth, P. and Hobbs, G. (2012). A new approach to isolating siderophore -producing actinobacteria. *Letters in Applied Microbiology*. 55: 68–72.

Nawani, N. N. and Kapadnis, B. P., (2004). Production dynamics and characterization of chitinolytic system of *Streptomyces* sp. NK 1057, a well equipped chitin degrader. *World Journal of Microbiology and Biotechnoogy*. 230: 487-494.

Nguyen, T. H. P., Sall, T., Bryngelsson, T. and Liljeroth. (2009). Variation among *Colletotrichum gloeosporioides* isolates from infected coffee berries at different locations in Vietnam. *Plant Pathology*. 58: 898-909.

Niladevi, K. N., Sukumaran, R. K., Jacob, N., Anisha, G. S. and Prema, P. (2009). Optimization of laccase production from a novel strain-*Streptomyces psammoticus* using response surface methodology. Microbiological Research. 164(1):105-113.

Nisha, A. K., Meignanalakshmi, S. and Ramasamy, K. (2008). Comparative effect of amino acid in the production of cyclosporin by solid and submerged fermentation. *Biotechnology*. 7(2): 202-208.

Nonoh, J. O., Lwande, W., Masiga, D., Herrmann, R., Presnail, J. K., Schepers, E., Okech, M. A., Bagine, R., Mungai, P., Nyende, A. B. and Boga, H. I. (2010). Isolation and characterization of *Streptomyces* species with antifungal activity from selected national parks in Kenya. *African Journal of Microbiology Research*. 4(9): 856-864.

Nonomura, H. and Ohara, Y. (1969). Distribution of actinomycetes in soil. IV. A culture methods effective for both preferential isolation and enumeration of *Microbispora* and *Streptosporangium* strains in soil (Part 1). *Journal of Fermentation Technology*. 47: 463-469.

Nonomura, H. and Ohara, Y. (1971). Distribution of actinomycetes in soil. VIII. Greenspored group of *Microtetraspora*, its prefential isolation and taxonomic characteristics. *Journal of Fermentation Technology*. 49: 887-894.

Nurjasmi, R., Widada, J. and Ngadiman. (2009). Diversity of actinomycetes at selected Forest types in Wanagama I Yogyakarta and their potency as a producer of antifungal compound. *Indonesian Journal of Biotechnology*. 14(2): 1196-1205.

Nurul Zarith, M. Z., Nor Asmara, T., Mohd Nasir, M. D., Cheah, Y. K., Zainul, A. Z., Rukman, A. H. and Mariana N. S. (2011). Characterization and antimicrobial activities of two Streptomyces isolates from soil in the periphery of Universiti Putra Malaysia. *Tropical Biomedicine*. 28(3): 651-660.

O'callaghan, M., Swaminathan, J., Lottmann, J., Wright, D.A. and Jackson, T. A. (2006). Seed coating with biocontrol strain *Pseudomonas fluorescens* F113. *New Zealand Plant Protection*. 59: 80-85.

Olano, C., Lombo, F., Mendez, C. and Salas, J. A., (2008). Improving production of bioactive secondary metabolites in actinomycetes by metabolic engineering. *Metabolic Engineering*. 10: 281–292.

Oskay, M. (2011). Effects of some environmental conditions on biomass and antimicrobial metabolite production by *Streptomyces* sp., KGG32. *International Journal of Agriculture and Biology*. 13: 317–324.

Oskay, M., A.U. Tamer and İ. Karaboz. (2010). Isolation and screening for antimicrobial activities of culturable mesophilic *Streptomyces* strains from North Cyprus soils. *Fresenius Environmental Bulletin*. 19: 154–163.

Oskay, M. (2009a). Antifungal and antibacterial compounds from *Streptomyces* strains. *African Journal of Biotechnology*. 8(13): 3007-3017.

Oskay, M. (2009b). Comparison of Streptomyces diversity between agricultural and non-agricultural soils by using various cultural media. *Scientific Research and Essay*, 4(10): 997-1005.

Oskay, M., Tamer, A. U. Azeri, C. (2004). Antibacterial activity of some Actinomycetes Isolated from farming soil of Turkey. *African Journal of Biotechnology*, 3(9): 441-446.

Osuna-Garcia, J. A., Wall, M. W. and Waddell, C. A. (1998). Endogenous levels of Tocopherol and ascorbic acid during fruit ripening of New Mexican-type chilli (*Capsicum annuum* L.) cultivars. *Journal of Agricultural and Food Chemistry*, 46(12):5093-5096.

Ouhdouch, Y., Barakate, M and Finance, C . (2001). Actinomycetes of Moroccan habitats: Isolation and screening for antifungal activities. *European Journal of Soil and Biology*. 37: 69-74.

Pae, D. H., Yoon, J. Y. and Lee, J. M. (1998). Screening for resistance to *Colletotrichum gloeosporioides* using detached fruits in pepper (*Capsicum annuum*) by high-pressure spray. *Journal of Korean Society and Horticulture Science*. 39: 690-692.

Pal, K. K. and Gardener, B. M. (2006). Biological control of plant pathogens. *The Plant Health Instructor*. http://www.apsnet.org/edcenter/advanced/topics/Documents / PHI-BiologicalControl.pdf. DOI: 10.1094/PHI-A-2006-1117-02

Park, C. M., Lee, J. M., Lee, D. and Kim, B. S. (2008). Antifungal activity of valinomycin, a peptide antibiotic produced by *Streptomyces* sp. strain M10 antagonistic to *Botrytis cinerea*. *Journal of Microbiology and Biotechnology*. 18(5): 880-884.

Park, H. G. (2007). Problems of anthracnose in pepper and prospects of its management. *In* D. G. Oh and K. T. Kim. *Abstract of the First National Horticultural Research Institute* (pp. 19). Republic of Korea: Rural Development of Administration.

Park, H. J., Lee, J. Y., Hwang, I. S., Yun, B. S., Kim, B, S. and Hwang, B. K. (2006). Isolation and antifungal and antioomycete activity of staurosporine from *Streptomyces roseoflavus* strain LS-A24. *Journal of Agriculture and Food Chemistry*. 54: 3041-3046.

Park, K. S. and Kim, C. H. (1992). Identification, distribution and etiological characteristics of anthracnose fungi of red pepper in Korea. *Korean Journal of Plant Pathology*. 8: 61-69.

Parry , D. W. (1990). *Plant Pathology Agriculture*. Cambridge University Press, Australia.

Patil, K. R., Rocha, I., Forster, J. and Nielsen, J. (2005). Evolutionary programming as a platform for in silico metabolic engineering. *BMC Bioinformatics*. 6: 308.

Pauli, G. F., Jaki, B. U., and Lankin, D. C. (2005). Quantitative 1H NMR: Development and potential of a method for natural products analysis. *Journal of Natural Products*. 68: 133–149.

Pelczar, M. J., Chan, E. C. S. and Krieg, N. R. (1993). *Microbiology: Concepts and Applications*. New York: McGraw-Hill.

Pérez-Gálvez, A., Martin, H. D. Sies, H. and Stahl, W. (2003). Incorporation of carotenoids from paparikaoleoresin into human chylomicron. *British Journal of Nutrition*. 89(6): 787-793.

Pernezny, K., Roberts, P. D., Murphy, J. F. and Goldberg, N. P. (2003). Compendium of pepper diseases (pp. 73). St. Paul, Minnedota: The American Phytopathological Society.

Perfect, S. E., Hughes, H. B., O'Connell, R. J. and Green, J. R. (1999). *Colletotrichum*: a model genus for studies on pathology and fungal-plant interactions. *Fungal Genetics and Biology*. 27(2-3): 186-198.

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

Phoulivong, S., Lei, C., Hang, C., McKenzie, E. H. C., Abdelsalam, K., Chukeatirote, E. and Hyde, K. D. (2010). *Colletotrichum gloeosporioides* is not a common pathogen on tropical fruits. *Fungal Diversity*. 44: 33-43.

Pickersgill, B. (1997). Genetic resources and breeding of *Capsicum* spp. *Euphytia*. 96(1): 129-133.

Pieri, V., Sturm, S., Seger, C., Franz, C. and Stuppner, H. (2012). 1H NMR based metabolic profiling and target analysis: a combined approach for the quality control of *Thymus vulgaris. Metabolomics*. 8: 335-346.

Pierens, G. K., Palframan, M. E., Tranter, C. J. (2005). A robust clustering approach for NMR spectra of natural product extracts. *Magnetic Resonance in Chemistry*. 43: 359-365.

Poonpolgul, S., Kumphai, S. (2007). Chilli pepper anthracnose in Thailand. Country Report. *In* D. G. Oh and K. T. Kim. *Abstracts of the First International Sysmposium on Chilli Anthracnose* (pp. 23). Republic of Korea: National Horticultural Resarch Institutre, Rural Development of Administration.

Posada, F., Vega, F. E., Rehner, S. A., Blackwell, M., Weber, D., Suh, S. O and Humber, R.O. (2004). *Syspastospora parasitica*, a mycoparasite of the fungus *Beauveria bassiana* attacking the Colorado potato beetle *Leptinotarsa decemlineata*: A tritrophic association. *Journal of Insect Science*. Retrieved from www.insectscience.org/4.24.

Postolakyi, O. (2006). Amino acid composition of biomass of strain *Streptomyces canosus* CNMN-71 and its variant. *Buletin of University of Agricultural Sciences and Verterinary Medicine – Cluj Napoca.* 63: 306-310.

Prapagdee, B., Kuekulvong, C. and Mongkosuk, S. (2008). Antifungal potential of extracellular metabolites by *Streptomyces hygroscopicus* against phytopathogenic fungi. *International Journal of Biological Science*. 4(5): 330-337.

Pridham, T. G. and Gottlieb, D. (1948). The utilization of carbon compounds by some *Actinomycetales* as an aid for species determination. *Journal of Bacterology*. 56:107-114.

Prihastuti, H., Cai, L., Chen, H. and Hyde. K. D. (2009). Characterization of Colletotrichum species associated with coffee berries in Chiang Mai, Thailand. *Fungal Diversity*. 39: 89-109.

Prusky, D., Koblier, I., Aridi, R., Beno-Moalem, D., Yakoby, N. And Keen, N. T. (2000). Resistance mechanisms of subtropical fruits to *Colletotrichum gloeosporioides*. In J. A. Bailey and M. J. Jeger. *Colletotrichum: Biology, pathology and control* (pp. 232-244). Wallingford*: CAB International.*

Quecine, M. C., Araujo, W. L., Marcon, J., Gai, C. S and Azevedo, J. L. (2008). Chitinolytic activity of endophytic Streptomyces and potential for biocontrol. *Letters in Applied Microbiology*. 47(6): 486–491.

Raamsdonk, L. M., Teusink, B., Broadhurst, D., Zhang, N., Hayes, A., Walsh, M. C., Berden, J. A., Brindle, K. M., Kell, D. B., Rowland, J. J., Westerhoff, H. V., van Dam, K. and Oliver, S. G. (2001). A functional genomics strategy that uses metabolome data to reveal the phenotype of silent mutations, *Nature Biotechnology*. 19: 45–50.

Rahulan, R. J., Nampoothiri, K. M., Szakacs, G., Nagy, V. and Pandey, A. (2009). Statistical optimization of l-leucine amino peptidase production from *Streptomyces gedanensis* IFO 13427 under submerged fermentation using response surface methodology. *Biochemical Engineering Journal*. 43(1): 64-71.

Rajapakse, R. G. A. S. Mode of anthracnose development in chilli (Capsicum annuum L.) pods, In Proceeding of the annual symposium of the, Peradeniya, Sri Lanka. Kudagama, C. and Nagaragah, S. Ed.; Department of Agriculture: Sri Lanka, 1999.

Ramasamy, V., Murugesan, S. and Panneerselvam, A. (2010). Isolation, characterization and antimicrobial activity of actinobacteria from Point Calimere coastal region, east coast of India. *International Research Journal of Pharmacy*. 1(1): 358-365.

Ramesh, S. and Mathivanan, N. (2009). Screening of marine actinomycetes isolated from the Bay of Bengal, India for antimicrobial activity and industrial enzymes. *World Journal of Microbiology and Biotechnology*. 25(12): 2103-2111.

Reddy, G. N., Ramakrishna, D.P.N. and Rajagopal, S.V. (2011a). Effect of different cultural, physiological and nutritional parameters on *Streptomyces rochei* (MTCC 10109) antimicrobial metabolites production. *Journal of Pharmacy Research*. 4(8): 2675-2678.

Reddy, G. N., Ramakrishna, D. P. N. and Rajagopal, S. V. (2011b). A morpgological, physiological and Biochemical studies of marine *Streptomyces rochei* (MTCC 10109) showing antagonistic activity against selective human pathogenic microorganisms. *Asian Journal of Biological Science*. 4(1): 1-14.

Remya, M. and Vijayakumar, R. (2008). Isolation and characterization of marine antagonistic *actinomycetes* from west coast India. *Facta Universitatis. Series: Medicine and Biology*. 15: 13-19.

Roberts, P. D., Pernezny, K. and Kucharek, T. A. (2001). Anthracnose caused by *Colletotrichum* sp. on pepper. *Journal of University of Florida*. Retrieved from http://edis.ifas.ufl.edu/PP104.

Rojas-Avelizapa, L. I., Cruz-Camarillo, R., Guerrero, M. I., Rodríguez-Vázquez, R. and Ibarra, J. E. (1999). Selection and characterization of a proteo-chitinolytic strain of *Bacillus thuringiensis*, able to grow in shrimp waste media. *World Journal of Microbioogy and Biotechnology*. 15: 299–308.

Ryley, J. F., Wilson, R.G. Gravestock, M. B. and Poyser, J. P. (1981). Experimental approaches to antifungal chemotheraphy. *Advances in Pharmacology and Chemotheraphy*. 18: 49-176.

Sacramento, D. R., Coelho, R. R. R., Wigg, M. D., Linhares, L. F. T. L., Santos, M.G.M., Semêdo, L. T. A. S. and Silva, A. J. R. (2004). Antimicrobial and antiviral activities of an actinomycete (*Streptomyces* sp.) isolated from a Brazilian tropical forest soil. *World Journal of Microbiology and Biotechnology*. 20: 225–229.

Sadeghi, A., Hessan, A. R., Askari, H., Aghighi, S., Shahidi Bonjar, G. H. (2006). Biological control potential of two *Streptomyces* isolates on *Rhizoctonia solani*, the causal agent of damping-off of sugar beet. *Pakistan Journal of Biological Sciences*. 9(5): 904-910.

Sadi, M. S and Masoud, A. (2012). Effect of pH on stability, sunflower growth promotion and biocontrol potential of a talc-based formulation of *Pseudomonas fluoresens* UTPF61. *Autralian Journal of Crop Science*. 6(3): 463-469.

Sajid, I., Khaled, A. S. and Shahida, H. (2011). Identification, isolation and optimization of antifungal metabolites from the *Streptomyces malachitofucus* CTF9. *Brazilian Journal of Microbiology*. 42: 592-604.

Sámi, L., Pusztahelyi, T., Emri, T., Varecza, Z., Fekete, A., Grallert, A., Karanyi, Z., Kiss, L. and Pócsi, I. (2001). Autolysis and aging of *Penicillium chrysogenum* cultures under carbon starvation: Chitinase production and antifungal effect of allosamidin. *The Journal of General and Applied Microbiology*. 47(4): 201–211.

Sangdee, A., Sachan, S. and Khanklum, S. (2011). Morphological, pathological and molecular variability of *Colletotrichum capsici* causing anthracnose of chilli in the North-east of Thailand. *African Journal of Microbiology Research*. 5(25): 4368-4372.

Sakano, K., Ishimaru, K. and Nakamura, S. (1980). New antibiotics, carbazomycins A and B. I. Fermentation, extraction, purification and physic-chemical and biological properties. *Journal of Antibiotics*. 33: 683-68.

Stach, J. E. M., Maldonado, L. A., Ward, A. C., Goodfellow, M. and Bull, A. T. (2003) New primers for the class Actinobacteria: application to marine and terrestrial environments. *Environmental Microbiology*. 5:828–841.

Semêdo, L. T. A. S., Gomes, R. C., Linhares, A. A., Duarte, G. F., Nascimento, R. P., Rosado, A. S., Margis-Pinheiro, M. Margis, R., Silva, K. R. A., Alviano, C. S., Manfio, G. P., Soares, R. M. A., Linhares, L. F. and Coelho, R. R. R. (2004). *Streptomyces drozdowiczii* sp. nov., a novel cellulolytic streptomycete from soil in Brazil. *International Journal of Systematic and Evolutionary Microbiology*. 54: 1323–1328.

Schwieger, F and Tebbe, C. C. (1998). A new approach to utilize PCR-single strand-conformation polymorphism for 16S rRNA gene-based microbial community analysis. *Applied and Environmental Microbiology*. 64: 4870-4876.

Sharma, H and Parihar, L. (2010). Antifungal activity of extracts obtained from actinomycetes. *Journal of Yeast and Fungal Research*. 1(10): 197-200.

Shekhar, N., Bhattacharya, D., Kumar, D. and Gupta, R. K. (2006). Biocontrol of wood-rotting fungi with *Streptomyces violaceusniger* XL2. *Canadian Journal of Microbiology*. 52: 805-808.

Shi, S. and Hickey, A. J. (2009). Multivariate data analysis as a semi-quantitative tool for interpretive evaluation of comparability or equivalence of aerodynamic particle size distribution profiles. *AAPS PharmSciTech*. 10(4): 1113–1120.

Shi, P. J., Yao, G. Y., Yang, P. L., Li, N., Luo, H. Y., Bai, Y. G., Wang, Y. R and Yao, B. (2010). Cloning, characterization, and antifungal activity of an endo-1,3-β-D-glucanase from *Streptomyces* sp. S27. *Applied Microbiology and Biotechnology*. 85(5): 1483-1490.

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.

Shirling, E. B. and Gottlieb, D. (1966). Methods of characterization of *Streptomyces* species. *International Journal of Systematic Bacteriology.* 61**:** 313-340.

Sigma Aldrich. (2012). Chitinase and chitin. Retrieved from http:// sigmaaldrich.com/lifescience/metabolomics/enzyme-explorer/learning-center/carbohydrate-analysis/ carbohydrate-analysis-ii.html#Chitinase

Singh, L. S., Baruah, I. and Bora, T. C. (2006). Actinomycetes of Loktak Habitat: Isolation and screening for antimicrobial activities. *Biotechnology*. 5(2): 217-221.

Singh, P. P., Yong, C. S., Chang, S. P and Young, R. C. (1999). Biological control of fusarium wilt of cucumber by chitinolytic bacteria. *Biological Control*. 89(1): 92-99.

Singh, V., Tripathi, C. K. M. and Bihari, V. (2008). Production, optimiation and purification of an antifungal compound from *Streptomyces capoamus* MTCC 8123. *Medicinal Chemistry Research*. 17: 94-102.

Sinnarkar, A. R., Sonune, N. A., Mule, A. D and Patil, R. C. (2012). Cost effective production of oxytetracylin (OTC) using *Ipomosa baatas* (Sweet potato) by *Streptomyces viridifuciens* NCIM 2506. *Journal of Empirical Biology*. 1(1): 55-60.

Smedsgaard, J., Hansen, M. E. and Frisvad, J. C. (2004). Classification of *Terverticillate penicillia* by Electrospray Mass Spectrometric profiling. *Studies in Mycology*. 49: 243-251.

Son, H. S., Kim, K. M., Van Den Berg, F., Hwang, G.S., Park, W. M., Lee, C. H., Hong, Y. S., (2008). 1H nuclear magnetic resonance based metabolomic characterization of wines by grape varieties and production areas. *Journal of Agricultural and Food Chemistry*. 57:1481-1490.

Song, Q., Huang, Y. and Yang, H. (2012). Optimization of fermentation conditions for antibiotic production by Actinomycetes YJ1 strain against *Sclerotinia sclerotiorum*. *Journal of Agriculture Science*. 4(7): 95-102.

Subramaniam, S., Ravi, V. and Narayanan, G. K. (2012). Studies on production of enzyme chitinase from *Streptomyces* sp. and its anti-fungal activity. *Journal of Pharmacy Research.* 5(3): 1409-1413.

Suneethat, V., Raj, K. and Prathusha, K. (2011). Isolation and identification of *Streptomyces* ST1 and ST2 strains from Tsunami affected soils: Morphological and biochemical studies. *Journal of Oceanography and Marine Science*. 2(4): 96-101.

Suwan, N., Boonying, W. and Nalumpang, S. (2012). Antifungal activity of soil actinomycetes to control chilli anthracnose caused by *Colletotrichum gloeosporioides*. *Journal of Agricultural Technology*. 8(2): 725-737.

Syed, D. G., Lee, J. C., Li, W, J., Kim, C. J. and Agasar, D. (2009). Production, characterization and application of keratinase from *Streptomyces gulbargensis*. *Bioresource Technology*. 100(5): 1866-1871

Sylvain, L.S., Lucia, V. M. and Elisabetta, G. (2009). Effect of α-linolenic capric and lauric acid on the fatty acid biosynthesis in *Staphylococcus aureus. International Journal of Food Microbiology*. 129: 288-294.

Sylvia, D. M., Fuhrmann, J. J., Hartel, P. G. And Zuberer, D. A. (2005). *Principles and applications of soil microbiology (2nd edition)*. Upper Saddle Rivers, New Jeysey: Pearson Education Inc.

Tanaka, Y. T. and Omura, S. (1993). Agroactive compounds of microbial origin. *Annual Review of Microbiology*. 47: 57-87.

Tarachiwin, L., Ute, K., Kobayashi, A. and Fukusaki, E. (2007). 1H NMR based metabolic profiling in the evaluation of Japanese green tea quality. *Journal of Agricultural and Food Chemistry.* 55: 9330-9336.

Tarkka, M. and Hampp, R. (2008). Secondary metabolites of soil streptomycetes in biotic interaction. In: P. Karlovsky. *Secondary metabolite in soil ecology. Soil Biology 14* (pp. 107-111). Berlin Heidelberg: Springer-Verlag.

Taechowisan, T., Chanaphat, S., Ruensamran, W. and Phutdhawong, W. S. (2012). Antifungal activity of 3-methylcarbazoles from *Streptomyces* sp. LJK109; an endophyte in *Alpinia galanga*. *Journal of Applied Pharmaceutical Science*. 02(03): 124-128.

Taechowisan, T.; Chuaychot, N.; Chanaphat, S.; Wanbanjob, A.; Tantiwachwutikul, P. (2009). Antagonistic effects of *Streptomyces* sp. SRM1 on *Colletotrichum musae*. *Biotechnology*. 8(1): 86-92.

Thakur, D., Yadav, A., Gogoi, B. K. and Bora, T. C. (2007). Isolation and screening of streptomyces in soil of protected forest areas from the states of Assam and Tripura, India, for antimicrobial metabolites. *Journal de Mycologie Medicale*. 17: 242-249.

Than, P. P., Jeewom, R., Hyde, K. D., Pongsupasamit, S., Monkholpom, O. and Taylor, P. W. J. (2008a). Characterization and pathogenicity of Colletorichum species associated with anthracnose disease on chilli (*Capsicum* spp.) in Thailand. *Plant Pathology*. 57: 562-572.

Than, P. P., Prihastuti, H., Phoulivong, S., Taylor, P. W. J and Hyde, K, H. (2008b). Chilli anthracnose disease caused by *Colletotrichum* species, *Journal of Zhenjiang University Science B*. 9(10): 764-778

Thangapandian, V., Ponmurugan, P. and Ponmurugan, K. (2007). Actinomycetes Diversity in the rhizosphere soils of different medicinal plants in Kolly Hills-Tamilnadu, India, for secondary metabolite production. *Asian Journal of Plant Sciences*. 6(1): 66-70.

Tong, N and Bosland, P. W. (1999). *Capsicum tovarii*, a new member of the *Capsicum* complex. *Euphytica*. 109(2): 71-72.

Tsujibo, H., Kubota, T., Yamamoto, M., Miyamoto, K and Inamori, Y. (2003). Characteristics of chitinase genes from an alkaliphilic actinomycete, *Nocardiopsis prasina* OPC-131. *Applied and Environmental Microbiology*. 69: 894-900.

Ullah, I., Arshad, M., Noursen, U., Chuadhry, M. J. I. and Jadoon, M. A. (2012). Isolation of *Streptomyces* from the sediments of selected thermal spring of Northern Pakistan and its intrinsic susceptibility and resistance. *Records of the Zoological Survey of Pakistan*. 21: 47-50.

Usuki, H., Nitoda, T., Ichikawa, M., Yamaji, N., Iwashita, T., Komura, H., and Kanzaki, H. (2008). TMG-chitotriomycin, an enzyme inhibitor specific for insect and fungal β-*N*-Acetylglucosaminidases, produced by actinomycete *Streptomyces anulatus* NBRC 13369. *Journal of the American Chemical Society*. 130(12): 4146–4152.

Valagurova, H. V., Koziritskaya, V. E., Iutinskaya, G. A., Pindrus, A. A. and Andreyuk, K. I. (1998). Diversity of soil streptomycetes at Evolution Canyon, Mount Carmel, Israel. *Actinomycetes*. 9: 10-18.

Vijayakumar, R., Gopika, G., Dhanasekaran, D. and Savaranamuthu, R. (2012). Isolation, characterization and antifungal activity of marine actinobacteria from Goa and Kerala, the west coast of India. *Archieves of Phytopathology and Plant Protection*. Doi: 10.1080/03235408.2012.655149.

Villas-Boas, S. G., Noel, S., Lane, G. A., Attwood, G. and Cookson, A. (2006). Extracellular metabolomics: A metabolomic footprinting approach to assess fiber degradation in complex media. *Analytical Biochemistry*. 349: 297-305

Vining, L. C. (1979). Antibiotic tolerance in producer organisms. *Advances in Applied Microbiol*ogy. 25: 147-168.

Vivantis. (2010). Retrieved from http://www.vivantis.com.

Von Arx, J. A. (1957). Die Arten der Gattung Colletotrichum Cda. *Phytopathologische Zeitschriff*. 29: 414-468.

Waksman, S. A., Reilly, H. C. and Johnstone, D. B. (1946). Isolation of Streptomycin-producing strains of *Streptomyces griseus*. *Journal of Bacteriology*. 52(3):393-397.

Walters, D., Raynor, L., Mitchell, A., Walker, R and Walker, K. (2004). Antifungal activities of four fatty acids against plant pathogenic fungi. *Mycopathologia.* 157(1): 87-90.

Wang, X., Huang, L., Kang, Z., Buchenauer, H and Gao, X. (2010). Optimization of the fermentation process of Actinomycete strain Hhs.015^{T}. *Journal of Biomedicine and Biotechnology*. Doi:10.1155/2010/141876.

Wang, Y., Zhang, Z. S., Ruan, J. S.,Wang, Y. M. and Ali, S. M. (1999). Investigation of actinomycete diversity In the tropical rainforests of Singapore. *Journal of Industrial Microbiology & Biotechnology*. 23(3): 178-187.

Ward, J. L., Baker, J. M., Miler, S. J., Deborde, C., Maucourt, M., Biais, B., Rolin, D., Moing, A., Moco, S., Vervoort, J., Lommen, A., Schafer, H., Humpfer, E. and Beale, M. H. (2010). An inter laboratory comparison demonstrates thet 1H-NMR metabolite fingerprinting is a robust technique for collaborative plant metabolomic data collection. *Metabolomics*. 6:263-273.

Wawrik, B., Kerkhof, L, Kukor, J. and Zylstra, G. (2005). Effect of different carbon sources on community composition of bacterial enrichment from soil. *Applied and Environmental Microbiology*. 71(11): 6776–6783.

Waybright, T. J., Van, Q. N. V., Muschik, G. M., Conrads, T. P. V eenstra, T. D. and Issaq, H (2006). LC-MSin metabolomics: Optimization of experimental conditions for the analysis of metabolite in human urine. *Journal of Liquid Chomatortography and Related Technologies*. 29: 2475-2497.

Weist, S. and Süssmuth, R. D. (2005). Mutational biosynthesis – a tool for the generation of structural diversity in the biosynthesis of antibiotics. *Applied Microbiology and Biotechnology*. 68: 141-150.

Wentzel, A., Sletta, H., Consortium, S., Ellingsen, T. E. and Bruheim, P. (2012). Intracellular metabolite pool changes in response to nutrient depletion induced metabolic switching in *Streptomyces coelicolor*. *Metabolites*. 2: 178-194.

Wharton, P. S., Diéguez-Uribeonodo, J. (2004). The biology of *Colletotrichum acutatum*. *Anales del Jardin Botanico de Madrid*. 61: 3-22.

White, T. J., Bruns, T., Lee, S. and Taylor, J. W. (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In M. A. Innis., D. H. Gelfand., J. J. Sninsky. and T. J. White. *PCR Protocols: A Guide to Methods and Applications* (pp. 315-322). New York: Academic Press, Inc.

Wiener, P. (2000). Antibiotic production in a spatially structured environment. *Ecology Letters*. 3: 122-133.

Wikipedia. (2012). Retrived from http://www.wikipedia.org

Woese, C. R. (1987). Bacterial evolution. *Microbiology Review*. 51: 221-271.

Worthington, P. A. (1988). Chemistry of sterol biosynthesis inhibitors: Piperazines, pyridines, pyrimidines, imidazoles, 1,2,4-triazoles, morpholines, piperidines, allylamines. *In* D. Berg and M, Plempel. *Sterol biosynthesis inhibitors: Pharmaceutical and agrochemical aspects: Part I; Chemistry mode of action, toxicology and general aspect of sterol biosynthesis inhibitors* (pp. 19-55). New York: Ellis Horwood Ltd.

Wu, J. Y., Jenn-Wen, H., Hsin-Der, S., Wei-Chen, L. and Yung-Chuan, L. (2008). Optimization of cultivation conditions for fungichromin production from *Streptomyces padanus* PMS-702. *Journal of the Chinese Institute of Chemical Engineers*. 39: 67–73.

Xiong, Z. Q., Zhang, Z. P., Li, Z. H., Wei, S. J. and Tu, G. Q. (2012). Characterization of *Streptomyces padanus* JAU4234, a producer of Actinomycin X_2, Fungichromin, and a new polyene macrolide antibiotic. *Applied and Environmental Microbiology*. 78(2): 589-592.

Xu, L., Li, Q. and Jiang, C. (1996). Diversity of soil actinomycetes in Yunnan, China. *Applied and Environmental Micrbiology*. 62: 244-248.

Xu, Z. F., Pan, A. Z., Yong, F., Shen, C. Y., Chen, Y. W. and Wu, R. H. (2012). Human umbilical mesenchymal stem cell and its adipogenic differentiation: Profiling by nuclear magnetic resonance spectroscopy. *World Journal of Stem Cells*. 4(4): 21-27.

Yoon, J. B. and Park, H. G. (2001). Screening method for resistance to pepper fruits anthracnose. Pathogen sporulation, innoculationmethods related to inoculation concentrations, post-inoculation environments. *Journal of Korean Society and Horticultural Science*. 42: 382-393.

Yuan, W. M. and Crawford, D. L. (1995). Characterization of *Streptomyces lydicus* WYEC108 as a potential biocontrol agent against fungal root and seed rots. *Applied and Environmental Microbiology*. 61: 3119-3128.

Yu, J., Liu, Q., Liu, Q., Liu, X., Sun, Q., Yan, J. Qi, X. and Fan, S. (2008). Effect of liquid culture requirements on antifungal antibiotic production by *Streptomyces rimosus* MY02. *Bioresources Technology*. 99: 2087-2091.

Zhang, N., Song, Z., Xie, Y., Cui, P., Jiang, H., Yang, T., Ju, R., Zhao, Y., Li, J. and Lui, X. (2013). Identification and characterization of antifungal active substances of *Streptomyces hygroscopicus* BS-112, *World Journal of Microbiology and Biotechnology*. Doi 10.1007s11274-013-1307-3.

Zhao, H. J., Parry, R. L., Ellis, D. I., Griffith, G. W. And Goodacre, R. (2006). The rapid differentiation of *Streptomyces* isolates using Fourier Transform Infrared spectroscopy. *Vibrational Spectroscopy*. 40(2): 213-218.

Zhao, K., Penttinen, P., Guan, T, Xiao, J., Chen, Q., Xu, J., Lindstrom, K., Zhang, X. and Stroble, G. A. (2011). The diversity and anti-microbial activity of endophytic actinomycetes isolated from medicinal plants in Panxi plateau, China. *Current Microbiology*. 62(1): 182-190.

Zhong, K., Gao, X. L., Xu, Z. J., Li, L. H., Rong-Jun Chen, R. J., Deng, X. J., Gao, H., Jiang, K., Yamaguchi, I. (2011). Isolation and characterization of a novel *Streptomyces* strain Eri11 exhibiting antioxidant activity from the rhizosphere of *Rhizoma Curcumae Longae*. *African Journal of Microbiology Research*. 5(11): 1291-1297.

Zin, N. M., Ng, K. T., Sarmin, N. M., Getha, K. and Tan, G. Y. (2011). Anti-trypanosomal activity of endophytic streptomycete. *Current Research in Bacteriology*. 4(1): 1-8.

Živković, S., Stojanović, S., Ivanović, Ž., Gavrilović, V., Popović, T. and Balaž, J. (2010). Screening of antagonistic activity of microorganisms against *Colletotrichuim acutatum* and *Colletotrichum gloeosporioides*. *Archives of Biological Science Belgrade*. 62(3): 611-623.

Zenova, G. M., Gryadunova, A. A., Pozdnyakov, A. I. and Zvyagintsev, D. G. (2008). Aerobic and microaerophilic actinomycetes of typical agropeat and peat soil. *Eurasian Soil Science*. 41(2): 210-214.