UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF PLANT GROWTH-PROMOTING RHIZOBACTERIA AND ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND YIELD OF STRAWBERRY (*Fragaria x ananassa* Duchesne)

NUR LAILI BINTI SAMSURRIJAL

FP 2019 45

INFLUENCE OF PLANT GROWTH-PROMOTING RHIZOBACTERIA AND ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND YIELD OF STRAWBERRY (*Fragaria* x *ananassa* Duchesne)

By

NUR LAILI BINTI SAMSURRIJAL

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

May 2019

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

INFLUENCE OF PLANT GROWTH-PROMOTING RHIZOBACTERIA AND ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND YIELD OF STRAWBERRY (*Fragaria* x *ananassa* Duchesne)

By

NUR LAILI SAMSURRIJAL

May 2019

Chair : Prof. Radziah Othman, PhD
Faculty : Agriculture

Strawberry is one of the main crops in Cameron Highlands, Pahang, Malaysia, which contribute significantly to the economy of local people. It was being grown all year round in substrate media under fertigation system. This system consumes high chemical fertilizer that can increase input cost and may lead to environmental pollution. The application of plant growth-promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF) could be the solution for better plant performance with lesser chemical input. The following studies aimed to 1) characterize the growth-promoting traits of bacteria isolated from strawberry roots, 2) determine the effects of PGPR and AMF on growth and fruit quality and 3) observe the bacterial colonization on plant roots under controlled condition. In Study 1, bacterial isolates obtained from rhizosphere of three strawberry cultivars (Camarosa, Festival and Chandler) grown in Cameron Highlands, were differentiated based on phenotypic characterization, evaluated for various beneficial traits and identified using molecular technique. The selected bacterial isolates were then evaluated for plant growth promoting performance. A fertigation study was conducted with five treatments consisting of four bacterial isolates and non-inoculated which was served as control. All plants were applied with 70% nutrient strength. The study was arranged in randomized complete block design (RCBD) with three replications (three plantlets per replication). In Study 2 the following treatments were; 1) control – non-inoculated (100% strength); 2) control - uninoculated (70% strength); 3) *G. mosseae* (70% strength); 4) *M. oxydans* (70% strength); and 5) dual inoculation (70% strength). Plant growth, berry yield production, fruit quality and plant root colonization were determined. In Study 3, colonization of bacteria on plant roots was observed using Scanning Electron Microscope (SEM). Results in Study 1 showed a total of 80 PGPR were isolated from different strawberry cultivars. Fifty isolates were positive for biological N_2-fixation and 26 showed potassium solubilizing activity. Five of the isolates showed phosphate solubilizing activity and the solubilizing efficiency ranged from 13.2 to 42.3%. Only few produced hydrolyzing enzyme. Most isolates produced phytohormone which ranged from 1.6 to 42.4 µg mL^{-1}. Four of the selected bacteria were identified as *Microbacterium oxydans* (STUPM01), *Bacillus cereus* (STUPM12),

Leclercia adecarboxylata (STUPM20) and *Pseudomonas umsongensis* (STUPM 25). Plants inoculated with *M. oxydans* showed better root development and highest in leaf surface area and leaf dry weight. In Study 2, microbial treatments enhanced root dry weight compared to non-inoculated control (70% strength). *M. oxydans* inoculation resulted in higher shoot and root dry weights than both controls. Leaf surface area also increased 13% - 21% with *G. mosseae* and *M. oxydans*, respectively. Microbial treatments resulted in increment of berry yield from 11% - 20% compared to non-inoculated control of the same nutrient strength. The number of fruits produced increased to 15% in *M. oxydans* treatment. Higher average weight of fruits was obtained in plant treated with *M. oxydans* and dual inoculation. Microbial treatments enhanced the amount of sugars (glucose, sucrose, fructose) as well organic acids (ascorbic, malic, citric) in the strawberry fruit. Mycorrhizal roots harvested were observed with the presence of vesicles and hyphae in the roots. In Study 3, the colonization of *M. oxydans* on strawberry roots was visually observed with SEM technique and bacterial cells were found to colonize the roots. These studies showed that beneficial PGPR were successfully isolated from strawberry roots, and growth and yield of strawberry was significantly increased when inoculated with PGPR and AMF.

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

PENGARUH RHIZOBAKTERIA PENGGALAK TUMBESARAN POKOK DAN KULAT MIKORIZA ARBUSKUL PADA PERTUMBUHAN DAN HASIL STRAWBERI (*Fragaria* x *ananassa* Duchesne)

Oleh

NUR LAILI BINTI SAMSURRIJAL

Mei 2019

Pengerusi : Prof. Radziah Othman, PhD
Fakulti : Pertanian

Strawberi adalah salah satu tanaman utama di Cameron Highlands, Pahang, Malaysia, yang memberi sumbangan besar kepada ekonomi penduduk tempatan. Ia ditanam sepanjang tahun menggunakan media substrat di bawah sistem fertigasi. Sistem ini menggunakan baja kimia yang tinggi yang dapat meningkatkan kos input dan boleh membawa kepada pencemaran alam sekitar. Penggunaan rhizobakteria penggalak tumbesaran pokok (PGPR) dan kulat mikoriza arbuskul (AMF) boleh menjadi penyelesaian untuk prestasi tumbuhan yang lebih baik di samping mengurangkan penggunaan input kimia. Kajian berikut bertujuan untuk 1) mengenalpasti ciri-ciri penggalak tumbesaran pada PGPR yang diasingkan dari akar strawberi, 2) menentukan kesan PGPR dan AMF terhadap tumbesaran pokok dan kualiti buah dan 3) membuat pemerhatian pada kolonisasi rhizobakteria terhadap akar tumbuhan di bawah penanaman terkawal. Dalam kajian 1, bakteria diasingkan dari rhizosfera tiga kultivar strawberi (Camarosa, Festival dan Chandler) yang ditanam di Cameron Highlands. Ianya dibezakan berdasarkan pencirian fenotip, kemudian ditentukan ciri-ciri bermanfaat dan dikenalpasti menggunakan teknik molekuler. Bakteria yang dikenalpasti telah dipilih untuk dinilai prestasinya pada tumbesaran pokok. Satu kajian fertigasi dijalankan dengan lima rawatan yang terdiri daripada empat jenis bakteria, manakala rawatan tanpa inokulasi bakteria berfungsi sebagai kawalan. Kesemua tumbuhan menggunakan kekuatan nutrien sebanyak 70% daripada kekuatan nutrien yang biasa digunakan. Kajian ini disusun dalam rekabentuk blok rawak penuh lengkap (RCBD) dengan tiga replikasi (tiga tanaman setiap replikasi). Rawatan bagi kajian 2 pula adalah; 1) kawalan – tanpa inokulasi (100% nutrien); 2) kawalan - tanpa inokulasi (70% nutrien); 3) *G. mosseae* (70% nutrien); 4) *M. oxydans* (70% nutrien); dan 5) dwi inokulasi (70% nutrien). Tumbesaran pokok, pengeluaran hasil beri, kualiti buah dan kolonisasi mikoriza pada akar tanaman telah ditentukan. Dalam kajian 3, kolonisasi bakteria pada akar tumbuhan telah diperhatikan dengan menggunakan mikroskop electron pengimbas (SEM). Keputusan diperolehi dalam kajian 1 menunjukkan bahawa sejumlah 80 PGPR telah diasingkan dari kultivar strawberi yang berbeza. Lima puluh PGPR adalah positif bagi pengikatan nitrogen dan 26 PGPR menunjukkan berlakunya aktiviti pelarutan kalium.

Lima PGPR menunjukkan aktiviti pelarutan fosforus dengan kadar pelarutan antara 13.2 hingga 42.3% manakala hanya beberapa PGPR menghasilkan enzim hidrolisasi. Kebanyakan PGPR dapat menghasilkan fitohormon dengan kadar antara 1.6 hingga 42.4 μg mL^{-1}. Empat jenis bakteria yang dipilih telah dikenalpasti sebagai *Microbacterium oxydans* (STUPM01), *Bacillus cereus* (STUPM12), *Leclercia adecarboxylata* (STUPM20) dan *Pseudomonas umsongensis* (STUPM 25). Pokok yang diinokulasi *M. oxydans* menunjukkan prestasi yang baik dalam perkembangan akar, juga paling tinggi luas permukaan daun dan berat kering daun. Manakala dalam kajian 2, berat kering akar bagi semua rawatan mikrob telah meningkat berbanding kawalan tanpa inokulasi (70% nutrien). Inokulasi *M. oxydans* pula menunjukkann luas permukaan daun dan berat kering akar yang tinggi berbanding kedua-dua rawatan kawalan. *G. mosseae* dan *M. Oxydans* masing-masing telah meningkatkan luas permukaan daun sebanyak 13% - 21%. Dari segi pengeluaran hasil beri, semua rawatan mikrob menunjukkan peningkatan sebanyak 11% - 20% berbanding kawalan tanpa inokulasi yang diberikan kekuatan nutrien yang sama. Bilangan buah beri yang dihasilkan pula meningkat kepada 15% dalam rawatan *M. Oxydans* dan purata berat beri yang lebih tinggi telah diperolehi dalam dua rawatan mikrob iaitu rawatan *M. oxydans* dan rawatan dwi inokulasi. Kandungan gula (glukosa, sukrosa, fruktosa) dan asid organik (askorbik, malik, sitrik) yang terdapat di dalam buah strawberi juga menunjukkan peningkatan dalam semua rawatan mikrob. Akar pokok yang dirawat mikoriza pula dituai dan dilihat kesan kolonisasi di mana menunjukkan kehadiran vesikel dan hifa di dalamnya. Dalam kajian 3, kolonisasi *M. oxydans* pada akar strawberi dilihat secara visual dengan teknik SEM dan sel-sel bakteria dijumpai pada permukaan akar. Seluruh kajian ini telah membuktikan bahawa beberapa jenis bakteria bermanfaat telah berjaya diasingkan daripada akar strawberi dan mempengaruhi tumbesaran dan hasil strawberi dengan memberi peningkatan secara signifikan apabila diinokulasi PGPR dan AMF.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and appreciation to my supervisor Prof. Radziah Othman for excellent guidance, continuous support and encouragement throughout the experiments and preparation of this thesis. A sincere appreciation also goes to my supervisor Assoc. Prof. Dr. Siti Zaharah Sakimin for the valuable suggestions and help during completing this study.

Special thanks to Datuk Syed Abdul Rahman and his staff from Al – Mashoor Strawberry Farm, Cameron Highlands, for providing materials and preparing the suitable place for planting.

I really appreciate the help from the staff in MARDI, Cameron Highlands especially Mrs. Shazalwardi Shoib, during the planting period while in Al – Mashoor Strawberry Farm.

A very much appreciation to the staff of Department of Land Management and Department of Crop Science, Faculty of Agriculture, for their help during the analysis of samples. I also wish to thank the staff of Microscopy Unit, Bioscience Institute for the assistance on determining bacterial root colonization and to the staff at Halal Products Research Institute for conducting HPLC.

Last but not least, I am greatly indebted to my parents, sisters and brothers for their love, support and encouragement. Special thanks to Nur Affah Zubir, Rohaniza Che Musa, Nur Syamimi A Rahman, Khairul Amin Ishak, Nur Walidah Ahmad, Noor Hidayah Hashim, Siti Nurain Sambuddin, Maizatul Idayu Othman, Nur Hanani Hanis Nawar, Nur Mahfuzah Noor Affendi and Mohd. Imran Suboh for their advice, help, moral support and the memorable days we shared.

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

Radziah Othman, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Siti Zaharah Sakimin, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

_____

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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 other 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 the 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) Rules 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 Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: Nur Laili Samsurrijal (GS39069)

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: Radziah Othman

Signature: _____
Name of Member of
Supervisory Committee: Siti Zaharah Sakimin

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AMF	Arbuscular Mycorrhizal Fungi
cfu	colony forming unit
cv	cultivar
DAI	Days After Inoculation
DAT	Days After Transplanting
EC	electrical conductivity
HDTMA	hexadecyltrimethylammonium
IAA	Indole-3 Acetic Acid
PBS	Phosphate Buffer Saline
PGPR	Plant Growth-promoting Rhizobacteria
RCBD	Randomized Completely Block Design
rpm	revolutions per minute
SEM	Scanning Electron Microscopy
TSA	Tryptic Soy Agar
TSB	Tryptic Soy Broth

CHAPTER 1

INTRODUCTION

Strawberries (*Fragaria* x *ananassa* Duchesne) are commonly found in its original cold sub-tropical and temperate region. In tropical region of Malaysia, they are widely grown all-year round at the high-latitude part known as Cameron Highlands. It is highly valued fruit crop and one of the most important species of berry fruits in the world (Pesakovic *et al.*, 2013). Strawberry gives the quickest profit in a short time and it is among the popular attraction in Cameron Highlands. They are mostly grown under greenhouse system and using cocopeat as a substrate of planting medium. Few disadvantages of using substrate are it consumes high inputs of water and fertigation, nearly tripled the inputs than that of field grown and increase in cost as well. Too much fertigation might damage the crop and can cause environmental pollution (Landis *et al*., 2010).

Compared to soils, substrate used in fertigation lacks of advantageous microorganisms like plant growth-promoting rhizobacteria (PGPR) and arbuscular mycorrhizal fungi (AMF) (Boyer *et al.,* 2016). The application of microorganisms is essential as an alternative to achieve sustainable agriculture and yet able to lessen the amount of fertigation requirement (Jeffries *et al.,* 2003). The idea of applying microorganisms on plant to lower the amount of chemical fertilizers being used is not new. The utilization to partially or maybe fully replacing fertilizers is however not much taken into the attention (Hungria *et al.,* 2013). The use of these beneficial microorganisms are always known to boost plant growth and help in sustaining the environmental health (Mitter *et al.,* 2013). Roots excrete nutrients-rich exudates which make them as a perfect factory that convey some plant-microbes interaction. The efficient use of microbial inoculant is the vital plan towards a sustainable agriculture and environmentally friendly with the purpose to reduce the chemical fertilizers, pesticides or the artificial growth regulator (Adesemoye *et al*., 2009; Hungria *et al*., 2010, 2013).

Studies have revealed most of bacterial species related with plant rhizosphere are beneficial for growth of plant, crop quality and yield, and they were known as PGPR. PGPR are beneficial whether for forage crops, cash crops or field production (Cvijanovic *et al.,* 2007; Pesakovic *et al.,* 2013). The AMF are obligate symbionts for most plant. The interaction of AMF and plant is also mutual and there is a bidirectional nutrient transfer between them (Bonfante and Andrea, 2008). In a study done by Borkowska (2002), commercial AMF inoculum was reported to enhance the growth of root, leaf area and crown of strawberry plant and even tolerance to water stress. Few other studies also showed better performance of strawberry plant with the addition of AMF (Castellanos-Morales *et al.,* 2010). Meanwhile the rhizospheric microbial consortium with mineral fertilization showed improvement in nutrient use efficiency in plant (Meena *et al*., 2017). There are potential of soil microorganisms in contributing positive effects to plant. The use of beneficial microorganisms instead of synthetic chemical in field will lead to sustainable fruit production. The use of the beneficial microbes in plants such as strawberry is very uncommon but their introduction into growth media substrate might improve plant growth and fruit quality. Since the beneficial microbes such as PGPR and

AMF in growth media substrate are almost absent, application of these microorganisms can potentially achieve better plant growth performance and yield of strawberry.

The study aimed to examine the effects of strawberry plant inoculated with PGPR and AMF. The ability of these microorganisms in creating healthy rhizosphere will improve the growth, yield and quality of strawberry. Therefore, the objectives of the study were:

1. To characterize the growth-promoting traits of bacteria isolated from strawberry roots from Cameron Highlands and their performances on plant growth.

2. To determine the effects of PGPR and AMF on growth, quality of strawberry production and mycorrhizal colonization.

3. To observe bacterial colonization on plant roots under controlled condition.

BIBLIOGRAPHY

Aaby, K., Ekeberg, D. and Skrede, G. 2007. Characterization of phenolic compounds in strawberry (*Fragaria* x *ananassa*) fruits by different HPLC detectors and contribution of individual compounds to total antioxidant capacity. *Journal Agriculture Food Chemistry* 55: 4395–4406.

Adesemoye, A. O., Torbert, H. A. and Kloepper, J. W. 2009. Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers. *Microbiology Ecology* 58: 921-929.

Ahemad, M. 2012. Implications of bacterial resistance against heavy metals in bioremediation: a review. *Institute of Integrative Omics and Applied Biotechnology Journal* 3: 39–46.

Ahemad, M. and Khan, M. S. 2012. Effects of pesticides on plant growth promoting traits of *Mesorhizobium* strain MRC4. *Journal of Saudi Society of Agricultural Science* 11: 63–71.

Ahemad, M. and Kibret, M. 2014. Mechanisms and applications of plant growth promoting rhizobacteria: current perspective. *Journal of King Saud University* 26: 1–20.

Ahemad, M. and Malik, A. 2011. Bioaccumulation of heavy metals by zinc resistant bacteria isolated from agricultural soils irrigated with wastewater. *Bacteriology Journal* 2: 12–21.

Ahemad, M., Khan, M. S., Zaidi, A. and Wani, P. A. 2009. Remediation of herbicides contaminated soil using microbes. In *Microbes in Sustainable Agriculture*. ed. Khan, M. S., Zaidi, A. and Musarrat, J. pp. 261 – 284. New York: USA Nova Science Publishers.

Aini, N., Yamika, W. S. D. and Ulum, B. 2019. Effect of nutrient concentration, PGPR and AMF on plant growth, yield, and nutrient uptake of hydroponic lettuce. *International Journal of Agriculture and Biology* 21(1): 175-183.

Akiyama, K., Matsuzaki, K. I. and Hayashi, H. 2005. Plant sesquiterpenes induce hyphal branching in arbuscular mycorrhizal fungi. *Nature* 435: 824-827.

Al-Garni, S. M. S. 2006. Increasing NaCl-salt tolerance of a halophytic plant *Phragmites australis* by mycorrhizal symbiosis. *American-Eurasian Journal of Agricultural and Environmental Science* 1: 19–26.

Alsmairat, N. G., Al-Ajlouni, M. G., Ayad, J. Y., Othman, Y. A. and Hilaire, R. S. 2018. Composition of soilless substrates affect the physiology and fruit quality of two strawberry (*Fragaria* x *ananassa* Duch.) cultivars. *Journal of Plant Nutrition* 41(18): 2356-2364.

Ameri, A. 2012. Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. *African Journal of Biotechnology* 11(56): 11960–66.

Amil-Ruiz, F., Blanco-Portales, R., Munoz-Blanco, J. and Caballero, J. L. 2011. The strawberry plant defense mechanism: a molecular review. *Plant and Cell Physiology* 52(11): 1873–1903.

Antoun, A. and Prevost, D. 2005. Ecology of plant growth promoting rhizobacteria. In *PGPR: Biocontrol and Biofertilization*, ed. Z. A. Siddique, pp. 1-38. Dordrecht, Netherlands: Springer.

Aslantas, R., Cakmakci, R. and Sahin, F. 2007. Effect of plant growth promoting rhizobacteria on young apple tree growth and fruit yield under orchard conditions. *Scientia Horticulturae* 111: 371–377.

Bago, B., Pfeffer, P. E., Abubaker, J., Jun, J., Allen, J. W., Brouillette, J. and Shachar-Hill, Y. 2003. Carbon export from arbuscular mycorrhizal roots involves the translocation of carbohydrate as well as lipid. *Plant Physiology* 131(3): 1496-1507.

Bais, H. P., Weir, T. L., Perry, L. G., Gilroy, S. and Vivanco, J. M. 2006. The role of root exudates in rhizosphere interactions with plants and other organisms. *Annual Review of Plant Biology* 57: 233–266.

Barea, J. M., Pozo, M. J., Azcon, R. and Aguilar, C. A. 2005. Microbial co-operation in the rhizosphere. *Journal of Experimental Botany* 56(417): 1761–1778.

Barreto, V., Seldin, L. and De Araujo, F. F. 2011. Plant growth promoting rhizobacteria: fundamentals and applications. *Growth Lakeland* 18: 21–44.

Bashan, Y. and L. E. de-Bashan. 2005. Bacteria/plant growth-promotion. *Encyclopedia of Soils in the Environment* 1: 103–15.

Baslam, M. and Goicoechea, N. 2012. Water deficit improved the capacity of arbuscular mycorrhizal fungi (AMF) for inducing the accumulation of antioxidant compounds in lettuce leaves. *Mycorrhiza* 22(5): 347-359.

Baslam, M., Garmendia, I. and Goicoechea, N. 2013. Enhanced accumulation of vitamins, nutraceuticals and minerals in lettuces associated with Arbuscular Mycorrhizal Fungi (AMF): a question of interest for both vegetables and humans. *Agriculture* 3(1): 188-209.

Basson, C. E., Groenewald, J. H., Kossmann, J., Cronje, C. and Bauer, R. 2010. Sugar and acid-related quality attributes and enzyme activities in strawberry fruits: invertase is the main sucrose hydrolysing enzyme. *Food Chemistry* 121: 1156–1162.

Baylis, G. T. S. 1962. Rhizophagus: the catholic symbiont. *Australian Journal of Science* 25: 195-200.

Berg, G. and Smalla, K. 2009. Plant species and soil type cooperatively shape the structure and function of microbial communities in the rhizosphere. *FEMS Microbiology Ecology* 68: 1–13.

Besserer, A., Puech-Pages, V., Kiefer, P., Gomez-Roldan, V., Jauneau, A., Roy, S.,

Portais, J. C., Roux, C., Becard, G. and Sejalon-Delmas, N. 2006. Strigolactones stimulate arbuscular mycorrhizal fungi by activating mitochondria. *PLOS Biology* 4(7): e226.

Bhardwaj, D. 2014. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories* 13(1): 1-9.

Bharti, N., Yadav, D., Barnawal, D., Maji, D. and Kalra, A. 2013. *Exiguobacterium oxidotolerans*, a halotolerant plant growth promoting rhizobacteria, improves yield and content of secondary metabolites in *Bacopa monnieri* (L.) Pennell under primary and secondary salt stress. *World Journal of Microbiology and Biotechnology* 29: 379–387.

Bhattacharyya, P. N. and D. K. Jha. 2012. Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture. *World Journal of Microbiology and Biotechnology* 28: 1327–50.

Bianco, C. and Defez, R. 2010. Improvement of phosphate solubilization and *Medicago* plant yield by an indole-3-acetic acid-overproducing strain of *Sinorhizobium meliloti*. *Applied Environmental Microbiology* 76: 4626–4632.

Bishop, P.E. and Jorerger, R. D. 1990. Genetics and molecular biology of an alternative nitrogen fixation system. *Plant Molecular Biology* 41: 109– 125.

Bona, E., Lingua, G., Manassero, P., Cantamessa, S., Marsano, F., Todeschini, V., Copetta, A., Massa, N., Avidano, L., Gamalero, E. and Berta, G. 2015. AM fungi and PGP pseudomonads increase flowering, fruit production and vitamin content in strawberry grown at low nitrogen and phosphorus levels. *Mycorrhiza* 25: 181–93.

Bonfante, P. and Andrea, G. 2008. Plants and arbuscular mycorrhizal fungi: an evolutionary-developmental perspective. *Trends in Plant Science* 13(9): 492–98.

Bonfante, P. and Andrea, G. 2010. Mechanisms underlying beneficial plant-fungus interactions in mycorrhizal symbiosis. *Nature Communications* 1(4): 48.

Borkowska, B. 2002. Growth and photosynthetic activity of micro-propagated strawberry plants inoculated with endomycorrhizal fungi (AMF) and growing under drought stress. *Acta Physiologiae Plantarum* 24: 365-370.

Borowicz, V. A. 2010. The impact of arbuscular mycorrhizal fungi on strawberry tolerance to root damage and drought stress. *Pedobiologia* 53(4): 265-270.

Boucher, Y., Douady, C. J., Papke, R. T., Walsh, D. A, Boudreau, M. E. R., Nesbo, C. L., Case, J. and Doolittle, W. F. 2003. Lateral gene transfer and the origins of prokaryotic groups. *Annual Review of Genetics* 37: 283-328.

Bowles, T. M., Barrios-masias, F. H. Eli A. Carlisle, E. A., Cavagnaro, T. R. and Louise E. J. 2016. Science of the total environment effects of arbuscular mycorrhizae on tomato yield, nutrient uptake, water relations and soil carbon dynamics under

deficit irrigation in field conditions. *Science of the Total Environment* 566–567: 1223–34.

Boyer, L. R., Feng, W., Gulbis, N., Hajdu, K., Harrison, R. J., Jeffries, P. and Xu, X. 2016. The use of arbuscular mycorrhizal fungi to improve strawberry production in coir substrate. *Frontiers in Plant Science* 7: 1237.

Bressan, R., Bohbert, H. and Zhu, J. K. 2009. Abiotic stress tolerance: from gene discovery in model organisms to crop improvement. *Molecular of Plant* 2: 1-2.

Buee, M., Rossignol, M., Jauneau, A., Ranjeva, R. and Becard, G. 2000. The pre-symbiotic growth of arbuscular mycorrhizal fungi is induced by a branching factor partially purified from plant root exudates. *Molecular of Plant-Microbe Interaction* 13: 693–698.

Cai, T., Cai, W., Zhang, J., Zheng, H., Tsou, A. M., Xiao, L., Zhong, Z. and Zhu, J. 2009. Host legume-exuded antimetabolites optimize the symbiotic rhizosphere. *Molecular of Microbiology* 73: 507-517.

Cai, Z., Kastell, A., Knorr, D. and Smetanska, I. 2012. Exudation: an expanding technique for continuous production and release of secondary metabolites from plant cell suspension and hairy root cultures. *Plant Cell Reports* 31: 461-477.

Carvalhais, L. C., Dennis, P. G., Fan, B., Fedoseyenko, D., Kierul, K., Becker, A., Von Wiren, N. and Borriss, R. 2013. Linking plant nutritional status to plant-microbe interactions. *PLoS One* 8(7): e68555.

Cassells, A., Mark, G. and Periappuram, C. 1996. Establishment of arbuscular mycorrhizal fungi in autotrophic strawberry cultures in vitro. Comparison with inoculation of microplants in vivo. *Agronomie* 16(10): 625-632.

Castellanos-Morales, V., Villegas, J., Wendelin, S., Vierheilig, H., Eder, R. and Cardenas-Navarro, R. 2010. Root colonisation by the arbuscular mycorrhizal fungus *Glomus intraradices* alters the quality of strawberry fruits (*Fragaria* × *ananassa* Duch.) at different nitrogen levels. *Journal of Science and Food Agriculture* 90: 1774–1782.

Castro, I., Goncalves, O., Teixeira, J. A. and Vicente, A. A. 2002. Comparative study of selva and camarosa strawberries for the commercial market. *Journal of Food Science* 67: 2132–2137.

Cecatto, A. P., Fatima, M. R., Eunice, O. C., Jesus, M. and Pedro, P. 2016. A mycorrhizal inoculation affects the phytochemical content in strawberry fruits. *Acta Scientiarum Agronomy* 38(2): 227–237.

Cekic, C. and Yilmaz, E. 2011. Effect of arbuscular mycorrhiza and different doses of phosphor on vegetative and generative components of strawberries applied with different phosphor doses in soilless culture. *African Journal of Agricultural Research* 6(20): 4736-4739.

Chandler, D., Davidson, G., Grant, W. P., Greaves, J. and Tatchell, G. M. 2008. Microbial biopesticides for integrated crop management: an assessment of environmental and regulatory sustainability. *Trends Food Science and Technology* 19: 275–283.

Chen, S., Jin, W., Liu, A., Zhang, S., Liu, D., Wang, F. and He, C. 2013. Arbuscular mycorrhizal fungi (AMF) increase growth and secondary metabolism in cucumber subjected to low temperature stress. *Scientia Horticulturae* 160(1): 222-229.

Choi, J. S. and Kim, Y. H. 2017. Research on export possibility of korean agricultural products to halal markets using PLS-SEM-Focusing on Malaysia and Indonesia. *Korean Journal of Food Marketing Economics* 34(4): 125-146.

Cordenunsi, B. R., Nascimento, J. R., Genovese, M. I. and Lajolo, F. M. 2002. Influence of cultivar on quality parameters and chemical composition of strawberry fruit grown in Brasil. *Journal of Agriculture and Food Chemistry* 50: 2581–86.

Costa, P.B., Granada, C.E., Ambrosini, A., Moreira, F., Souza, R., Passos, J. F. M., Arruda, L. and Passaglia, L. M. P. 2014. A model to explain plant growth promotion traits: A multivariate analysis of 2,211 bacterial isolates. *PLoS One* 9(12): e116020.

Costa, R., Gotz, M., Mrotzek, N., Lottmann, J., Berg, G. and Smalla, K. 2006. Effects of site and plant species on rhizosphere community structure as revealed by molecular analysis of microbial guilds. *FEMS Microbiology Ecology* 56: 236–249.

Crespo, P., Bordonaba, J. G., Terry, L. A. and Carlen, C. 2010. Characterisation of major taste and health-related compounds of four strawberry genotypes grown at different swiss production sites. *Food Chemistry* 122(1): 16–24.

Cvijanovic, G., Milosevic, N. and Jarak, M. 2007. The importance of diazotrophs as biofertilizers in the maize and soybean production. *Genetica* 39(3): 395–404.

D'Anna, F. D., Incalcaterra, G., Moncada, A., Miceli, A. 2003. Effects of different electrical conductivity levels on strawberry grown in soilless culture. *Acta Horticulturae* 609: 355-360.

Dakora, F. D. and Phillips, D. A. 2002. Root exudates as mediators of mineral acquisition in low-nutrient environments. *Plant Soil* 245: 35–47.

Davies P. J. 2010. The plant hormones: their nature, occurrence, and functions. In *Plant Hormones*. ed. Davies, P. J. Springer, Dordrecht.

De Boer, W., Folman, A. B., Summerbell, R. C. and Boddy, L. 2005. Living in a fungal world: impact of fungi on soil bacterial niche development. *FEMS Microbiology Reviews* 29: 795–811.

De Silva, A., Petterson, K., Rothrock, C. and Moore, J. 2000. Growth promotion of highbush blueberry by fungal and bacterial inoculants. *HortScience* 35: 1228–1230.

Dean, D.R., Jacobson, M.R., 1992. Biochemical genetics of nitrogenase. In *Biological Nitrogen Fixation*, ed. Stacey, G., Burris, R. H. and Evans, H. J. pp. 763-834. Chapman and Hall, New York.

Demba, D., Ndiogou, G., Carras, S. I., Adiouma, D. and Abdoulaye, D. T. 2019. Study of the effect of *Pseudomonas putida* and *Funneliformis mosseae* on the growth and productivity of tomato (*Solanum lycopersicum* L.) in Senegal. *European Scientific Journal* 15(6): 380.

Depardieu, C., Premont, V., Boily, C. and Caron, J. 2016. Sawdust and bark-based substrates for soilless strawberry production: irrigation and electrical conductivity management. *PLoS One* 11(4): e0154104.

Derkowska, E., Paszt, L. S., Harbuzov, A. and Sumorok, B. 2015. Root growth, mycorrhizal frequency and soil microorganisms in strawberry as affected by biopreparations. *Advances in Microbiology* 5: 65-73.

Dickson, S. and Kolesik, P. 1999. Visualisation of mycorrhizal fungal structures and quantification of their surface area and volume using laser scanning confocal microscopy. *Mycorrhiza* 9: 205-213.

Dixon, R. and Kahn, D. 2004. Genetic regulation of biological nitrogen fixation. *Nature Review of Microbiology* 2: 621-631.

Doumett, S., Fibbi. D., Cincinelli, A., Giordani, E., Nin, S. and Del, M. 2011. Comparison of nutritional and nutraceutical properties in cultivated fruits of *Fragaria vesca* L. produced in Italy. *Food Research International* 44(5): 1209–16.

Draft, M. J. and Nicolson, T. H. 1966. The effect of endogone mycorrhizae on plant growth. *New Phytologist* 65: 343-350.

Egamberdiyeva, D. 2007. The effect of plant growth promoting bacteria on growth and nutrient uptake of maize in two different soils. *Applied Soil Ecology* 36: 184–189.

Elbeltagy, A., Nishioka, K., Sato, T., Suzuki, H., Ye, B., Hamada, T., Isawa, T., Mitsui, H. and Minamisawa, K. 2001. Endophytic colonization and in plant nitrogen fixation by a *Herbaspirillum* sp. isolated from wild rice species. *Applied Environmental Microbiology*. 67: 5285-5293.

Erturk, Y., Ercisli, S. and Cakmakci, R. 2012. Yield and growth response of strawberry to plant growth-promoting rhizobacteria inoculation. *Journal of Plant Nutrition* 35(6): 817–26.

Erturk, Y., Ercisli, S., Haznedar, A. and Cakmakci, R. 2010. Effects of plant growth promoting rhizobacteria (PGPR) on rooting and root growth of kiwi fruit (*Actinidia deliciosa*) stem cuttings. *Biological Research* 43: 91–98.

Esitken, A., Karlidag, H., Ercisli, S., Turan, M. and Sahin, F. 2003. The effect of spraying a growth promoting bacterium on the yield, growth and nutrient element composition of leaves of apricot (*Prunus armeniaca* L. cv. Hacihaliloglu). *Australian Journal of Agricultural Research* 54: 377–380.

Esitken, A., Pirlak, L., Turan, M. and Sahin, F. 2006. Effects of floral and foliar application of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrition of sweet cherry. *Scientia Horticulturae* 110(4): 324–27.

Esitken, A., Yildiz, H. E., Ercisli, S., Donmez, M. F., Turan, M. and Gunes, A. 2010. Effects of plant growth promoting bacteria (PGPB) on yield, growth and nutrient contents of organically grown strawberry. *Scientia Horticulturae* 124: 62–66.

Etesami, H., Hossein, A. A. and Abolfazl, A. A. 2009. Evaluation of plant growth hormones production (IAA) ability by Iranian soils, rhizobial strains and effects of superior strains application on wheat growth indexes. *World Applied Sciences Journal* 6(11): 1576–1584.

Evelin, H., Kapoor, R. and Giri, B. 2009. Arbuscular mycorrhizal fungi in alleviation of salt stress: a review. *Annual Botany* 104: 1263–80.

Ezawa, T. and Saito, K. 2018. How do arbuscular mycorrhizal fungi handle phosphate? New insight into fine-tuning of phosphate metabolism. *New Phytologist* 220(4): 1116-1121.

Farahani, A., Lebaschi, H., Hussein, M., Shiranirad, A. H., Valadabadi, A. R. and Daneshian, J. 2008. Effects of arbuscular mycorrhizal fungi, different levels of phosphorus and drought stress on water use efficiency, relative water content and proline accumulation rate of Coriander (*Coriandrum sativum* L.). *Journal of Medicinal Plants Research* 2: 125–31.

Feng, G., Zhang, F. S., Li, X. L., Tian, C. Y., Tang, C. and Rengel, Z. 2002. Improved tolerance of maize plants to salt stress by arbuscular mycorrhiza is related to higher accumulation of soluble sugars in roots. *Mycorrhiza* 12: 185–90.

Finlay, R. D. 2005. Mycorrhizal symbiosis: Myths, misconceptions, new perspectives and future research priorities. *Mycologist* 19: 90-95.

Gerdemann, J. W. 1964. The effect of mycorrhiza on the growth of maize. *Mycologia* 56(3): 342-349.

Gine, B. J. and Terry, L. A. 2010. Manipulating the taste-related composition of strawberry fruits (*Fragaria* × *Ananassa*) from different cultivars using deficit irrigation. *Food Chemistry* 122(4): 1020–26.

Giovannetti, M. and Mosse, B. 1980. An evaluation of techniques for measuring vesicular-arbuscular mvcorrhizal infection in roots. *New Phytologist* 84: 489-5l0.

Giovannetti, M., Avio, L., Barale, R., Ceccarelli, N., Cristofani, R., Iezzi, A. and Scarpato, R. 2012. Nutraceutical value and safety of tomato fruits produced by mycorrhizal plants. *British Journal of Nutrition* 107(2): 242-251.

Glick, B. R. 2012. Plant growth-promoting bacteria: Mechanisms and applications. *Scientifica* 2012: 1-15.

Gordon, A. S. and Weber, R. P. 1950. Colorometric estimation of indoleacetic acid. *Plant*

Physiology 26: 192–195.

Gouda, S., Kerry, R. G., Das, G., Paramithiotis, S., Shin, H. S. and Patra, J. K. 2018. Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture. *Microbiological research* 206: 131-140.

Grant, O. M., Johnson, A. W., Davies, M. J., James, C. M. and Simpson, D. W. 2010. Physiological and morphological diversity of cultivated strawberry (*Fragaria* × *ananassa*) in response to water deficit. *Environmental and Experimental Botany* 68(3): 264–72.

Gray, E. J. and Smith, D. L. 2005. Intracellular and extracellular PGPR: commonalities and distinctions in the plant-bacterium signalling processes. *Soil Biology and Biochemical* 37: 395–412.

Gryndler, M., Vosatka, M., Hrselova, H., Catska, V., Chvatalova, I. and Jansa, J. 2002. Effect of dual inoculation with arbuscular mycorrhizal fungi and bacteria on growth and mineral nutrition of strawberry. *Journal of Plant Nutrition* 25(6): 1341–58.

Guerrero-molina, M. F., Winik, B. C. and Pedraza, R. O. 2012. More than rhizosphere colonization of strawberry plants by *Azospirillum brasilense*. *Applied Soil Ecology* 61: 205–12.

Gunes, A., Ataoglu, N., Turan, M., Esitken, A. and Ketterings, Q. M. 2009. Effects of phosphate-solubilizing microorganisms on strawberry yield and nutrient concentrations. *Journal of Plant Nutrition and Soil Science* 172: 385– 392.

Guo, Y., Ni, Y. and Huang, J. 2010. Effects of rhizobium, arbuscular mycorrhiza and lime on nodulation, growth and nutrient uptake of lucerne in acid purplish soil in China. *Tropical Grasslands* 44: 109–14.

Gupta, A., Gopal, M. and Tilak, K. V. 2000. Mechanism of plant growth promotion by rhizobacteria. *Indian Journal of Experimental Biology* 38: 856–862.

Gupta, S. S. 2003. Chemotactic response of plant-growth-promoting bacteria towards roots of vesicular-arbuscular mycorrhizal tomato plants. *FEMS Microbiology Ecology* 45: 219–227.

Guttman, D., McHardy, A. C. and Schulze-Lefert, P. 2014. Microbial genome-enabled insights into plant-microorganism interactions. *Nature Review of Genetics* 15: 797-813.

Hamdy, E. L. Z., Czarnes, S., Hallett, P. D., Alamercery, S., Bally, R. and Monrozier, L. J. 2007. Early changes in root characteristics of maize (*Zea mays*) following seed inoculation with the PGPR *Azospirillum lipoferum* CRT1. *Plant Soil* 291: 109–118.

Hancock, J. F. 1999. Strawberries crop production science. In *Horticulture*. CABI Publishing 109-112.

Harrison, M. J. 2005. Signaling in the arbuscular mycorrhizal symbiosis. *Annual Review of Microbiology* 59: 19–42.

Hart, M., Forsythe, J., Oshowski, B., Bucking, H., Jansa, J. and Kiers, E. T. 2013. Hiding in a crowd - does diversity facilitate persistence of a low-quality fungal partner in the mycorrhizal symbiosis? *Symbiosis* 59: 47–56.

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

Helgason, T. and Fitter, A. 2005. The ecology and evolution of the arbuscular mycorrhizal fungi. *Mycologist* 19(3): 96–101.

Helgason, T., Daniell, T. J., Husband, R., Fitter, A. H. and Young, J. P. W. 1998. Ploughing up the wood-wide web? *Nature* 394: 431-431.

Hoeksema, J. D., Chaudhary, V. B., Gehring, C. A., Johnson, N. C., Karst, J., Koide, R. T., Pringle, A., Zabinski, C., Bever, J. D., Moore, J. C., Wilson, G. W. T., Klironomos, J. N. and Umbanhowar, J. 2010. A meta-analysis of context-dependency in plant response to inoculation with mycorrhizal fungi. *Ecology Letters* 13: 394-407.

Hossain, A., Begum, P., Zannat, M. S., Rahman, M. H. and Ahsan, M. 2016. Nutrient composition of strawberry genotypes cultivated in a horticulture farm. *Food Chemistry* 199: 648–52.

Hungria, M., Campo, R. J., Souza, E. M. and Pedrosa, F. A. 2010. Inoculation with selected strains of *Azospirillum brasilense* and *A. lipoferum* improves yields of maize and wheat in Brazil. *Plant Soil* 331: 413–425.

Hungria, M., Nogueira, M. A. and Araujo, R. S. 2013. Co-inoculation of soybeans and common beans with rhizobia and azospirilla: Strategies to improve sustainability. *Biology and Fertility of Soils* 49: 791-801.

Imperlini, E., Bianco, C., Lonardo, E., Camerini, S., Cermola, M., Moschetti, G., Defez, R. 2009. Effects of indole-3-acetic acid on *Sinorhizobium meliloti* survival and symbiotic nitrogen fixation and stem dry weight production. *Applied Microbiology and Biotechnology* 83: 727–738.

Isayenkov, S., Fester, T., and Hause, B. 2004. Rapid determination of fungal colonization and arbuscule formation in roots of *Medicago truncatula* using real-time (RT) PCR. *Journal of Plant Physiology* 161: 1379–1383.

Jeffries, P., Gianinazzi, S., Perotto, S., Turnau, K. and Barea, J. M. 2003. The contribution of arbuscular mycorrhizal fungi in sustainable maintenance of plant health and soil fertility. *Biology and Fertility of Soils* 37: 1–16.

Jensen, M. H. 1997. Hydroponics. *Hortscience* 32:1018- 1021.

Kafkas, E., Kosar, M., Paydas, S., Kafkas, S. and Baser, K. H. C. 2007. Quality

characteristics of strawberry genotypes at different maturation stages. *Food Chemistry* 100(3): 1229–36.

Kang, S. M., Hamayun, M., Joo, G. J., Khan, A. L., Kim, Y. H., Kim, S. K., Jeong, H. J. and Lee, I. J. 2010. Effect of *Burkholderia* sp. KCTC11096BP on some physiochemical attributes of cucumber. *European Journal of Soil Biology* 46: 264–268.

Kang, S. M., Khan, A. L., Waqas, M., You, Y. H., Kim, J. H., Kim, J. G., Hamayun, M. and Lee, I. J. 2014. Plant growth-promoting rhizobacteria reduce adverse effects of salinity and osmotic stress by regulating phytohormones and antioxidants in *Cucumis sativus*. *Journal of Plant Interaction* 9(1): 673-682.

Karlidag, H., Esitken, A., Turan, M. and Sahin, F. 2007. Effects of root inoculation of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrient element contents of leaves of apple. *Scientia Horticulturae* 114: 16–20.

Keutgen, A. and Pawelzik, E. 2007. Modifications of taste-relevant compounds in strawberry fruit under NaCl salinity. *Food chemistry* 105(4): 1487-1494.

Keyeo, F., Ai'shah, O. N. and Amir, H. G. 2011. Diazotroph in promoting growth of rice seedlings. *Biotechnology* 10(3): 267-273.

Khalid, A., Arshad, M. and Zahir, Z. A. 2004. Screening plant growth-promoting rhizobacteria for improving growth and yield of wheat. *Journal of Applied Microbiology* 96(3): 473–480.

Khaosaad, T., Vierheiling, H., Nell, M., Zitterl-Eglsser, K. and Novak, J. 2006. Arbuscular mycorrhiza alter the concentration of essential oils in oregano (*Origanum* sp., Lamiaceae). *Mycorrhiza* 16: 443–446.

Kim, J. and Rees, D. C. 1994. Nitrogenase and biological nitrogen fixation. *Biochemistry* 33: 389–397.

Kitir, N., Gunes, A., Turan, M., Yildirim, E., Topcuoglu, B., Turker, M. and Firildak, G. 2019. Bio-boron fertilizer applications affect amino acid and organic acid content and physiological properties of strawberry plant. *Erwerbs-Obstbau* 61(2): 129-137.

Klamkowski, K. and Treder, W. 2006. Morphological and physiological responses of strawberry plants to water stress. *Agriculturae Conspectus Scientificus* 71(4): 159–65.

Kloepper, J. W. 2003. A review of mechanisms for plant growth promotion by PGPR. In *6th international PGPR workshop* 10: 5-10.

Kloepper, J.W. and Schroth, M.N. 1981. Relationship of in vitro antibiosis of plant growth promoting rhizobacteria to plant growth and the displacement of root microflora. *Phytopathology* 71; 1020–1024.

Kloepper, J. W. and Schroth, M. N. Plant growth promoting rhizobacteria on radish. In *Proceedings of the Fourth International Conference on Plant Pathogenic Bacteria*, Angers, France 2: 879–892. *INRA*. 1978.

Kokalis-Burelle, N. 2003. Effects of transplant type, plant growth-promoting rhizobacteria and soil treatment on growth and yield of strawberry in Florida. *Plant and Soil* 256(2): 273–80.

Kosuta, S., Chabaud, M., Lougnon, G., Gough, C., Denarie, J., Barker, D. G. and Becard, G. 2003. A diffusible factor from arbuscular mycorrhizal fungi induces symbiosis-specific MtENOD11 expression in roots of *Medicago truncatula*. *Plant Physiology* 131: 952-962.

Koyuncu, M. and Dilmacunal, T. 2010. Determination of vitamin c and organic acid changes in strawberry by HPLC during cold storage. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 38(3): 95–98.

Krings, M., Taylor, T. N., Hass, H., Kerp, H., Dotzler, N. and Hermsen, E. J. 2007. Fungal endophytes in a 400-million-yr-old land plant: infection pathways, spatial distribution, and host responses. *New Phytologist 174*(3): 648-657.

Ladha, J. K., de Bruijn, F. J. and Malik, K. A. 1997. Introduction: assessing opportunities for nitrogen fixation in rice - a frontier project. *Plant Soil* 124: 1–10.

Ladygina, N. and Hedlund, K. 2010. Plant species influence microbial diversity and carbon allocation in the rhizosphere. *Soil Biology and Biochemical.* 42: 162–168.

Landis, T. D., Pinto, J. R. and Davis, A. S. Fertigation-injecting soluble fertilizers into the irrigation system: Part 2. In *Forest Nursery Note.* ed. Dumroese, R. K. and Landis, T. D. p. 4-9. Lincoln, NE: US Department of Agriculture, Forest Service, Natural Resources Conservation Service, National Agroforestry Center. 2010.

Lee, J. H., Khor, T. O., Shu, L., Su, Z., Fuentes, F. and Kong, A. T. 2013. Pharmacology and therapeutics dietary phytochemicals and cancer prevention : Nrf2 signaling, epigenetics, and cell death mechanisms in blocking cancer initiation and progression. *Pharmacology and Therapeutics* 137(2): 153-171.

Lehmann, A. and Rillig, M. C. 2015. Arbuscular mycorrhizal contribution to copper, manganese and iron nutrient concentrations in crops-A meta-analysis. *Soil Biology Biochemical* 81: 147–158.

Li, J. M., Jin, Z. X. and Gu, Q. P. 2011. Effect of plant species on the function and structure of the bacterial community in the rhizosphere of lead-zinc mine tailings in Zhejiang, China. *Canadian Journal of Microbiology* 57: 569–577.

Lingua, G., Bona, E., Manassero, P., Marsano, F. and Todeschini, V. 2013. Arbuscular mycorrhizal fungi and plant growth-promoting pseudomonads increases anthocyanin concentration in strawberry fruits (*Fragaria* x *Ananassa* var. Selva) in conditions of reduced fertilization. *International Journal of Molecular Science* 16207–25.

Lopez-Raez, J. A., Flors, V., Garcia, J. M. and Pozo, M. J. 2010. AM symbiosis alters phenolic acid content in tomato roots. *Plant Signaling and Behavior* 5(9): 1138-1140.

Lugtenberg, B. and Kamilova, F. 2009. Plant growth-promoting rhizobacteria. *Annual Review of Microbiology* 63: 541–556.

Lutfi, P. and Murat, K. 2009. Effects of plant growth promoting rhizobacteria on yield and some fruit properties of strawberry. *Journal of Plant Nutrition* 32: 1173–1184.

Mahmood, T., Anwar, F., Abbas, M., Boyce, M. C. and Saari, N. 2012. Compositional variation in sugars and organic acids at different maturity stages in selected small fruits from Pakistan. *International Journal of Molecular Science* 13(2): 1380–1392.

Malhotra, M. and Srivastava, S. 2009. Stress-responsive indole-3-acetic acid biosynthesis by *Azospirillum brasilense* SM and its ability to modulate plant growth. *European Journal of Soil Biology* 45: 73–80.

Mandave, P. C., Pawar, P. K., Ranjekar, P. K., Mantri, N. and Kuvalekar, A. A. 2014. Comprehensive evaluation of in vitro antioxidant activity, total phenols and chemical profiles of two commercially important strawberry varieties. *Scientia Horticulturae* 172: 124–34.

Martinez-Viveros, O., Jorquera, M. A., Crowley, D. E., Gajardo, G. and Mora, M. L. 2010. Mechanisms and practical considerations involved in plant growth promotion by rhizobacteria. *Journal of Soil Science and Plant Nutrition* 10: 293–319.

Matsubara, Y., Ishigaki, T. and Koshikawa, K. 2009. Changes in free amino acid concentrations in mycorrhizal strawberry plants. *Scientia Horticulturae* 119: 392–396.

Meena, V. S., Meena, S. K., Verma, J. P., Kumar, A., Aeron, A., Mishra, P. K. and Dotaniya, M. L. 2017. Plant beneficial rhizospheric microorganism (Pbrm) strategies to improve nutrients use efficiency: a review. *Ecological engineering*, 107: 8-32.

Mehnaz, S. and Lazarovits, G. 2006. Inoculation effects of *Pseudomonas putida*, *Gluconacetobacter azotocaptans* and *Azospirillum lipoferum* on corn plant growth under greenhouse conditions. *Microbiology Ecology* 51(3): 326–335.

Mendes, R., Garbeva, P. and Raaijmakers, J. M. 2013. The rhizosphere microbiome: Significance of plant beneficial, plant pathogenic, and human pathogenic microorganisms. *FEMS Microbiology Review* 37(5): 634-63.

Miransari, M. 2010. Contribution of arbuscular mycorrhizal symbiosis to plant growth under different types of soil stress. *Plant Biology* 12: 563–9.

Mitter, B., Brader, G., Afzal, M., Compant, S., Naveed, M., Trognitz, F. and Sessitsch, A. 2013. Advances in elucidating beneficial interactions between plants, soil and bacteria. *Advances in Agronomy* 121: 381-445.

Mohamed, I., Eid, K. E., Abbas, M. H., Salem, A. A., Ahmed, N., Ali, M. and Fang, C. 2019. Use of plant growth promoting rhizobacteria (PGPR) and mycorrhizae to improve the growth and nutrient utilization of common bean in a soil infected with white rot fungi. *Ecotoxicology and Environmental Safety* 171: 539-548.

Morton, J. B. and Benny, G. L. 1990. Revised classification of arbuscular mycorrhizal fungi (Zygomycetes): a new order, Glomales, two new suborders, Glomineae and Gigasporineae and two new families, Acaulosporaceae and Gigasporaceae with an emendation of Glomaceae. *Mycotaxon* 37: 471–91.

Mosse, B. 1953. Fructifications associated with mycorrhizal strawberry roots. *Nature* 171: 974.

Muzaffer, I., Pirlak, L., Esitken, A., Donmez, M. F., Turan, M. and Sahin, F. 2014. Plant growth-promoting rhizobacteria (PGPR) increase yield, growth and nutrition of strawberry under high-calcareous soil conditions. *Journal of Plant Nutrition* 37(7): 990–1001.

Mwajita, M. R., Murage, H., Tani, A. and Kahangi, E. M. 2013. Evaluation of rhizosphere, rhizoplane and phyllosphere bacteria and fungi isolated from rice in Kenya for plant growth promoters. *SpringerPlus* 2: 606.

Nadeem, S. M., Ahmad, M., Zahir, Z. A., Javaid, A. and Ashraf, M. 2014. The role of mycorrhizae and plant growth promoting rhizobacteria (PGPR) in improving crop productivity under stressful environments. *Biotechnology Advances* 32(2): 429–48.

Nadtochiy, S. M. and Redman, E. K. 2011. Mediterranean diet and cardio protection: the role of nitrite, polyunsaturated fatty acids and polyphenols. *Nutrition* 27(7-8): 733-744.

Naga, E. V. and Divakar, G. 2013. Screening and isolation of pectinase producing bacteria from various regions in Bangalore. *International Journal of Research in Pharmaceutical and Biomedical Science* 4(1): 151–54.

Nagahashi, G. and Douds, D. D. 1997. Appressorium formation by AM fungi on isolated cell walls of carrot roots. *New Phytologist* 136: 299-304.

Naher, U. A., Othman, R., Shamsuddin, Z. H. J., Saud, H. M. and Ismail, M. R. 2009. Growth enhancement and root colonization of rice seedlings by *Rhizobium* and *Corynebacterium* spp. *International Journal of Agriculture and Biology* 11: 586-590.

Nemec, S. 1981. Histochemical characterization of Glomus etunicatum infection of citrus limon roots. *Canadian Journal of Botany* 59: 609–17.

Nestby, R., Ieten, F., Pivot, D., Raynal Lacroix, C. and Evenhuis, B. 2004. Influence of mineral nutrients on strawberry fruit quality and their accumulation in plant organs. *Acta Horticulture* 649: 201–205.

Nguyen, C., Yan, W., Le Tacon, F. and Lapeyrie, F. 1992. Genetic variability of

phosphate solubilizing activity by monocaryotic and dicaryotic mycelia of the ectomyccorhizal fungus *Laccaria bicolor* (Maire) P.D. Orton. *Plant Soil* 143: 193–199.

Nicholas, O. I. and Olubukola, O. B. 2018. Below-ground-above-ground plant-microbial interactions: focusing on soybean, rhizobacteria and mycorrhizal fungi. *The Open Microbiology Journal* 12: 261-279.

Nicolson, T. H. and Gerdemann, J. W. 1968. Mycorrhizal endogone species. *Mycologia* 60(2): 313-325.

Njoloma, J., Tanaka, K., Shimizu, T., Nishiguchi, T., Zakria, M., Akashi, R., Oota, M. and Akao, S. 2006. Infection and colonization of aseptically micropropagated sugarcane seedlings by nitrogen-fixing endophytic bacterium, *Herbaspirillum* sp. B501gfp1. *Biology and Fertility of Soils* 43: 137-143.

Nuutila, A. M., Vestberg, M. and Kauppinen, V. 1995. Infection of hairy roots of strawberry (*Fragaria* x *Ananassa* Duch.) with arbuscular mycorrhizal fungus. *Plant cell reports* 14(8): 505-509.

Orhan, E., Esitken, E., Ercisli, S., Turan, M. and Sahin, F. 2006. Effects of plant growth promoting rhizobacteria (PGPR) on yield, growth and nutrient contents in organically growing raspberry. *Scientia Horticulturae* 111: 38–43.

Oskolina, N. M. and Zamorska, I. L. 2014. The content and composition of organic acids in strawberries (*Fragaria ananassa* Duch.)of various varieties, grown in the right-bank forest steppe zone of Ukraine. *Bulletin of the Uman National University of Horticulture* 1: 112-117.

Panhwar, Q. A., Radziah, O., Naher, U. A., Zaharah, A. R., Sariah, M. and Razi, M. I. 2012. Root colonization and association of phosphate-solubilizing bacteria at various levels of triple supper phosphate in aerobic rice seedlings. *African Journal of Microbiology Research* 6(10): 2277–86.

Parniske, M. 2008. Arbuscular mycorrhiza: the mother of plant root endosymbioses. *Nature Reviews Microbiology* 6(10): 763-775.

Paszt, L. S., Sumorok, B., Malusa, E., Gluszek, S. and Derkowska, E. 2011. The influence of bioproducts on root growth and mycorrhizal occurrence in the rhizosphere of strawberry plants 'Elsanta'. *Journal of Fruit and Ornamental Plant Research* 19(1): 13–34.

Pathak, D., Lone, R., Khan, S. and Koul, K. K. 2019. Isolation, screening and molecular characterization of free-living bacteria of potato (*Solanum tuberosum* L.) and their interplay impact on growth and production of potato plant under mycorrhizal association. *Scientia Horticulturae* 252: 388-397.

Patten, C. and Glick, B. R. 1996. Bacterial biosynthesis of indole-3- acetic acid. *Canadian Journal of Microbiology* 42: 207-220.

Perez-de-Luque, A., Tille, S., Johnson, I., Pascual-Pardo, D., Ton, J. and Cameron, D.

D. 2017. The interactive effects of arbuscular mycorrhiza and plant growth-promoting rhizobacteria synergistically enhance host plant defences against pathogens. *Scientific Reports* 7(1): 16409.

Pesakovic, M., Karaklajic-Stajic, Z., Milenkovic, S. and Mitrovic, O. 2013. Biofertilizer affecting yield related characteristics of strawberry (*Fragaria* x *ananassa* Duch.) and soil micro-organisms. *Scientia Horticulturae* 150: 238–43.

Philippot, L., Raaijmakers, J. M., Lemanceau, P. and Van der Putten, W. H. 2013. Going Back to the roots: the microbial ecology of the rhizosphere. *Nature Reviews Microbiology* 11(11): 789–99.

Phillips, J. M. and Hayman, D. 1970. Improved procedures for clearing roots and staining parasitic and vesicular-arbuscular mycorrhizal fungi for rapid assessment of infection. *Transactions of the British Mycological Society* 55(1): 158-161.

Pikovskaya, R. I. 1948. Mobilization of phosphorus in soil in connection with vital activity of some microbial species. *Microbiologiya* 17: 362– 370.

Piotr, S. M., Nes, A., Wold, A. B., Remberg, S. F., Martinsen, B. K. and Aaby, K. 2014. Effects of ripeness and cultivar on chemical composition of strawberry (*Fragaria* x *ananassa* Duch.) fruits and their suitability for jam production as a stable product at different storage temperatures. *Food Chemistry* 146: 412–22.

Pirozynski, K.A. and Malloch, D.W. 1975. The origin of land plants: a matter of mycotropism. *Biosystems* 6: 153–164.

Porcel, R. and Ruiz-Lozano, J. M. 2004. Arbuscular mycorrhizal influence on leaf water potential, solute accumulation, and oxidative stress in soybean plants subjected to drought stress. *Journal of Experimental Botany* 55: 1743–50.

Poulton, J. L., Bryla, D., Koide, R. T. and Stephenson, A. G. 2002. Mycorrhizal infection and high soil phosphorus improve vegetative growth and the female and male functions in tomato. *New Phytologist* 154: 255–264.

Rahman, M., Sabir, A. A., Mukta, J. A., Khan, M. M. A., Mohi-Ud-Din, M., Miah, M. G., Rahman, M. and Islam, M. T. 2018. Plant probiotic bacteria *Bacillus* and *Paraburkholderia* improve growth, yield and content of antioxidants in strawberry fruit. *Scientific Reports* 8: 2504.

Raklami, A., Bechtaoui, N., Tahiri, A., Anli, M., Meddich, A. and Oufdou, K. 2019. Use of rhizobacteria and mycorrhizae consortium in the open field as a strategy for improving crop nutrition, productivity and soil fertility. *Frontiers in Microbiology* 10: 1106.

Ramey, B. E., Koutsoudis, M., von Bodman, S. B. and Fuqua, C. 2004. Biofilm formation in plant-microbe associations. *Current Opinion in Microbiology* 7: 602–609.

Rechkemmer, G. 2001. Functional foods-nutrition of the future de-marketing strategy. *Research Report Special Issue* 1: 12–15.

Reinhardt, D. 2007. Programming good relations - development of the arbuscular mycorrhizal symbiosis. *Current Opinion in Plant Biology* 10(1): 98–105.

Remans, R., Ramaekers, L., Shelkens, S., Hernandez, G., Garcia, A., Reyes, G. L., Mendez, N., Toscano, V., Mullin, M., Galvez, L. and Vanderleyden, J. 2008. Effect of *Rhizobium-Azospirillu*m co-inoculation on nitrogen fixation and yield of two contrasting *Phaseolus vulgaris* L. genotypes cultivated across different environments in Cuba. *Plant Soil* 312: 25–37.

Resh, H. M. Hydroponic Food Production. Woodbridge Press: Santa Barbara, CA. 2004.

Requena, N. and Breuninger, M. 2004. The old arbuscular mycorrhizal symbiosis in the light of the molecular era. In *Progress in Botany*, ed. K. Esser, U. Luttge, W. Beyschlag and J. Murata, pp. 323-356. Berlin, Heidelberg: Springer.

Requena, N., Serrano, E., Ocon, A. and Breuninger, M. 2007. Plant signals and fungal perception during arbuscular mycorrhiza establishment. *Phytochemistry* 68(1): 33–40.

Rubio, L. M. and Ludden, P. W. 2008. Biosynthesis of the iron-molybdenum cofactor of nitrogenase. *Annual Reviews of Microbiology* 62: 93– 111.

Ruiz-Lozano, J. M., Porcel, R., Calvo-Polanco, M. and Aroca, R. 2018. Improvement of salt tolerance in rice plants by arbuscular mycorrhizal symbiosis. In *Root Biology*, pp. 259-279. Cham: Springer.

Ruzzi, M. and Aroca, R. 2015. Plant growth-promoting rhizobacteria act as biostimulants in horticulture. *Scientia Horticulturae* 196: 124–34.

Saharan, K., Schutz, L., Kahmen, A., Wiemken, A., Boller, T. and Mathimaran, N. 2018. Finger millet growth and nutrient uptake is improved in intercropping with pigeon pea through "biofertilization" and "bioirrigation" mediated by arbuscular mycorrhizal fungi and plant growth promoting rhizobacteria. *Frontiers in Environmental Science* 6: 46.

Saied, A. S., Keutgen, A. J. and Noga, G. 2005. The influence of NaCl salinity on growth, yield and fruit quality of strawberry cvs. 'Elsanta' and 'Korona'. *Scientia Horticulturae* 103(3): 289-303.

Santner, A., Calderon-Villalobos, L. I. A. and Estelle, M. 2009. Plant hormones are versatile chemical regulators of plant growth. *Nature Chemical Biology* 5: 301–307.

Santos, B. M. and Chandler, C. K. 2009. Influence of nitrogen fertilization rates on the performance of strawberry cultivars. *International Journal of Fruit Science* 9: 126–135.

Schubler, A., Schwarzott, D. and Walker, C. 2001. A new fungal phylum, the Glomeromycota: phylogeny and evolution. *Mycological Research* 105: 1413-1421.

Schwyn, B. and Neilands, J. 1987. Universal chemical assay for the detection and determination of siderophores. *Analytical Biochemistry* 160: 47–56.

Seema, K., Mehta, K. and Singh, N. 2018. Studies on the effect of plant growth promoting rhizobacteria (PGPR) on growth, physiological parameters, yield and fruit quality of strawberry cv. Chandler. *Journal of Pharmacognosy and Phytochemistry* 7(2): 383-387.

Serradilla, M. J., Lozano, M., Bernalte, M. J., Ayuso, M. C., Lopez-Corrales, M. and Gonzalez-Gomez, D. 2011. Physicochemical and bioactive properties evolution during ripening of Ambrunes' sweet cherry cultivar. *LWT Food Science and Technology* 44: 199–205.

Sevilla, M., Burris, R. H., Gunapala, N. and Kennedy, C. 2001. Comparison of benefit to sugarcane plant growth and $^{15}N_2$ incorporation following inoculation of sterile plants with *Acetobacter diazotrophicus* wild-type and Nif-mutant strains. *Molecular of Plant-Microbe Interaction* 14: 358:366.

Shanmugam, G. S. 2005. *Soil and Plant Response of Organic Amendments on Strawberry and Half-High Blueberry Cultivars*, Master's thesis, Dalhousie University, Halifax, Nova Scotia.

Sheng, M., Tang, M., Chen, H., Yang, B. W., Zhang, F. F. and Huang, Y. H. 2009. Influence of arbuscular mycorrhizae on the root system of maize plants under salt stress. *Canadian Journal of Microbiology* 55: 879–86.

Shridhar, B. S. 2012. Nitrogen fixing microorganisms. *International Journal of Microbiology Research* 3: 46-52.

Singh, A. and Singh, J. N. 2009. Effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cv. Sweet Charlie. *Indian Journal of Horticulture* 66: 220–224.

Smith, S. E. and Read, D. J. 2008a. *Mycorrhizal Symbiosis. 3rd*. New York: Academic Press.

Smith, S. E. and Read, D. J. 2008b. The symbionts forming arbuscular mycorrhizas. In *Mycorrhizal Symbiosis*, pp. 13–41. New York: Academic Press.

Smith, S. E. and Read, D. J. 2008c. Mycorrhizas in ecological interactions. In *Mycorrhizal Symbiosis*, pp. 573–610. New York: Academic Press.

Somasegaran, P. and Hoben, H. J. 1985. Methods in legume-Rhizobium technology. Paia, Maui: University of Hawaii NifTAL Project and MIRCEN, Department of Agronomy and Soil Science, Hawaii Institute of Tropical Agriculture and Human Resources, College of Tropical Agriculture and Human Resources.

Somers, E., Vanderleyden, J. and Srinivasan, M. 2004. Rhizosphere bacterial signalling: a love parade beneath our feet. *Critical Reviews on Microbiology* 30: 205–240.

Souza, R., Ambrosini, A. and Passaglia, L. M. P. 2015. Plant growth-promoting bacteria

as inoculants in agricultural soils. *Genetics and Molecular Biology* 419: 401–19.

Spaepen, S., Vanderleyden, J. and Remans, R. 2007. Indole-3-acetic acid in microbial and microorganism-plant signaling. *FEMS Microbiology Reviews* 31: 425-448

Sturm, K., Koron, D. and Stampar, F. 2003. The composition of fruit of different strawberry varieties depending on maturity stage. *Food Chemistry* 83: 417–22.

Sudhakar, P., Chattopadhyay, G. N., Gangwar, S. K. and Ghosh, J. K. 2000. Effect of foliar application of *Azotobacter, Azospirillum and Beijerinckia* on leaf yield and quality of mulberry (*Morus alba*). *Journal of Agriculture Science* 134: 227–234.

Sun, P., Mantri, N., Lou, H., Hu, Y., Sun, D., Zhu, Y., Dong, T. and Lu, H. 2012. Effects of elevated CO_2 and temperature on yield and fruit quality of strawberry (*Fragaria* × *ananassa* Duch.) at two levels of nitrogen application. *PLoS One* 7(7): e41000.

Surendirakumar, K., Pandey, R. R. and Muthukumar, T. 2019. Influence of indigenous arbuscular mycorrhizal fungus and bacterial bioinoculants on growth and yield of *Capsicum chinense* cultivated in non-sterilized soil. *The Journal of Agricultural Science* 157(1): 31-44.

Tamasloukht, M., Sejalon-Delmas, N., Kluever, A., Jauneau, A., Roux, C., Becard, G. and Franken, P. 2003. Root factors induce mitochondrial- related gene expression and fungal respiration during the developmental switch from asymbiosis to presymbiosis in the arbuscular mycorrhizal fungus *Gigaspora rosea*. *Plant Physiology* 131: 1468–1478.

Taylor, J. and Harrier, L. A. 2001. A comparison of development and mineral nutrition of micropropagated *Fragaria* x *ananassa* cv. Elvira (strawberry) when colonised by nine species of arbuscular mycorrhizal fungi. *Applied Soil Ecology* 18(3): 205-215.

Taylor, T. N., Remy, W., Hass, H. and Kerp, H. 1995. Fossil arbuscular mycorrhizae from the Early Devonian. *Mycologia* 87: 560-573.

Terakado-Tonooka, J., Ohwaki, Y., Yamakawa, H., Tanaka, F., Yoneyama, T. and Fujihara, S. 2008. Expresses *nifH* genes of endophytic bacteria detected in field-growth sweet potatoes (*Ipomoea batata* L.). *Microbes Environmental* 23: 89-93.

Todeschini, V., AitLahmidi, N., Mazzucco, E., Marsano, F., Gosetti, F., Robotti, E., Bona, E., Massa, N., Bonneau, L., Marengo, E., Wipf, D., Berta, G. and Lingua, G. 2018. Impact of beneficial microorganisms on strawberry growth, fruit production, nutritional quality, and volatilome. *Frontiers in Plant Science* 9: 1611.

Tomic, J. M., Milivojevic, J. M. and Pesakovic, M. I. 2015. The response to bacterial inoculation is cultivar-related in strawberries. *Turkish Journal of Agriculture and Forestry* 39: 332–341.

Turan, M., Ataoglu, N. and Sahin, F. 2007. Effects of *Bacillus* FS-3 on growth of tomato (*Lycopersicon esculentum* L.) plants and availability of phosphorus in soil. *Plant Soil Environment* 53: 58–64.

Turan, M., Ekinci, M., Yildrim, E., Gunes, A., Karagos, K., Kotan, R. and Dursun, A. 2014. Plant growth-promoting rhizobacteria improved growth, nutrient and hormone content of cabbage (*Brassica oleracea*) seedlings. *Turkish Journal of Agriculture and Forestry* 38: 327–33.

Umair, M., Inam-ul-Haq, M., Saeed, M., Altaf, A. and Azam, F. 2018. A brief review on plant growth promoting rhizobacteria (PGPR): a key role in plant growth promotion. *Plant Protection* 02 (02): 77-82.

Vessey, J. K. 2003. Plant growth-promoting rhizobacteria as biofertilizers. *Plant Soil* 255: 571 - 586.

Vestberg, M. 1992. Arbuscular mycorrhizal inoculation of micropropagated strawberry and field observations in Finland. *Agronomie* 12(1): 865-867.

Walker, T. S., Bais, H. P., Grotewold, E. and Vivanco, J. M. 2003. Root exudation and rhizosphere biology. *Plant Physiology* 132: 44–51.

Weissknopf, L., Le Bayon, R. C., Kohler, F., Page, V., Jossi, M., Gobat, J. M., Martinoia, E. and Aragno, M. 2008. Spatio-temporal dynamics of bacterial communities associated with two plant species differing in organic acid secretion: a one-year microcosm study on lupin and wheat. *Soil Biology and Biochemical* 40: 1772–1780.

Willems, A. 2007. The taxonomy of rhizobia: an overview. In F*irst International Meeting on Microbial Phosphate Solubilization*. ed. Velazquez, E. and Rodryguez-Barrueco, C., pp. 3-14. Berlin: Springer.

Yahya, A. and Syed, A. R. Production of strawberries in A-frame under tropical highlands, Malaysia. In *Proceeding of the International Conference on Vertical Farming and Urban Agriculture*, University of Nottingham, UK, Sept. 9-10, 2014.

Yildirim, E., Donmez, M. F. and Turan, M. 2008. Use of bioinoculants in ameliorative effects on radish plants under salinity stress. *Journal of Plant Nutrition* 31: 2059–2074.

You, M., Nishiguchi, T., Saito, A., Isawa, T., Mitsui, H. and Minamisawa, K. 2005. Expression of the *nifH* gene of a *Herbaspirillum* endophyte in wild rice species: daily rhythm during the light-dark cycle. *Applied Environmental Microbiology* 71: 8183-8190.

Yu, J., Wang, M., Dong, C., Xie, B., Liu, G., Fu, Y. and Liu, H. 2015. Analysis and evaluation of strawberry growth, photosynthetic characteristics, biomass yield and quality in an artificial closed ecosystem. *Scientia Horticulturae* 195: 188–94.

Zhao, K., Penttinen, P., Chen, Q., Guan, T., Lindstrom, K., Ao, X., Zhang, L. and Zhang, X. 2012a. The rhizospheres of traditional medicinal plants in Panxi, China, host a diverse selection of actinobacteria with antimicrobial properties. *Applied Microbiology and Biotechnology* 94: 1321–1335.

Zheng, J., Huang, C., Yang, B., Kallio, H., Liu, P. and Ou, S. 2019. Regulation of phytochemicals in fruits and berries by environmental variation—Sugars and organic acids. *Journal of Food Biochemistry* 43(6): e12642

BIODATA OF STUDENT

Nur Laili Samsurrijal was born in Alor Setar, Kedah on 7th August 1990. She obtained her primary and secondary educations from Sekolah Kebangsaan Binjal and Sekolah Menengah Kebangsaan Agama Kedah, Kedah, respectively. She attended Kedah Matriculation College for a year before being accepted into Universiti Putra Malaysia for bachelor degree study. She graduated with a Bachelor of Science Horticulture with honors in 2013.

In the year 2014, she enrolled for master study in Master of Science in Soils Science at Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia. Currently, she is seeking for job opportunity relevant to her field of study.

LIST OF PUBLICATIONS

Journal

Zakiah, M., Radziah,O., **Laili N. S**., Nashriyah, M., Jamil, A. Z. and Hasima N. M. Determination of nitrogen fixing capacity of bacteria isolated from the rhizosphere of *Acacia mangium* from the BRIS soil of Tembila, Besut, Terengganu, Malaysia. *International Journal of Engineering & Technology* 7 (4.43): 140-144.

Laili, N. S., Radziah, O. and Zaharah S. S. 2017. Isolation and characterization of plant growth-promoting rhizobacteria (PGPR) and their effects on growth of strawberry (*Fragaria ananassa*). *Bangladesh Journal of Botany* 46(1): 277-282.

Proceedings

Laili, N. S., Radziah, O. and Zaharah S. S. "Influence of Arbuscular Mycorrhizal Fungi and Plant Growth-promoting Rhizobacteria on Root Development and Yield of Strawberry (*Fragaria ananassa*) in Cameron Highlands", "Soil Science Conference of Malaysia 2016". TH Hotel & Convention Centre, Kuala Terengganu, Terengganu, 5 – 7 April 2016.

Laili, N. S., Radziah, O. and Zaharah S. S. "Isolation and Characterization of Plant Growth-promoting Rhizobacteria (PGPR) From Strawberry (*Fragaria ananassa*)", "32nd Symposium of the Malaysian Society for Microbiology". Terengganu Equestrian Resort, Terengganu, 6 – 8 December 2014.

UNIVERSITI PUTRA MALAYSIA

STATUS CONFIRMATION FOR THESIS / PROJECT REPORT AND COPYRIGHT

ACADEMIC SESSION : Second Semester 2018/2019

TITLE OF THESIS / PROJECT REPORT :

INFLUENCE OF PLANT GROWTH-PROMOTING RHIZOBACTERIA AND ARBUSCULAR MYCORRHIZAL FUNGI ON GROWTH AND YIELD OF STRAWBERRY (*Fragaria* x *ananassa* Duchesne)

NAME OF STUDENT : NUR LAILI BINTI SAMSURRIJAL

I acknowledge that the copyright and other intellectual property in the thesis/project report belonged to Universiti Putra Malaysia and I agree to allow this thesis/project report to be placed at the library under the following terms:

1. This thesis/project report is the property of Universiti Putra Malaysia.
2. The library of Universiti Putra Malaysia has the right to make copies for educational purposes only.
3. The library of Universiti Putra Malaysia is allowed to make copies of this thesis for academic exchange.

I declare that this thesis is classified as :

*Please tick (√)

☐	**CONFIDENTIAL**	(Contain confidential information under Official Secret Act 1972).
☐	**RESTRICTED**	(Contains restricted information as specified by the organization/institution where research was done).
☐	**OPEN ACCESS**	I agree that my thesis/project report to be published as hard copy or online open access.

This thesis is submitted for :

☐	**PATENT**	Embargo from_____ (date) until _____ (date)

Approved by:

_____
(Signature of Student)
New IC No/ Passport No.:

Date :

_____
(Signature of Chairman of Supervisory Committee)
Name:

Date :

[Note : If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization/institution with period and reasons for confidentially or restricted.]