UNIVERSITI PUTRA MALAYSIA

IMPACT OF WATER STRESS ON CHARACTERISTICS OF SOYBEAN (Glycine max L.) INOCULATED WITH PLANT GROWTH-PROMOTING RHIZOBACTERIA AT DIFFERENT GROWTH STAGES

FATEMEH BALOUEI

FP 2016 39

IMPACT OF WATER STRESS ON CHARACTERISTICS OF SOYBEAN (*Glycine max* L.) INOCULATED WITH PLANT GROWTH-PROMOTING RHIZOBACTERIA AT DIFFERENT GROWTH STAGES

By

FATEMEH BALOUEI

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

September 2015

DEDICATIONS

This thesis is dedicated to my:

Lovely mother and father (Effat and Esffandiyar)
And
Adorable sister and brother (Fahima and Ali)

With innermost and everlasting affection and love

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

IMPACT OF WATER STRESS ON CHARACTERISTICS OF SOYBEAN (*Glycine max* L.) INOCULATED WITH PLANT GROWTH-PROMOTING RHIZOBACTERIA AT DIFFERENT GROWTH STAGES

By

FATEMEH BALOUEI

September 2015

Chairman : Associate Professor Hawa ZE Jaafar, PhD
Faculty : Agriculture

In this study, the effect of water stress on physiological characteristics and biochemical changes of soybean inoculated with PGPRs were considered. Soybean (*Glycine max* (L) Merr.) like most other legumes is able to fix nitrogen (N_2), once it can establish a symbiotic relationship with soil nodulating bacteria belonging to the Rhizobiales order. This close association with N_2-fixing bacteria makes possible for normal growth and development of legumes in nitrogen-poor soil under abiotic stresses. Soybean N_2-fixation is a primary plant mechanism responsible for meeting plant-N demand during plant development. Nitrogen fixation is recognized as a drought-sensitive mechanism, especially in response to water deficit at different growth stages. Information about the effects of indigenous PGPRs (UPMB10 and UPMB12) and *Bradyrhizobium* (UPMR19) isolates as nitrogen fixer and their potential for soybean under drought, and their biological influence in tropical areas are still scarce; such data would be useful to provide information on availability of nitrogen for soybeans growth and development under abiotic stress particularly drought in tropical region. A factorial design experiment 1 was designed to determine the effect of water stress (well-watered, high and severe water stress) on nitrogenase activity, Malondialdehyde (MDA) and proline contents as well as Peroxidase (POX) activities of inoculated soybean with UPMB10, UPMB12 and UPMR19; and to inspect any potential of incremented tolerance of inoculated soybean to water stress. The average value of nitrogenase activity ranged from 22.25 to 51.3 nmol C_2H_4 plant^{-1} h^{-1}. Highest amounts of MDA and proline were recorded at 92.98 µg groot^{-1} and 15.91 mg groot^{-1}, respectively, and POX was 2.75 EU mg protein leaf^{-1} in un-inoculated soybean at severe stress level. In second experiment, the effect of water stress imposition at flowering (R2) and pod-filling (R6) stages (well-watered and high water stress) on MDA, proline and POX was designed in a factorial manner. The results showed values of mentioned parameters in ascending manner at flowering stage, but lightly decreasing at pod-filling and sharply diminishing at well-watered treatment. The results from experiment 2 showed that soybean exposed to high stress levels at pod-filling stage had best performance compared to flowering stage. In experiment 3, a factorial RCBD study was carried out to determine and investigate the most sensitive reproductive stage to stress during pod-filling (R6), either at the onset of pod (R3) stage or the onset of seed (R5) stage, as demonstrated by

the nitrogenase enzyme production, MDA, proline and POX activities. The results showed that soybean at onset of pod stage is more sensitive to water stress compared to the onset of seed stage; and that, PGPRs+*Bradyrhizobium* (co-inoculated) protected the soybean plant more than inoculated and un-inoculated soybean under water deficit condition. Taken together, these results indicated that inoculated and co-inoculated of indigenous PGPRs and *Bradyrhizobium* with soybean are able to protect plant against oxidative damage generated by water stress due to their symbiosis that can directly alleviate the stress effect through nodule metabolism and N_2-fixation.

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

KESAN TEKANAN AIR TERHADAP CIRI-CIRI KUALITATIF DAN KUANTITATIF KACANG SOYA (*Glycine max* L.) DENGAN RHIZOBAKTERIA (PGPR) PENGGALAK TUMBUHAN RHIZOBAKTERIA (PGPR) PADA PERINGKAT PERTUMBUHAN BERBEZA

Oleh

FATEMEH BALOUEI

September 2015

Pengerusi : Profesor Madya Hawa ZE Jaafar, PhD
Fakulti : Pertanian

Dalam kajian ini, kesan tekanan air terhadap ciri-ciri fizikal dan perubahan biokimia kacang soya berinokulasi dengan PGPR telah dipertimbangkan. Kacang soya (*Glycine max* (L) Merr.) seperti pokok kekacang yang lain mampu untuk mengikat nitrogen (N_2), dengan mewujudkan hubungan simbiotik dengan bakteria nodul tanah dari order Rhizobiales. Hubungan rapat dengan bakteria pengikat N_2 ini membolehkan pertumbuhan normal dan perkembangan pokok kekacang dalam tanah yang kekurangan nitrogen di bawah tekanan abiotik. Pengikatan N_2 oleh soya adalah mekanisma utama yang bertanggungjawab untuk memenuhi permintaan tumbuhan terhadap N ketika perkembangan pokok. Pengikatan nitrogen telah dikenalpasti sebagai mekanisma yang sensitif terhadap kemarau, terutamanya dalam tindakbalas terhadap kekurangan air pada peringkat pertumbuhan yang berbeza. Maklumat mengenai kesan asal pemencilan PGPR asli (UPMB10 dan UPMB12) dan *Bradyrhizobium* (UPMR19) sebagai pengikat nitrogen dan potensi mereka terhadap kacang soya pada musim kemarau, dan terhadap pengaruh biologi kawasan tropikal masih terhad; data seperti ini amat berguna untuk memberi maklumat mengenai ketersediaan nitrogen bagi pertumbuhan dan perkembangan kacang soya di bawah tekanan abiotik terutamanya pad a musim kemarau di rantau tropika. Kajian faktorial telah dijalankan untuk menentukan kesan tekanan air (disiram, ketegasan air yang tinggi dan teruk) terhadap aktiviti nitrogenase, MDA dan kandungan proline serta aktiviti-aktiviti POX kacang soya berinokulasi dengan UPMB10, UPMB12 dan UPMB19; dan untuk menentukan mana-mana potensi peningkatan toleransi inokulasi kacang soya terhadap ketegasan air. Nilai purata aktiviti nitrogenase adalah di antara 22.25 hingga 51.3 nmol C_2H_4 pokok^{-1} j^{-1}. Jumlah tertinggi MDA dan proline direkodkan pada 92.98 µg g root^{-1} dan 15.91 mg g root^{-1}, masing-masing, dan POX adalah 2.75 EU mg protein daun^{-1} dalam kacang soya yang tidak berinokulasi pada tahap ketegasan yang teruk. Pada eksperimen kedua, kesan pengenaan ketegasan air pada peringkat berbunga (R2) dan pengisian pod (R6) (disiram dan ketegasan air yang tinggi) keatas MDA, proline dan POX telah direka dalam kajian faktorial. Hasil kajian menunjukkan bahawa nilai-nilai parameter yang disebut meningkat pada peringkat berbunga, tetapi berkurangan sedikit pada pengisian pod dan menurun dengan ketara

pada rawatan yang disiram. Hasil daripada Eksperimen 2 menunjukkan bahawa kacang soya yang terdedah kepada tahap ketegasan yang tinggi pada peringkat pengisian pod mempunyai prestasi yang terbaik berbanding peringkat berbunga. Kajian faktorial yang dijalankan dalam Eksperimen 3 adalah untuk menyiasat sensitiviti dalam peringkat pra-pengisian pod (R6), sama ada pada permulaan pod (R3) atau permulaan benih (R5) terhadap enzim nitrogenase, MDA, proline dan aktiviti-aktiviti POX di bawah tahap ketegasan yang tinggi. Merujuk kepada hasil keputusan, kacang soya lebih sensitif kepada kemarau pada permulaan pod berbanding permulaan benih dan juga, kacang soya yang berinokulasi bersama dengan PGPR+*Bradyrhizobium* didapati mendapat perlindungan yang lebih daripada kacang soya berinokulasi dan tidak berinokulasi di bawah keadaan yang kekurangan air. Bersama-sama ini, hasil keputusan menunjukkan bahawa inokulasi dan inokulasi bersama PGPR dan *Bradyrhizobium* dengan kacang soya boleh melindungi tumbuhan daripada kerosakan oksidatif yang dihasilkan oleh kemarau kerana simbiosis mereka boleh mengurangkan tekanan kemarau dengan mempengaruhi metabolisma nodul dan pengikatan N_2 secara langsung dengan meningkatkan kadar fotosintesis, meningkatkan penghidratan daun, menangguhkan penurunan potensi air daun dan mempertingkatkan ciri-ciri kualitatif dan kuantitatif kacang soya pada peringkat pertumbuhan yang berbeza.

ACKNOWLEDGEMENT

A special thanks to my family. Words cannot express how I am grateful to my parents, sister and brother for all of the sacrifices that you have made on my behalf. Their prayers for me were what sustained me thus far.

I would also like to express the deepest appreciation to my committee chair Associate Professor Dr. Hawa ZE Jaafar, who has shown the attitude and the substance of a genius: he continually and persuasively conveyed a spirit of adventure in regard to research. Without his supervision and constant help, this thesis would not have been possible. I would also like to thank my committee members, Associate Professor Dr. Radziah Othman and Professor Dr. Norhani Abdullah for serving as my committee members even at hardship.

I certify that a Thesis Examination Committee has met on 25 February 2016 to conduct the final examination of Fatemeh Balouei on her thesis entitled "Impact of Water Stress on Characteristics of Soybean (*Glycine max* L.) Inoculated with Plant Growth-Promoting Rhizobacteria at Different Growth Stages" 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 Thesis Examination Committee were as follows:

Izham bin Ahmad, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Mohd Razi bin Ismail, PhD
Professor
Institute of Tropical Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Halimi bin Mohd Saud, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Chantal J Beauchamp, PhD
Professor
Laval University
Canada
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 25 May 2016

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

Hawa ZE Jaafar, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

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

Norhani Abdullah, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, 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
- the thesis has not been submitted previously or comcurrently 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 owned from supervisor and 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: Fatemeh Balouei, GS 31247

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) were adhered to.

Signature: ____________________
Name of Chairman of Supervisory Committee: Associate Professor Dr.Hawa ZE Jaafar

Signature: ____________________
Name of Member of Supervisory Committee: Associate Professor Dr.Radziah Othman

Signature: ____________________
Name of Member of Supervisory Committee: Professor Norhani Abdullah

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ºC	Degree centigrade
g	gram
kg	kilogram
g/L	gram per liter
h	hour
DAI	day after inoculation
L	liter
M	mole
EU	enzyme unit
mg	milligram
ml	milliliter
mM	milimole
mm	millimeter
nmol C_2H_4/mL/h	nanomol methanol per millileter per hour
nm	nanometer
ppm	parts per million
rpm	Round per minute
RT	Retention Time
m	meter
J	microgram
µg/ mL	microgram per milliliter
JO	microgram per litter
JJ	microgram per gram
O	microliter
P	micromilimeter
0	Micromol
g/plant	gram per plant
mL/min	millilitre per minute
CFU	colony forming unit
MPa	Mega-Pascal
cm	Centimeter

ABBREVIATIONS OF STATISTIC ANALYSIS

ANOVA	Analysis of Variance
P	Probably
CRD	Complete Randomized Design
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis Software
SD	Standard Deviation
SEM	Standard Error of Means

& + $ 3 7 (5

, 1 7 5 2 ' 8 & 7 , 2 1

* H Q H U D O , Q W U R G X F W L R Q

Soybean (*Glycine max*) is a legume crop; perform nitrogen fixation and establishing a symbiotic relationship with the bacterium *Bradyrhizobium japonicum* (as an aerobic microbe) in soil. It can break down nitrogen gas from the atmosphere into ammonia, which is a nitrogen product that is usually low in the soil (Van wyk, 2005). Soybean needs much more water by increasing plant development, peaking during the flowering and pod filling stages and decreasing thereafter (Embrapa, 2011, Farias et al., 2007). The loss of productivity under water deficit conditions depends on the soybean phenological stage, duration and intensity of water shortages (Doss and Thurlow, 1974).

In Malaysia, same as other tropical areas, most of their soils are deficient in available N and also microbial activities are diminished because of high temperature, direct and high light intensity, rainfall and leaching of nutrients. The enhancement of available N in these areas involves the using and improving indigenous bacterial isolates from tropical Malaysian soils which could be directly attributed to the beneficial effects from biological N_2-fixation (BNF). BNF is one way of converting elemental nitrogen into plant usable form. A number of microbes are involved in the process of BNF, which contains nitrogenase enzyme responsible for fixing atmospheric dinitrogen into soil or establishing a symbiotic relationship with legume. Indigenous bacterial isolates required in this research as plant growth-promoting rhizobacteria (PGPR) includes UPMB10 and UPMB12 (*Bacillus sp.*) isolated from oil palm roots and UPMR19 (*Bradyrhizobium japonicum*) isolated from soybean root that cultivated and grown in Malaysian soils. All PGPR indigenous isolates stimulated plant growth through increasing root distribution, phytohormone production (IAA), increasing nodulation leading to increasing BNF and enhancing access to N. PGPRs symbiosis can alleviate drought stress by affecting nodule metabolism and N_2-fixation directly, enhancing of root growth and plant height, postpone declined leaf water potential and protection plants against the oxidative damage generated by drought.

In developing of indigenous bio-inoculants, native PGPRs and *Bradyrhizobium* isolates from tropical Malaysian soils played an important role as biofertilizer. The fact that environmental conditions can impact on the activity of indigenous isolates of PGPRs and *Bradyrhizobium*, may give an insight how inoculated (PGPRs and *Bradyrhizobium)* and co-inoculated (PGPR+*Bradyrhizobium)* soybean under greenhouse could be manipulate to produce high quality harvest of soybean at different growth stages in Malaysia. However, there has been no detail study to relate this, and hence need further investigation.

2 E M H F W L Y H V

A project consisting of three major experiments hence, was carried out with the overall objectives:

1) To investigate the effects of indigenous PGPRs isolates as nitrogen fixer under drought stress condition on soybean growth and development.

2) To determine the role of PGPR on drought alleviation of soybean at different pheonological stages (Flowering and pod-filling stages).

3) To determine the critical impact of nitrogenase enzyme as the mechanism to the tolerate against stress condition on pre-podfilling stages.

+ \ S R W K H V L V

This study investigates the hypothesis that native PGPRs isolates as biofertilizer can protect soybean (*Glycine max* L. cv. Williams) co-inoculated and inoculated against drought condition. Soybean can continue growth and development under water deficit through increasing nitrogen fixing activity and close association with soil nodulaing bacteria, increased uptake of nutrient specially nitrogen, augmenting root distribution, increasing chlorophyll content and postpone declines in leaf water potential by reducing oxidative damage cause by the reactive oxygen species (ROS) generated during drought condition. Furthermore, PGPRs and *Bradyrhizobium* would improve accumulation of proline, MDA and POX activities under drought and this correlated to plant protection against environmental stresses. In the same way, soybean co-inoculated and inoculated with PGPRs and *Bradyrhizobium* subjected to drought had lower oxidative damage to lipids (MDA) and proline in roots (nodules + roots) than un-inoculated soybean, and this was linked to protection against nodule senescence and would enhance process of nodulation and nitrogen fixation synergistically in order to boosting growth and development of soybean in tropical regions. Thus, bio-inoculants as biofertilizers are gaining prominence role in the maintenance of soil fertility

5 ( ) (5 (1 & (6

Abbasi, M.K. Sharif, S. Kazmi, M. Sultan, T. and Aslam, M. (2011). *Isolation of plant growth promoting rhizobacteria from wheat rhizosphere and their effect on improving growth, yield and nutrient uptake of plants*: Plant Biosyst. 145:16-159.

Adesemoye, A.O. and Kloepper, J.W. (2009). *Plant-microbes interactions in enhanced fertilizer use efficiency*: Appl. Microbial. Biotechnol. 85:1-12.

Adesemoye, A. Torbert, H. and Kloepper, J. (2009). *Plant growth-promoting Rhizobacteria allow reduced application rates of chemical fertilizers*: Microbial Ecology. 58: 921-929.

Ahemad, M. Khan, M. S. (2012). *Effects of pesticides on plant growth promoting traits of Mesorhizobium strain MRC4*: J. Saudi. Soc. Agric. Sci. 11:63-71.

Ahemad, M. and Kibret, M. (2014). *Mechanisms and applications of plant growthpromoting rhizobacteria: current perspective*: J. King. Saudi. Uni. Sci. 26: 1-20.

Ahmad, F. Ahmad, I. and Khan, M.S. (2008). *Screening of free-living rhizospheric bacteria for their multiple plant growth promoting activities*: Microbiol. Res.163: 173-181.

Akhtar, M.S. and Siddiqui, Z.A. (2009). *Use of plant growth-promoting rhizobacteria for the biocontrol of root-rot disease complex of chickpea*: Australian Plant Pathology.38:44 ±50.

Albrecht, S. L. Bennett, J. M. and Boote, K. J. (1994). *Relationship of nitrogenase activity to plant water stress in field grown soybeans*: Field Crop Res. 8:61 ±71.

Alexander, D.B. and Zuberer, D.A. (1991). *Use of chrome azurol S reagents to evaluate siderophore production by rhizosphere bacteria*: Biol. Fertil. Soil.12:39-45.

Alikhani, H.A. Saleh-Rastin, N. and Antoun, H. (2006). *Phosphate solubilization activity of rhizobia native to Iranian soils*: Plant and soil. 287: 35-41.

Allakhverdiev, S. I. Sakamoto, A. Nishiyama, Y. and N. Murata. (2000). *Inactivation of photosystems I and II in response to osmotic stress in Synechococcus:* Contribution of water channels. Plant Physiol. 122:1201 ±1208.

Alvarez, M.I. Sueldo, R.J. and Barassi, C.A. (1996). *Effect of Azospirillum on coleoptiles growth in wheat seedlings under water stress*: Cereal Res Commun 24:101 ±107.

Anjum, F. Yaseen, M. Rasul, E. Wahid, A. and Anjum, S. (2003a). *Water stress in barley (Hordeum vulgare L.). I. Effect on morphological characters*: Pakistan J. Agric. Sci. 40: 43 ±44.

Anjum, F., Yaseen, M. Rasul, E. Wahid A. and Anjum, S. (2003b). *Water stress in barley (Hordeum vulgare L.) II. Effect on chemical composition and chlorophyll contents*: Pakistan J. Agric. Sci. 40: 45 ±49.

Anna, L.B., Alessandra, S. Claudia, E. Paola, C. and Maddalena, D.G. (2013). *In vitro and in vivo inoculation of four endophytic bacteria on Lycopersicon esculentum*: New Biotechnol. 30:666 ±674.

Arshad, M. Shaharoona, B. and Mahmood, T. (2008). *Inoculation with Pseudomonas spp. containing ACC deaminase partially eliminates the effects of drought stress on growth, yield and ripening of pea (Pisum sativum L.)*: Pedosphere. 18: 611 ±620.

Ashraf, M.Y., Azmi, A.R. Khan, A.H. and Ala, S.A. (1994). *Effect of water stress on total phenols, peroxidase activity and chlorophyll content in wheat (Triticum aestivum L.) genotypes under soil water deficits*: Acta Physiol. Plant. 16: 185 ± 191.

Ashrafuzzaman, M. Hossen, F.A. Ismail, M.R. Hoque, M.A. and Islam, M.Z. (2009). *Efficiency of Plant Growth-Promoting Rhizobacteria (PGPR) for the enhancement of rice growth*: African J. Biotechnol. 8:1247-1252.

Aspinall, D. and Paleg, L.G. (1981). *Proline accumulation: physiological aspects*: in: L.G. Paleg, D. Aspinall (Eds.), The Physiology and Biochemistry of Drought Resistance in Plants, Academic Press, Sydney, 1981, pp. 205 ±241.

Badiani, M. De Biasi, M.G. Colognola, M. and Artemi, F. (1990). *Catalase, peroxidase and superoxide dismutase activities in seedling submitted to increasing water deficit*: Agrochimica. 34:90-102.

Bai, L. P. Sui, F. G. Ge, T. D. Sun, Z. H. Lu, Y. Y. and Zhou, G. S. (2006). *Effect of Soil Drought Stress on Leaf Water Status, Membrane Permeability and Enzymatic Antioxidant System of Maize*: Pedosphere, 16: 326-332.

Baohui, S. Marchant, M.A. and Xu S. (2006).*"Competitive Analysis of Chinese Soybean Import Suppliers—U.S., Brazil, and Argentina" (PDF). American Agricultural Economics Association Annual Meetings*: Research in Agricultural and Applied Economics, University of Minnesota.

Barriuso, J. and Solano, B.R. (2008). *Ecology, Genetic Diversity and Screening Strategies of Plant Growth Promoting Rhizobacteria (PGPR)*: Journal of Plant nutrition. 1-17.

Barton, C.J. (1948). *Photometric analysis of phosphate rock*: Anal. Chem., 20: 1068-1073.

Bashan, Y. and Holguin, G. (1997). *Azospirillum/plant relationship: environmental and physiological advances (1990–1996)*: Can. J. Microbiol. 43; 103 ±121.

Bates, L.S. Waldren, R.P. and Teare, I.D. (1973). *Rapid determination of free proline for water stress studies*: Plant Soil. 39:205-207.

Battacharjee, R.B. Journad, P. Chaintreuil, C. Dreyfus, B. Singh, A. and Mukhopadhyay, S.N. (2012). *Indole acetic acid and ACC deaminase-producing Rhizobium leguminosarum bv. trifolii SN10 promote rice growth and in the process undergo colonization and chemotaxis*: Biol. Fert. Soils. 48: 173-182.

Bhatt, R.M. and Srinivasa and Rao, N.K. (2005). *Influence of pod load response of okra to water stress*: Indian J. Plant Physiol. 10: 54 ±59.

Bhattacharyya, P. N. and Jha, D.K. (2012). *Plant growth-promoting rhizobacteria (PGPR): emergence in agriculture*: World J. Microbiol. Biotechnol. 28:1327-1350.

Bhuvaneswari, T.V. Goodman, R.N. and Bauer, W.D. (1980). *Early events in the infection of soybean [Glycine max L. Merr] by Rhizobium japonicum*: I. Location of infectible root cells. Plant Physiol. 66. 1027-1031.

Bishop, P. E. Jorerger, R.D. (1990). *Genetics and molecular biology of and alternative nitrogen fixation system*: Plant Mol. Biol. 41:109-125.

Biswas, J.C. Ladha, J.K. and Dazzo, F.B. (2000). *Rhizobia inoculation improves nutrient uptake and growth of lowland rice*: Soil Sci. Society Am.J.64: 1644-1650.

Blum, A. Sinmena, B. Mayer, J. Golan, G. and Shpiler, L. (1994). *Stem reserve mobilization supports wheat grain filling under heat stress*: Australian Journal of Plant Physiology. 21:771 ±781.

Board, J. E. and Settimi, J. R. (1986). *Photoperiod effect before and after flowering on branch development and indeterminate soybean*: Agron J. 78:995-1002.

Bradford, M.M. (1976). *A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding*: Anal. Biochem. 72:248-254.

Bremner, J.M. (1960). *Determination of nitrogen in soil by the Kjeldahl method*: J. Agric. Sci. 55: 11-31.

Bussis, D. and Heineke, D. (1998). *Acclimation of potato plants to polyethylene glycol-induced water deficit. II. Contents and subcellular distribution of organic solutes*: J. Exp. Bot. 49:1361 ±1370.

Cassana, F. Perriga, D. Sgroya, V. Masciarellia, O. Pennab, C. and Lunaa, V. (2009). *Azospirillum brasilense Az39 and Bradyrhizobium japonicum E 109, inoculated singly or in combination, promote seed germination and early seedling growth in corn (Zea mays L) and soybean (Glycine max L)*: European Journal of Soil Biology. 45: 28 ±35.

Cattelan, A.J. Hartel, P.G. and Fuhrmann, J.J. (1999). *Screening for Plant Growth–Promoting Rhizobacteria to Promote Early Soybean Growth*: Soil Science Society of America Journal. 63: 1670 ±1680.

Chabot, R. Antoun, H. and Cescas, M.P. (1996). *Growth promotion of maize and lettuce by phosphate solubilizing Rhizobium leguminosarum biovar. Phaseoli*: *Plant Soil*.184: 311-321.

Chakraborty, U. Chakraborty, B. and Basnet, M. (2006). *Plant growth promotion and induction of resistance in Camellia sinensis by Bacillus megaterium*: Journal of Basic Microbiology. 46: 186 ±195.

Chanway C.P. and Holl, F.B. (1994). *Growth of out planted lodepole pine seedlings one year after inoculation with plant growth promoting rhizobacteria*: Forest Sci.40:238-246.

Charest, M.H. Beauchamp, C.J. and Antoun, H. (2005). *Effects of the humic substances of de- inking paper sludge on the antagonism between two compost bacteria and Pythium ultimum*: FEMS Microbiology Ecology. 52: 219 ±227.

Chaves, M. M. Maroco, J. P. and Pereira, J. S. (2003). *Understanding Plant response to drought: from genes to the whole plant:* Funct.Plant.Biol. 30:239-264.

Compant, S. Nowak, J. Coenye, T. Clement, C. and Ait Barka, E. (2008). *Diversity and occurrence of Burkholderia spp. in the natural environment*: FEMS Microbiol Rev 32:607 ±626.

Cornic, G. (2000). *Drought stress inhibits photosynthesis by decreasing stomatal aperture- not by affecting ATP synthesis*: Trends plant science. 5: 187-198.

Cosentino, S.L. 5LJJL (DQG '¶$JRVWL2 * *Leaf photosynthesis in kenaf (Hibiscus cannabinus L.) in response to water stress*: Proceedings of the 2nd World Biomass Conference, Roma, Italy, pp. 374-376.

Creus, C.M. Graziano, M. Casanovas, E.M. Pereyra, M.A. Simontacchi, M. Puntarulo, S. Barassi, C.A. and Lamattina, L. (2005). *Nitric oxide is involved in the Azospirillum brasilense-induced lateral root formation in tomato*: Planta. 221:297 ±303.

Dahmardeh, M. Ghanbari, A. Syasar, B. and Ramrodi, M. (2009). *Effect of intercropping maize with cowpea on green forage yield and quality evaluation*: Asian. J. Plant. Sci. 8:235 ±239

Dashti, N. Zhang, F. Hynes, R. and Smith, D.L. (1998). *Plant growth promoting rhizobacteria accelerate nodulation and increase nitrogen fixation activity by field grown soyabean (Glycine Max (L) Merr) under short season conditions*: Plant and Soil. 200: 205-213.

Dardanelli, M.S. Fernandez de Cordoba, F.J. Espuny, M.R. Carvajal, M.A.R. Diaz, M.E.S. Serrano, A.M.G. Okon, Y. and Megìas, M. (2008). *Effect of Azospirillum brasilense coinoculated with Rhizobium on Phaseolus vulgaris flavonoids and Nod factor production under salt stress*: Soil Biol Biochem. 40:2713 ±2721.

Davies, F.T. Potter, J.R. and Linderman, P.G. (1992). *Mycorrhiza and repeated drought exposure affect drought resistance and extraradical hyphae* *development of pepper plants independent of plant size and nutrient content*: Journal of Plant Physiology. 139, 289-294.

Davies, W.J. Zhang, J. Yang, J. and Dodd, I.C. (2010). *Novel crop science to improve yield and resource use efficiency in water-limited agriculture*: J. Agric. Sci. 10:1017.

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

Deepak, M. Wattal, P. N. and Mathue, D. (1995). *Influence of water stress on seed yield of Canadian mustard at flowering and role of metabolic factors*: Plant Physiol. Bioch. 22: 115-118.

Delauney, A.J. and Verma, D.P.S. (1993). *Proline biosynthesis and osmoregulation in plants*: Plant. J. 4: 215 ±223.

Demirtas, C. Yazagan, S. Candogan, B.N. Sincik, M. Buyukcangaz, C. and Guksoy, A.T. (2010). *Quality and yield response of soybean (Glycine max L.Merrill) to drought stress in sub–humid environment*: African Journal of Biotechnology. 9: 6873-6881.

Denison, R.F. and Sinclair, T.R. (1985). *Diurnal and seasonal variation in dinitrogen fixation (Acetylene reduction) rates by field-grown soybeans*: Agronomy Journal. 77: 679 ±684.

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

Dietz, K.J. and Pfannschmidt, T. (2011). *Novel regulators in photosynthetic redox control of plant metablism and gene expression*: Plant Phyiol. 155: 1477-1485.

Djekoun, A. and Planchon, C. (1990). *Water Status Effect on Dinitrogen Fixation and Photosynthesis in Soybean*: Agronomy Journal. 83:316-322.

Dobbelaere, S. Vanderleyden, J. and Yaacov, Y. (2003). *Plant growth promoting effects of diazotrophs in the rhizosphere*: Crit Rev Plant Sci. 22: 107 ±149.

Dobereiner, J. and Day, J.M. (1975). *Associative symbiosis in tropical grasses: Characterization of microorganisms and dinitrogen fixing sites*: Proceedings of the 1st ,QWHUQDWLRQDO 6\PSRVLXP RQ 1LWURJHQ) Washington State University Press., Pullman, pp: 518-538.

Dogan, E. Kirnak, H. and Copur, O. (2007). *Deficit irrigations during soybean reproductive stages and CROPGRO-soybean simulations under semi-arid climatic conditions*: Field Crops Research. 103: 154-159.

Doss, B.D. Pearson, R.W. and Rogers, H.T. (1974). *Effect of soil water stress at various growth stages on soybean yield*: Agron. J. 66:297-299.

Doss, B. D. and Thulow, D. L. (1974). *Irrigation, row width and plant population in relation to growth characteristics of two soybean varieties*: Agronomy Journal, Madison, V. 65: 620-623.

Duangpaeng, A. Phetcharat, P. Chanthapho, S. Boonkantong, N. and Okuda, N. (2012). *The study and development of endophytic bacteria for enhancing organic rice growth*: Procedia Eng., 32:172-176.

Egamberdieva, D. (2012). *Colonization of Mycobacterium phlei in the rhizosphere of wheat grown under saline conditions*: Turk J. Biol. 36: 487-492.

Egli, D. B. (1994). *Cultivar maturity and reproductive growth duration in soybean*: J. Agron Crop Sci. 173:249-254.

Egli, D.B. (1997). *Cultivar maturity and response of soybean to shade stress during seed filling*: Field Crops Research. 52: 1 ±8.

Egli, D. B. and Bruening, W. P. (2000). *Potential of early-maturing soybean cultivars in late plantings*: Agron J. 92:532-537.

Elkoca, E. Turan, M. and Donmez, M.F. (2010). *Effects of single, dual and triple inoculations with Bacillus subtilis, Bacillus megaterium and Rhizobium leguminosarum Bv. Phaseoli on nodulation, nutrient uptake, yield and yield parameters of common bean (Phaseolus vulgaris L.cv.' Elkoca-05')*: J. Plant Nutr. 33: 2104-2119.

El-Tohamy, W. Schnitzler, W.H. and El-Betagy, M.S. (1999). *Effect of VA mycorrhiza on improving drought and chilling tolerance of been plants*: Journal of Applied Botany. 73: 178-183.

Embrapa. (2011). *Sistema de Produção 15 . Exigências Climáticas* : In: Tecnologia de produção de soja - Região central do Brasil ± 2012 e 2013. Londrina: Embrapa Soja, p. 11-12.

Estill, K. Delaney, R.H. Smith W.K. and Ditterline, R.L. (1991). *Water relations and productivity of alfalfa leaf chlorophyll variants*: Crop Sci. 31: 1229 ±1233.

FAO. (2010). *FAO Production*: Food and Agriculture Organization. 2011. Retrieved February 18, 2012.

Farias, J. R. B., Nepomuceno, A. L. and Neumaier, N. (2007). *Ecofisiologia da soja*. Londrina: EMBRAPA-CNPSo, 9 p. (EMBRAPA-CNPSo. Circular técnica, 48).

Farooq, M., Wahid, A. Kobayashi, N. Fujita D. and Basra, S.M.A. (2009). *Plant drought stress*: *effects, mechanisms and management*: Agron. Sustain. Dev. 29: 185-212.

Fehr, W.R. Caviness, C.F. Burmood, D.T. and Pennington, J.S. (1971). *Stage of development descriptions for soybeans, Glycine max (L.) Merrill*: Crop Sci.11:929-931.

Fehr, W.R. and Caviness, C.E. (1977). *Stages of soybean development*: Cooperative Extension Service, Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa.

Fernandez, O. Theocharis, A. Bordiec, S. Feil, R. Jasquens, L. Clement, C. Fontaine, F. and Ait Barka, E. (2012). *Burkholderia phytofirmans PsJN acclimates grapevine to cold by modulating carbohydrate metabolism*: Mol Plant Microbe Interact. 25:496 ±504.

Foreman, J. Demidchik, V. and Bothwell, J.H.F. (2003). *Reactive oxygen species produced by NADPH oxidase regulate plant cell growth*: Nature 422: 442-446.

Foroud, N. Mundel, H.H. Saindon, G. and Entz, T. (1993). *Effect of level and timing of moisture stress on soybean yield components*: Irrigation Science. 13: 149-155.

Gallacher, A. E. and Sprent, J.I. (1978). *The effect of different water regimes on growth and nodule development of greenhouse-grown Vicia faba:* J.exp.Bot.29:413-423.

Gan, Y. Angadi, S. V. Cutforth, H. W. Potts, D. Angadi, V. V. and Mc Donald, C. L. (2004). *Soybean and mustard response to short period of high temperature and water stress at different developmental stages*: Can. J. Plant Sci.84:697-704.

Gangwar, M. and Kaur, G. (2009). *Isolation and characterization of endophytic bacteria from endorhizosphere of sugarcane and ryegrass*: The Internet Journal of Microbiology.

Garcia, J.A.L. Probanza, A. Ramos, B. Palomino, M.R. and Manero, F.J.G. (2004). *Effect of inoculation of Bacillus licheniformis on tomato and pepper*: Agronomie for Sustainable Development. 24: 169-176.

Garcia, J.A.L. Probanza, A. Ramos, B. Flores, J.J.C. and Manero, F.J.G. (2004a). *Effects of Plant Growth Promoting Rhizobacteria (PGPRs) on the biological nitrogen fixation, nodulation, and growth of Lupinus albus L cv. Multolupa*: Engineering in Life Sciences. 4: 71 ±77.

Ghorbanpour, M. and Hatami, M. (2013). *PGPR strains affect seedling vigor index and seed secondary metabolites accumulation of Black Henbane under water stress*: Trakia Journal of Sciences, No.2, PP 135-143.

Ghorbanpour, M. Hatami, M. and Khavazi, K. (2013). *Role of plant growth promoting rhizobacteria on antioxidant enzyme activities and tropane alkaloid production of Hyoscyamus niger under water deficit stress:* Turk J Biol. 37: 350-360.

Giller, K. E. (2001). *Nitrogen Fixation in Tropical Cropping Systems*: CAB International, Wallingford.

Gillman, G.P. (1979). *A proposed method for the measurement of exchange properties of highly weathered soils*: Australian Journal of Soil Reasearch. 17 (1): 129-139.

Giordano, W. and Hirsch, A.M. (2004). *The expression of MaEXP1, a melilotus alba expansin gene, is upregulated during the sweet clover-sinorhizobium meliloti interaction*: MPMI. 17: 613-622.

Glick, B.R. Liu, C. Ghosh, S. and Dumbroff, E.B. (1997). *The effect of the plant growth promoting rhizobacteriaum Pseudomonas putida GR 12-2 on the development of canola seedlings subjected to various stresses*: Soil BiolBiochem.29:1233 -1239.

Glick, B. R. Todorovic, B. Czarny, J. Cheng, Z. Duan, J. and McConkey, B. (2007). *Promotion of plant growth by bacterial ACC deaminase*: Crit. Rev. Plant Sci. 26, 227-242.

Glick, B.R. (2012). *Plant Growth-promoting Bacteria: Mechanisms and applications*: Hindawi Publishing Corporation, Scientifica.

Gray, E. J. and Smith, D. L. (2005). *Intracellular and extracellular PGPR Commonalities and distinctions in the plantbacterium signaling process*: Soil Biology and Biochemistry. 37:395 ±412.

Gomes, M.A.F. and Sodek, E. (1987). *Reproductive development and nitrogen fixation in soybean (Glycine max L. Merril)*: Journal of Experimental Botany. 38: 1982 ±1987.

Gonzalez, L. and Gonzalez-Vilar, M. (2003). *Determination of relative water content*: In: Reigosa MJ, editor. Handbook of plant ecophysiology techniques. Dordrecht: Kluwer Academic; p. 207 ±212.

Gordon, S.A. and Weber, R.P. (1951). *Colorimetric estimation of indoleacetic acid*: Plant Physiol. 26: 192-195.

Gupta, N.K. Gupta, S. and Kumar, S. (2001). *Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages*: J Agron Crop Sci 186:55 ±62.

Gutierrez Manero, F.J. Probanza, A. Ramos, B. Colon Flores, J.J. and Lucas Garcia, J.A. (2003). *Ecology, Genetic Diversity and Screening Strategies of Plant Growth Promoting Rhizobacteria (PGPR)*: Journal of Plant Nutrition. 26: 1101 ±1115.

Hafeez, F.Y. Yasmin, S. Ariani, D. Mehboob-ur-Rahman Zafar, Y. and Malik, K.A. (2006). *Plant growth-promoting bacteria as biofertilizer*: Agronomy for Sustainable Development. 26:143-150.

Handa, S. Handa, A.K. Hasegawa, P.M. and Bressan, R.A. (1986). *Proline accumulation and the adaptation of cultured plant cells to salinity stress*: Plant Physiol. 80: 938 ±945.

Hardy, R.W.F. Holsten, R.D. Jackson, E.K. and Burns, R.C. (1968). *The acetylene-ethylene assay for nitrogen fixation: Laboratory and field evaluation*: Plant Physiol. 43: 1185-1207.

Harper, J.E. and Hageman, R.H. (1972). *Canopy and seasonal profiles of nitrate reductase in soybeans (Glycine max L. Merr.)*: Plant Physiology. 49: 146 ± 154.

Heath, R.L. and Packer, L. (1968). *Photoperoxidation in isolated chloroplasts. I. Kinetics and stoichiometry of faaty acid peroxidation*: Arch. Biochem. Biophys. 125:189-198.

Herzog, V. and Fahimi, H. (1973). *Determination of the activity of peroxidase*: Anal. Biochem. 55 :554-562.

Heuer, B. (1994). *Osmoregulatory role of proline in water- and salt-stressed plants*. in: M. Pessarakli (Ed.), Handbook of Plant and Crop Stress, Marcel Dekker, New York, 1994, pp. 363 ±381.

Hogland, D.R. and Arnon, D.I. (1950). *The water-culture method for growing plants without soil*: Calif Agric Exp Station Circular. 347: 1-32.

Hugo Lemcoff, J. Ling, F. and Neumann, P. M. (2006). *Short episodes of water stress increase Barly root resistance to radial shrinkage in a dehydrating environment*: Physiologia Plantarum Jou. 127: 603-611.

Hungria, M. and Vargas, M. A. T. (2000). *Environmental factors affecting N_2 fixation in grain legumes in the tropics, with an emphasis on Brazil*: Field Crops Res. 65: 151 ±164.

Husen, E. (2003). *Screening of soil bacteria for plant growth promotion activities in vitro*: Indones J Agric. Sci. 4:27-31.

Idris, S.E. Iglesias, D.J. Talon, M. and Borriss, R. (2007). *Tryptophan-dependent production of Indole-3-Acetic Acid (IAA) affects level of plant growth promotion by Bacillus amyloliquefaciens FZB42*: Molecular Plant-Microbe Interactions. 20: 619 ±626.

Jaleel, C.A. Gopi, R. Manivannan, P. and Panneerselvam, R. (2007). *Antioxidative potentials as a protective mechanism in Catharanthus roseus plants under salinity stress*: Turkish Journal of Botany. 31: 245-251.

Jaleel, C.A. Manivannan, P. Sankar, B. Kishorekumar, A. Gopi, R. Somasundaram, R. and Panneerselvam, R. (2007d). *Induction of drought stress tolerance by ketoconazole in Catharanthus roseus is mediated by enhanced antioxidant potentials and secondary metabolite accumulation*: Colloids Surf. B: Biointerfaces. 60: 201 ±206.

Jaleel, C.A. Gopi, R. Sankar, B. Gomathinayagam, M. and Panneerselvam, R. (2008a). *Differential responses in water use efficiency in two varieties of Catharanthus roseus under drought stress*: Comp. Rend. Biol. 331: 42 ±47.

Jaleel, C.A. Manivannan, P. Lakshmanan, G.M.A. Gomathinayagam, M. and Panneerselvam, R. (2008c). *Alterations in morphological parameters and photosynthetic pigment responses of Catharanthus roseus under soil water deficits*: Colloids Surf. B: Biointerfaces. 61: 298 ±303.

Jaleel, C.A. Manivannan, P. Murali, P.V. Gomathinayagam, M. and Panneerselvam, R. (2008d). *Antioxidant potential and indole alkaloid profile variations with water deficits along different parts of two varieties of Catharanthus roseus*: Colloids Surf. B: Biointerfaces. 62: 312 ±318.

Jaleel, C.A. Manivannan, P. Wahid, A. Farooq, M. Somasundaram, R. and Panneerselvam, R. (2009). *Drought stress in plants: a review on morphological characteristics and pigments composition*: Int J. Agric. Biol. 11:100-105.

Jalill, F. Khavazi, K. Pazira, E. Nejati, A. Tahmani, H.A. Sadaghiani, H.R. and Miransari, M. (2009). *Isolation and characterization of ACC deaminase producing fluorescent pseudomonas, to alleviate salinity stress on canola (Brassica napus L.) growth*: J. Plant Physiol. 166: 667- 674.

Jaizme-Vega, M.D.C. Rodriguez-Romero, A.S. and Guerra, M.S.P. (2004). *Potential use of rhizobacteria from the Bacillus genus to stimulate the plant growth of micropropagated bananas*: Fruits. 59: 83-90.

Javanmard, A. Mohammadi-Nasab, A.D. Javanshir, A. Moghaddam, M. and Janmohammadi, H. (2009). *Forage yield and quality in intercropping of maize with different legumes as double-cropped*: J. Food Agric Environ. 7:163 ±166.

Jay, P.V. Janardan, Y. Kavindra, N.T. Ashok, K. (2013). *Effect of indigenous Mesorhizobium spp. and plant growth promoting rhizobacteria on yields and nutrients uptake of chickpea (Cicer arietinum L.) under sustainable agriculture*: Ecol Eng. 51:282 ±286.

Jensen, C.R. (1989). *Plant water relations approaches and measurements*: in: Persson, R., Wredin, A., (Eds.). Vattninsbehov och Narings-tillforsel. Foredrag presenterade vid NJF-seminarium nr. 151 Landskrona, 1 ±3. 45 ±63.

Johansen, C. Baldev, B. Brouwer, J.B. Erskine, W. Jermyn, W.A. Li-Juan, L. Malik, B.A. Ahad Miah A. and Silim, S.N. (1992). *Biotic and abiotic stresses constraining productivity of cool season food legumesin Asia, Africa and Oceania*: In: Muehlbauer, F.J., W.J. Kaiser (eds.), Expanding the Production and Use of Cool Season Food Legumes, pp: 75 ±194.

Joseph, B. Patra, R.R. and Lawrence, R. (2007). *Characterization of plant growth promoting Rhizobacteria associated with chickpea (Cicer arietinum L)*: International Journal of Plant Production. 1: 141-152.

Kage, H. Kochler, M. and Stützel, H. (2004). *Root growth and dry matter partitioning of cauliflower under drought stress conditions: measurement and simulation*: European J. Agron. 20: 379-394.

Kang, S.M. Khan, A.L. Waqas, M. You,Y.H. Kind, 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:* J.Plant Interaction. 9: 673 ±682.

Karakurt, H. Kotan, R. and Dadasoglu, F. (2011). *Effects of plant growth promoting rhizobacteria on fruit set, pomological and chemical characteristics, color values, and vegetative growth of sour cherry (Prunus cerasus cv. Kutahya)*: Turk J. Biol. 35: 283-291.

Karimi, M. and Baghal Mohseni, A. (2013). *Effects of osmotic stress on soybean varieties*: Journal of Novel Applied Sciences. JNAS Journal. 2-4:101-105.

Kasana, R.C. Salwan, R. Dhar, H. Dutt, S. and Gulati, A. (2008). *A rapid and easy method for the detection of microbial cellulases on agar plates using Gram's iodine*: Current Microbiol. 57: 503-507.

Kasim, W.A. Osman, M.E. Omar, M.N. Abd El-Daim, I.A Bejai, S. and Meijer, J. (2013). *Control of drought stress in wheat using plant-growthpromoting bacteria*: J Plant Growth Regul. 32:122-130.

Katupitiya, S. Millet, J. Vesk, M. Viccars, L. and Zeman, A. (1995). *A mutant of Azospirillum brasilense Sp7 impaired in flocculation with a modified colonization pattern and superior nitrogen fixation in association with wheat*: Applied Environ. Microbial. 61: 1987-1995.

Kauser, R. Athar, H. R. and Ashraf, M. (2006). *Chlorophyll Fluorescence: A potential indicator for rapid assessment of water stress tolerance in soybean*: Pakistan J. Bot. 38: 1501-1509.

Kaymak, H.C. Yarali, F. Guvenc, I. and Donmez, M.F. (2008). *The effect of inoculation with plant growth Rhizobacteria (PGPR) on root formation of mint (Mentha piperita L) Cuttings*: African Journal of Biotechnology.7: 4479-4483.

Kettlewell, P.S Heath, W.L and Haigh, I.M. (2010). *Yield enhancement of droughted wheat by film antitranspirant application: rationale and evidence*: Agric Sci. 1:143 ±147.

Keyeo F. Ai'shah, O. and Amir, H.G. (2011). *The effects of nitrogen fixation activity and phytohormone production of diazotroph in promoting growth of rice seedlings*: Biotechnology. 10:267-273.

Kheradmand, M.A. Shahmoradzadeh Fahraji, S. Fatahi, E. and Raoofi, M.M. (2014). *Effect of water stress on oil yield and some characteristics of brassica napus*: International Research Journal of Applied and Basic Sciences. 8: 1447-1453.

Kiani, S.P. Maury, P. Sarrafi A. and Grieu, P. (2008). *QTL analysis of chlorophyll fluorescence parameters in sunflower (Helianthus annuus L.) under well-watered and water-stressed conditions*: Plant Sci. 175: 565 ±573.

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

King, C.A. and Purcell, L.C. (2001). *Soybean nodule size and relationship to nitrogen fixation response to water deficit*: Crop Sci 41:1099 ±1107.

King, C.A. and Purcell, L.C. (2006). *Genotypic Variation for Shoot N Concentration and Response to Water Deficits in Soybean*: Crop Science 46:2396-2402.

Klapwijk, D. and De Lint, P.J.A.L. (1974). *Fresh weight and flowering of tomato plants as influenced by container type and watering condition*: Acta Hort. 39: 237 ±247.

Kloepper, J. W. (1993). *Plant growth-promoting rhizobacteria as biological control agents*: In Soil Microbial Ecology. Ed. F. B Metting, Jr.pp 225-274.

Kobraee, S. and Shamsi, K. (2011). *Effect of irrigation regimes on quantitative traits of soybean (Glycine max L.)*: ASIANJ. Exp. Biol. Sci. Vol 2(3): 441-448.

Kohler, J. Caravaca, F. and Carrasco, L. (2006). *Contribution of Pseudomonas mendocina and Glomus intraradices to aggregates stabilization and promotion of biological properties in rhizosphere*: Soil of lettuce plants under field conditions: Soil Use Manage. 22:298-304.

Kokubun, M., Shimada, S., and Takahashi, M., (2001). *Flower abortion caused by preanthesis water deficit is not attributed to impairment of pollen in soybean*: Crop Sci. 4:1517 ±1521.

Kolb, W. and Martin, P. (1988). *Influence of nitrogen on the number of N_2-fixing and total bacteria in the rhizosphere*: Soil Biol. Biochem. 20:221-225.

Kothari, S.K. Marchner, H. and George, E. (1990). *Effect of VA mycorrhizal fungi and rhizosphere microorganisms on root and shoot morphology, growth and water relations in maize*: New Phytol. 116: 303 ±311, 1990.

Kouas, S. Debez, A. Plassard, C. Drevon, J. and Abdelly, C. (2009). *Effect of phosphorus limiting on phytase activity, proton efflux and oxygen consumption by nodulated roots of common bean (Phaseolus vulgaris)*: Afr. J. Biotechnol. 8: 5301-5309.

Kramer, P.J. and Boyer, J.S. (1995). *Water relations of plant and soils*: Academic Press, New York.

Krivosudska, E. and Filova, A. (2013). *Evaluation of selected soybean genotypes (Glycine max L.) by physiological responses during water deficit*: J Cent Eur. Agric. 14:691-706.

Kumar, K.V. Srivastava, S. Singh, N. and Behl, H.M. (2009). *Role of metal resistant plant growth promoting bacteria in ameliorating fly ash to the growth of Brassica juncea*: J. Hazardous Material., 170: 51-57.

Kumudini, S. V. (1999). *Physiological traits associated with genetic gain in yield of short-season soybean cultivars*: Ph.D. dissertation, University of Guelph, Guelph, Canada.

Kundu, P. B. and Paul, N. K. (1997). *Effects of water stress on chlorophyll, proline and sugar accumulation in rape (Brassica campestris L.)*: Bang. J. Bot. 1: 83-85.

Kurdali, F. Al-Ain, F. and Al-Shamma, M. (2002). *Nodulation, dry matter production and N_{2-} fixation by fababean and chickpea as affected by soil moisture and potassium fertilizer*: J. Plant Nutr. 25:355-368.

Kusaka, M. Ohta, M. and Fujimura, T. (2005). *Contribution of inorganic components to osmotic adjustment and leaf folding for drought tolerance in pearl millet*: Physiol. Plant. 125: 474 ±489.

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

Lawn, R.J. and Brun, W.A. (1974). *Symbiotic nitrogen fixation in soybeans, I. Effect of photosynthetic source-sink manipulations*: Crop Science. 14: 11 ±16.

Leffel, R.C. Cregan, P.B. Bolgiano, A.P. and Thibeace, D.L. (1992). *Nitrogen metabolism of normal and high-seed-protein soybean*: Crop Science. 32:747 ± 750.

Lafitte, H.R. Yongsheng, G. Yan, S. and Li, Z.K. (2007). *Whole plant responses, key processes and adaptation to drought stress: the case of rice*: J. Exp. Bot. 58: 169 ±175.

Levanony, H. and Bashan, Y. (1989). *Enhancement of cell division in wheat root tips and growth of root elongation zone induced by Azospirillum brasilense Cd*: Can. J. Bot. 67: 2213 ±2216.

Lichtenthaler, H.K. and Wellburn, A.R. (1985). *Determination of total carotenoids and chlorophylls A and B of leaf in different solvents*: Biochemical Society Transactions 11: 591 ±592.

Loper, J.E. and Henkels, M.D. (1997). *Availability of iron to Pseudomonas fluorescens in rhizosphere and bulk soil evaluated with an ice nucleation reporter gene*: Applied and Environmental Microbiology.63: 99-105.

Mandal, S.M. Mondal, K.C. Dey, S. and Pati, B.R. (2007). *Optimization of Cultural and Nutritional conditions for Indol-3-Acetic acid (IAA) production by a Rhizobium sp. isolated from rot nodules of Vigna mungo (L) hepper*: Research Journal of Microbiology. 2: 239-246.

Mantelin, S. and Touraine, B. (2004). *Plant growth-promoting bacteria and nitrate availability impacts on root development and nitrate uptake*: J. Exp. Bot. 55:27-34.

Marcelo, A.G. Saul, B. and Okon, Y. (2000). *Effects of Azospirillum brasilense on root morphology of common bean (Phaseolus vulgaris L.) under different water regimes*: Biol. Fert. Soils. 32:259 ±264.

Marulanda, A. Porcel, R. Barea, J.M. and Azcon, R. (2007). *Drought tolerance and antioxidant activities in lavender plants colonized by native drought-tolerant or drought-sensitive Glomus species*: Microb. Ecol. 54: 543 ±552.

Marulanda, A. Azcon, R. Ruiz-Lozano, J.M. and Aroca, R. (2008). *Differential effects of a Bacillus megaterium strain on Lactuca sativa plant growth depending on the origin of the arbuscular mycorrhizal fungus coinoculated: physiologic and biochemical traits*: J. plant Growth Regul. 27:10-18.

Massacci, A. Nabiev, S.M. Pietrosanti, L. Nematov, S.K. Chernikova, T.N. Thor K. and Leipner, J. (2008). *Response of the photosynthetic apparatus of cotton (Gossypium hirsutum) to the onset of drought stress under field conditions studied by gas-exchange analysis and chlorophyll fluorescence imaging*: Plant Physiol. Biochem. 46: 189 ±195.

Mastrodomenico, A. and Purcell, L.C. (2012). *Soybean nitrogen fixation and nitrogen remobilization during reproductive development*: Crop Science. 52:1281 ± 1289.

Mastrodomenico, A. Purcell, L.C. and King, C.A. (2013). *The response and recovery of nitrogen fixation activity in soybean to water deficit at different reproductive developmental stages*: Environmental and experimental Botany. 85:16 ±21.

Mayak, S. Tirosh, T. and Glick, B.R. (2004). *Plant growth-promoting bacteria that confer resistance to water stress in tomato and pepper*: Plant Sci. 166:525 ± 530.

McCully, M. E. (2001). *Niches for bacterial endophytes in crop plants*: a plant ELRORJLVW¶V YLHZ $XVW-990. SODQW SK\VLRO

Mederski, H.J. Jeffers, D.L. and Peters, D.B. (1973). *Water and water relations. In: Caldwell BE, ed. Soybeans: Improvement, production, and uses*: American Society of Agronomy, Madison. WI, pp. 239-266.

Mehboob, I. Naveed, M. and Ahmad Zahir, Z. (2009). *Rhizobial association with non-legumes: mechanisms and applications*: Crit Rev Plant Sci. 28: 432-456.

Mehlich, A. (1953). *Determination of P, Ca, Mg, K, Na, and NH4. Soil Test Division (Mimeo)*: Raleigh, North Carolina, USA.

Meloni, D.A. Oliva, M.A. and Ruiz, H.A. (2001). *Contribution of proline and inorganic solutes to osmotic adjustment in cotton under salt stress*: J Plant Nutr. 24: 599-612.

Merah, O. (2001). *Potential importance of water status traits for durum wheat improvement under Mediterranean conditions*: Journal of Agricultural Research. 137:139-145.

Mia, M.A.B. Shamsuddin, Z.H. and Mahmood, M. (2012). *Effects of rhizobia and plant growth promoting bacteria inoculation on germination and seedling vigor of lowland rice*: African J. Biotechnol. 11: 3758-3765.

Milhailovic, N. and Jelic, G. (1992). *Effect of nitrogen form on Maize response to drought stress*: Journal of Plant and Soil, 144, 191-197.

Miller, M. J. (2008). *Siderophores (microbial iron chelators) and siderophore-drug conjugates (new methods for microbially selective drug delivery)*: University of Notre Dame.

Mittler, R. (2002). *Oxidative stress, antioxidants and stress tolerance*: Trends Plant Sci. 7:405 ±410.

Mohammadi, A. Habibi, D. Rihami, M. and Mafakheri, S. (2011). *Effect of Drought Stress on Antioxidant Enzymes Activity of Some Chickpea Cultivars. Am-Euras*: J. Agric. Environ. Sci. 11(6): 782-785.

Molla, A.H. Shamsuddin, Z.H. Halimi, M.S. Morziah, M. and Puteh, A.B. (2001). *Potential for enhancement of root growth and nodulation of soybean co-inoculated with Azospirillum and Bradyrhizobium in laboratory systems*: Soil Biol Biochem. 33:457 ±463.

Moussa, H. and Abdel-Aziz, S. M. (2008). *Comparative Response of Drought Tolerant and Drought Sensitive Maize Genotypes to Water Stress*: Aust. J. Crop Sci. 1: 31-36.

Muthukumarasamy, R., Revathi, G., Seshadri, S. and Lakshminarsimhan, C. (2002). *Gluconacetobacter diazotrophicus (syn. Acetobacter diazotrophicus) endophyte in tropics*: Curr. Sci. 83(2): 137-145.

Nadeem, S.M. Zahir, Z.A. Naveed, M. Arshad, M. and Shahzad, S.M. (2006). *Variation in growth and ion uptake of maize due to inoculation with plant growth promoting rhizobacteria under salt stress*: Soil Environ. 25:78 ±84.

Naher, U.A. Radziah, O. Shamsuddin, Z.H. Halimi, M.S. and Razi, I.M. (2009). *Isolation of diazotrophs from different soils of Tanjong Karang rice growing area in Malaysia*: Int. J. Agric. Biol.11: 547-552.

Nair, A. S. Abraham, T. K and Jaya, D. S. (2008). *Studies on the Changes in Lipid Peroxidation and Antioxidants in Drought Stress Induced Cowpea (Vigna unguiculata L.) Varieties*: J. Environ. Biol., 29: 689-691.

Narula, N. Deubel, A. Gans, W. Behl, R.K. and Merbach, W. (2006). *Paranodules and colonization of wheat roots by phytohormone producing bacteria in soil*: Plant Soil and Environment. 52: 119 ±129.

Nautiyal, C.S. (1999). *An efficient microbiological growth medium for screening phosphate solubilizing microorganisms*: FEMS Microbiol. Lett. 170: 265-270.

Naveed, M. Hussain, M. B. Zahir, A. Mitter, B. and Sessitsch, A. (2014). *Drought stress amelioration in wheat through inoculation with Burkholderia phytofirmans strain PsJN*: Plant Growth Regul. 73: 121-131.

Neelam, S. Farooq, A.H.A. and Rajender, S. (1994). *Effect of drought stress on growth and essential oil metabolism in lemongrasses:* New Phytol. 128: 173-179.

Nelson, L.M. (2004). *Plant Growth Promoting Rhizobacteria (PGPR): Prospects for New Inoculants*: Online. Crop Management.

Nelson, A.N. and Weaver, R.W. (1980). *Seasonal nitrogen accumulation and fixation by soybean grown at different densities*: Agronomy Journal. 72:613 ±616.

Neilands, J.B. (1952). *A Crystalline Organo-iron pigment from a Rust Fungus (Ustilago sphaerogena)*: Journal of the American Chemical Society.74: 4846-4847.

Neumann, P. M. (2008). *Croping mechanisms for crop plants in drought-prone environments*: J. Annals. Botany. 101: 901-907.

Noorieh, B. Arzanesh, M.H. Mahlegha, G. and Maryam, S. (2013). *The effect of plant growth promoting rhizobacteria on growth parameters, antioxidant enzymes and microelements of canola under salt stress*: J Appl Environ Biol Sci. 3:17 ± 27.

Okon, Y. and Vanderleyden, J. (1997). *Root-associated Azospirillum species can stimulate plants*: ASM News. 63: 366-370.

Olsen, S.R. Cole, C.V. Watanbe, F.S. and Dean, L.A. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*: US Department of Agriculture Circula. 939:1-19.

Omar, M.N.A. Osman, M.E.H. Kasim, W.A. and Abd El-Daim, I.A. (2009). *Improvement of salt tolerance mechanisms of barley cultivated under salt stress using Azospirillum brasilense*: 10.1007/978-1-4020-9065-3_15.

Oprica, L. and Marius, S. (2014). *Evaluation of morphological and biochemical parameters of soybean seedlings induced by saline stress*: Romanian Biotechnological Letter.Vol. 19, No.4.

Orhan, E. Esitken, A. 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.

Paclik, R. Sakova, L. and Curn, V. (1996). *Reaction of different cultivars of Soybean subsp. oleifera to water stress*: Fytotechnicka-Rada. 1: 55-62.

Pareek, R.P. Chandra, R. and Pareek, N. (2002). *Role of BNF technology in sustainable agriculture:* Proceedings of National symposium (eds. Masood, A., Chaturvedi, S.K. and Gurha, S.N.), Indian Institute of Pulses Research, Kanpur, p. 33-42.

Patten, C.L. and Glick, B.R. (2002). *Role of Pseudomonas putida indoleaccetic acid in development of the host plant root system*: Applied Environ. Microbiol. 68: 3795-3801.

Pederson, P. (2004). *Soybean growth and development*: Publ. PM-1945. Iowa State University Extension.

Peng, S. Biswas, J.C. Ladha, J.K. Gyaneshwar, P. and Chen, Y. (2002). *Influence of rhizobial inoculation on photosynthesis and grain yield of rice*: Agron. J. 94: 925-929.

Petropoulos, S.A. Dimitra Daferera, M.G. Polissiou H. and Passam, C. (2008). *The effect of water deficit stress on the growth, yield and composition of essential oils of parsley*: Sci. Hort. 115: 393-397.

Perez-Alfocea, F. Estan, M.T. Caro, M. Guerrier, G. (1993). *Osmotic adjustment in Lycopersicon esculentum and L. pennellii under NaCl and polyethylene glycol 6000 iso-osmotic stresses*: Physiol. Plant 87:493 ±498.

Pikovskaya, R.I. (1948). *Mobilization of phosphours in soil in connection with vital activity by some microbial species*: Microbiologica. 17: 362-370.

Plaut, Z. Edelstein, M. and Ben-hur, M. (2013). *Overcoming salinity barriers to crop production using traditional methods*: Critical Rev. Plant Sci. 32:250- 291.

Poorter, H. and Nagel, O. (2000). *The role of biomass allocation in the growth response of plants to different levels of light, CO_2, nutrient and water*: a quantitative review. Aust J Plant Physiol. 27:595 ±607.

Prado, F.E. Boero, C. and Gallardo, M. (2000). *Effect of NaCl on germination, growth, and soluble sugar content in Chenopodium quinoa wild seeds*: Bot Bull Acad Sinica. 41: 27-34.

Premalatha, P. (2006). PhD Thesis. Colonization of *oryza sativa* roots by plant growth-promoting rhizobacterium, *Bacillus sphaeticus* UPMB10 and subsequent inoculants formulation. Universiti Putra Malaysia, 2006.

Price, A.H. and Hendry, G.A.F. (1991). *Iron-catalysed oxygen radical formation and its possible contribution to drought damage in nine native grasses and three cereals*: Plant cell Environ. 14:477-484.

Probanza, A. Lucas Garcia J.A. Ruiz Palomino, M. Ramos, B. and Gutierrez Manero, F.J. (2002). *Pinus pinea L seedling growth and bacterial rhizosphere structure after inoculation with PGPR Bacillus (B. licheniformis CECT 5106 and B. pumilus CECT 5105)*: Applied Soil Ecology. 20: 75 ±84.

Pruden, M. Salon, Ch. Souleimanov, A. Neil Emery, R.J. and Smith, D.L. (2014). *Soybean is less impacted by water stress using Bradyrhizobium japonicum and Thuricin-17 from Bacillus thuringiensis*: Agron. Sustain. Dev.

Purcell, L.C. (2009). *Physiological responses of N2 fixation to drought and selecting genotypes for improved N_2-fixation*: In: Krishnan, H.B., Emerich, D.W. (Eds.), Nitrogen Fixation in Crop Production. Agron. Monogr. 52. ASA CSSA SSSA, Madison, WI, pp. 211 ±238.

Qudsaia, B. Noshinil, Y. Asghari, B. Nadia, Z. Abida, A. and Fayazul, H. (2013). *Effect of Azospirillum inoculation on maize (Zea mays L.) under drought stress*: Pak J Bot. 45:13 ±20.

Quiroga, M. Guerrero, C. and Botella, M.A. (2000). *A tomato peroxidase involved in the synthesis of lignin and suberin*: Plant Physiol.122: 1119-112.

Rakshapal, S. Sumit, K.S. Rajendra, P.P. and Alok, K. (2013). *Technology for improving essential oil yield of Ocimum basilicum L. (sweet basil) by application of bioinoculant colonized seeds under organic field conditions*: Indian Crop Prod. 45:335 ±342.

Ramos, M. L. G., Gordon, A. J. Minchin, F. R. Sprent, J. I. and Parsons, R. (1999). *Effect of water stress on nodule physiology and biochemistry of a drought tolerant cultivar of common bean (Phaseolus vulgaris L.)*: Ann. Bot. 83: 57 ± 63.

Raymond, J. Siefert, J. L. Staptes, C.R. and Blankenship, R.E. (2004). *The natural history of nitrogen fixation*: Mol. Biol. Evol. 21:541-554.

Reddy, C.P. Vajranabhaian, S.N. and Udaya Kumar, M. (1998). *Lipid peroxidation as a mechanism of stress tolerance in upland rice (Oryza sativa L.) calli*: Ind. J. Plant Physiol. 3: 68-70.

Remans, R. Croonenborghs, A. Gutierrez, R.T. Michiels, M. and Vanderleyden, J. (2007). *Effects of plant growth-promoting rhizobacteria on nodulation of Phaseolus vulgaris L. are dependent on plant P nutrition*: Eur.J. Plant Pathol. 119: 341-351.

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-Azospirillum 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.

Reynolds, M. P., Kazi, A. M. and Sawkins, M. (2005). *Prospects for utilizing plant adaptive mechanisms to improve wheat and other crops in drought and salinity prone environments*: Annals.Appl.Biol.146:239-259.

Ribeiro, C.M. and Cardoso, E.J.B.N. (2012). *Isolation, selection and characterization of root-associated growth promoting bacteria in Brazil Pine (Araucaria angustifolia)*: Microbiol. Res. 167: 69-78.

Rojas-Tapias, D. Moreno-Galván, A. Pardo-Díaz, S. Obando, M. Rivera, D. and Bonilla, R. (2012). *Effect of inoculation with plant growth-promoting bacteria (PGPB) on amelioration of saline stress in maize (Zea mays)*: Appl Soil Ecol. 61:264 ±272.

Rubio, L.M. and Ludden, P.W. (2008). *Biosynthesis of iron-molybdenum cofactor of nitrogenase*. Annu. Rev. Microbiol. 62: 93-111.

Sacks, M.M. Silk W.K. and Burman, P. (1997). *Effect of water stress on cortical cell division rates within the apical meristem of primary roots of maize*: Plant Physiol. 114: 519-527.

Saghafi, K. Ahmadi, J. Asgharzadeh, A. and Bakhtiari, Sh. (2013). *The effect of microbial inoculats on physiological responses of two wheat cultivars under salt stress*: International journal of Advanced Biological and Biomedical Research. Volume 1, Issue 4:421-431.

Saharan, B.S. and Nehra, V. (2011). *Plant growth promoting rhizobacteria: A critical review*: Life Sci. Med. Res. 21: 1-29.

Saikia, S.P. Dutta, S.P. Goswami, A. Bahau, B.S. and Kanjilal, P.B. (2010). *Role of Azospirillum in the improvement of legumes. Microbes Legum Improv*: doi:10.1007.

Sakova, L. Paclik, R. and Curn, V. (1995). *The drought tolerance of four Brassica species*: Sbornik -Jihoceska-Univerzita-Zemedelska-Fakulta,- Ceske-Budejovice.-Fytotechnicka-Rada. 1: 77-86.

Samaras, Y. Bressan, R.A. Csonka, L.N. Garcia- 5 L R V 0 3 D L Q R '¶ 8 U] R 0 D C Rhodes, D. (1995). *Proline accumulation during water deficit*: In: Smirnoff, N. (Ed.). Environment and plant metabolism: Flexibility and acclimation, Oxford: Bios Scientific Publishers

Sanchez-Rodriguez, E. Rubio-Wilhelmi, M. Cervilla, L. M. Blasco, B. Rios, J. J. Rosales, M. A. Romero, L. and Ruiz, J. M. (2010). *Genotypic Differences in Some Physiological Parameters Symptomatic for Oxidative Stress under Moderate Drought in Tomato Plants*: Plant Sci. 178: 30-40.

Sandhya, V. Ali, S.Z. Minakshi, K. Gopal, G. Reddy, G. and Venkateswarlu, B. (2009). *Alleviation of drought stress effects in sunflower seedlings by the exopolysaccharides producing Pseudomonas putida strain GAP-P45*: Biol Fertil Soils.46:17-26.

Sandhya,V. Ali, S.Z. Grover, M. Reddy, G. and Venkateswarlu, B. (2010). *Effect of plant growth promoting Pseudomonas spp. On compatible solutes, antioxidant status and plant growth of maize under drought stress*: Plant Growth Regul. 62:21 ±30.

Sangakkara, U.R. Hartwing, U.A. and Nosberger, J. (1996). *Soil moisture and potassium affect the performance of symbiotic nitrogen fixation in faba bean and common bean*: Plant Soil. 184:123-130.

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

Santos, C. Pinto, G. Loureiro, J. Oliveira, H. and Costa, A. (2002). *Response of sunflower cells under Na_2SO_4. I. Osmotic adjustment and nutrient responses* *and proline metabolism in sunflower cells under Na_2SO_4 stress*: J. Plant Nut. Soil Sci. 165:366-372.

Saravanakumar, D. Kavino, M. Raguchander, T. Subbian, P. and Samiyappan, R. (2011). *Plant growth promoting bacteria enhance water stress resistance in green gram plants*: Acta Physiol Plant. 33:203 ±209.

6$6 6$6 67$7 8VHU¶V *XLGH 9HUVLRQ NC, 6$6 ,QVWL USA.

Saubidet, M.I. and Barneix, A.J. (1998). *Growth stimulation and nitrogen supply to wheat plants inoculated with Azospirillum brasilense*: J. Plant Nutr. 21 (12), 2565 ±2577.

Schwyn, B. and Neilands, J.B. (1987). *Universal chemical assay for the detection and determination of siderophores*: Analytical Biochem.160: 47-56.

Sciarappa,W.J.(2005). *Edamame: the vegetable soybean*: Fact sheet, cooperative extension. Available from http// www.rce.

Sepanlo, N. Talebi, R. Rokhzadi, A. and Hohammadi, H. (2014). *Morphological and physiological behavior in soybean (Glycine max) genotypes to drought stress implemented at pre and post-anthesis stages*: Acta Biologica Szegediensis. Volume 58(2):109-113.

Serraj, R., Bona, S. Purcell, L. C. and Sinclair, T. R. (1997). *Nitrogen fixation response to water-deficits in field-grown 'Jackson' soybean*: Field Crops Res. 52: 109 ± 116.

Serraj, R. Sinclair, T.R. and Purcell, L.C. (1999). *Symbiotic N_2-fixation response to drought*: J Exp Bot. 50:143 ±155.

Sessitsch, A. Coenye, T. Sturz, A.V. Vandamme, P. Ait Barka, E. Faure, D. Reiter, B. Glick, B.R. Wang-Pruski, G. and Nowak, J. (2005). *Burkholderia phytofirmans sp. nov., a novel plant-associated bacterium with plant beneficial properties*: Int J Syst Evol Microbiol. 55:1187 ±1192.

Shaharoona, B. Arshad, M. and Zahir. Z.A. (2006). *Effect of plant growth promoting rhizobacteria containing ACC-deaminase on maize (Zea mays L.) growth under axenic conditions and on nodulation in mung bean (Vigna radiata L.)*: Letters in Applied Microbiology. 42: 155-159.

Shao H.B. Chu, L.Y. Shao, M.A. Abdul Jaleel, C. and Hong-Mei, M. (2008). *Higher plant antioxidants and redox signaling under environmental stresses*: Comp. Rend. Biol. 331: 433 ±441.

Shukla, P.S. Agarwal, P.K. and JHA, B. (2012). *Improved salinity tolerance of Arachis hypogaea (L.) by the interaction of halotolerant plant-growth promoting rhizobacteria*: J. Plant Growth Regul. 31: 195, 206.

Siddique, M.R.B. Hamid, A. and Islam, M.S. (2000). *Drought stress effects on water relations of wheat:* Bot. Bull. Acad. Sin. 41:35-39.

Siegel, B.Z. (1993). *Plant peroxidases- an organismic perspective*: Plant Growth Regul. 12: 303-312.

Simova-Stoilova, L. Demirevska, K. Petrova, T. Tsenov, N. and Feller, U. (2008). *Antioxidative protection in wheat varieties under severe recoverable drought at seedling stage*: Plant Soil Environ. 54: 529-536.

Sinaki, J. M. Heravan, E. M. Rad, A. H. S. Noormohammadi, G. and Zarei, G. (2007). *The effects of water deficit during growth stages of soybean*: American-eurasian J. Agri. & Environ. Sci. 4: 417-422.

Sionit, N. Strain, B.R. and Flint, E.P. (1987). *Interaction of temperature and CO_2 enrichment on soybean photosynthesis and seed yield*: Can J. Plant Sci. 67:629-636.

Sitepu, I.R. Hashidoko, Y. Santoso, E. and Tahara, S. (2007). *Potent phosphate-solubilizing bacteria isolated from dipterocarps grown in peat swamp forest in central Kalimantan and their possible utilization for biorehabilitation of degraded peat swamp forest in Central Kalimantan*: Proceedings of the International Symposium and Workshop on Tropical Peatland. Aug.27-29, Yogyakarta, Indonesia.

Smirnoff, N. (1993). *The role of active oxygen in the response of plants to water deficit and desiccation*: New Phytol. 125: 27-58.

Somasegaran, P. and Hoben, H.J. (1985). *Methods in Legume-Rhizobium Technology*: 1st Edn., University of Hawaii NifTAL Project and MIRCEN, pp: 367.

Somasegaran, P. (1994). *Handbook for rhizobia: methods in legume-rhizobium technology*: New York: Springer-Verlag. 1 ±6:167.

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

Spaepen, S. Vanderleyden, J. and Remans, R. (2007). *Indole- 3-acetic acid in microbial and microorganism-plant signaling*: FEMS Microbiol. Rev. 31, 425 ±448.

Spaepen, S. and Vanderleyden, J. (2011). *Auxin and plant-microbe interactions*: Cold Spring Harb. Perspect. Biol.

Specht, J.E. Chase, K. Macrander, M. Graef, G.L. Chung, J. Markwell, J.P. Germann, M. Orf, J.H., and Lark, K.G. (2001). *Soybean response to water. A QTL analysis of drought tolerance*: Crop Sci. 41: 493 ±509.

Sridevi, M. and Mallaiah, K.V. (2007). *Bioproduction of indole acetic acid by Rhizobium strains isolated from root nodules of green manure crop, Sesbania sesban (L) Merr*: Iranian Journal of Biotechnology. 5: 178-182.

Stajkovic, O. Delic, D. Josic, D. Kuzmanovic, D. Rasulic, N. and Knezevic-vukcevic, J. (2011). *Improvement of common bean growth by co-inoculation* *with Rhizobium and plant growth-promoting bacteria*: Romanian Biotech.16: 5919-5926.

Streeter, J.G. (2003). *Effects of drought on nitrogen fixation in soybean root nodules*: Plant Cell Environ. 26:1199 ±1204.

Suneja, P. Dudeja, S.S. and Narula, N. (2007). *Development of multiple co-inoculations of different biofertilizers and their interaction with plants*: Arch. Agr. Soil Sci. 53: 221-230.

Sweeney, D.W. Long, J.H. and Kirkham, M.B. (2003). *A single irrigation to improve early maturing soybean yield and quality*: Soil Science Society of America Journal. 67(1): 235-240.

Tahir, M.H.N. and Mehid, S.S. (2001). *Evaluation of open pollinated sunflower (Helianthus annuus L.) populations under water stress and normal conditions*: Int. J. Agric. Biol. 3: 236-238.

Tahir, M.H.N. Imran M. and Hussain, M.K. (2002). *Evaluation of sunflower (Helianthus annuus L.) inbred lines for drought tolerance*: Int. J. Agric. Biol. 3: 398-400.

Tambussi, E. A. Bartoli, C. G. Bettran, J. Guiamet, J. J. and Araus, J. C. (2000). *Oxidative damage to thylakoids proteins in water stressed leaves of wheat (Triticum aestivum L.)*: Physiol. Plant. 108:398-404.

Tan, K. Z. Radziah, O. Halimi, M.S. Khairuddin, A.R. Habib, S.H. and Shamsuddin, Z.H. (2014). *Isolation and characterization of rhizobia and plant growth-promoting rhizobacteria and their effects on growth of rice seedlings*: American Journal of Agricultural and biological Sciences.9:342-360.

Theocharis, A. Bordiec, S. Fernandez, O. Paquis, S. Dhondt-Cordelier, S. Baillieul, F. Clement, C. and Ait Barka, E. (2012). *Burkholderia phytofirmans PsJN primes Vitis vinifera L. and confers a better tolerance to low nonfreezing temperatures*: Mol Plant Microbe Interact. 25:241 ±249.

Thibodeau, P.S. and Jaworski, E.G. (1975). *Patterns of nitrogen utilization in the soybean*: Planta. 127:133 ±147.

Timmusk, S. and Wagner, E.G.H. (1999). *The plant growth promoting rhizobacterium Paenibacillus polymyxa induces changes in Arabidopsis thalianan gene expression: a possible connection between biotic and abiotic stress responses*: Mo l Plant-Microb Interact.12:951-959.

Timmusk, S. Nicander, B. Granhall, U. and Tillberg, E. (1999). *Cytokinin production by Paenibacillus polymyxa*: Soil Biol Biochem. 31:1847 ±1852.

Tian, F. Ding, Y. Zhu, H. Yao, L. and Du, B. (2009). *Genetic diversity of siderophore-producing bacteria of tobacco rhizosphere*: Brazilian Journal of Microbiology. 40: 276-284.

Tripathi, A.K. Mishra, B.M. and Tripathi, P. (1998). *Salinity stress responses in plant growth promoting rhizobacteria*: J. Biosci. 23:463 ±471.

Turner, N. C. (1979). *Drought resistance and adaptation to water deficit in crop plants*: In Stress Physiology in crop plants (H. Mussell and R.C. Staples, eds.): 87-103.

Turtola, S. Manninen, A. and Rikala, R. (2003). *Drought stress alters the concentration of wood terpenoids in Scots pine and Norway spruce seedlings*: J. Chem. Ecol. 29: 1981-1995.

Valverde, A. Burgos, A. Fiscella, T. Rivas, R. Vela zequez, E. Guezbarrueco, C. R. Zhang, F. Dashti, N. Hynes, R. K. and Smith, D. L. (1996). *Plant growth-promoting rhizobacteria and soybean (Glycine max L. Merr.) nodulation and nitrogen fixation at suboptimal root zone temperatures*: Ann. Bot. 77, 453 ± 459.

Van Heerden, P.D.R. and Krüger, G.H.J. (2000) *Photosynthetic limitation in soybean during cold stress*: South Afr. J. Sci. 96:201-206.

Van Wyk, B.E. (2005). *Food Plants of the World (Glycine max)*: An Illustrated Guide. Portland, OR: Timber Press. p. 201.

Vardharajula, S. Ali, S.Z Grover, M. Reddy, G. and Bandi, V. (2011). *Drought-tolerant plant growth promoting Bacillus spp. effect on growth, osmolytes, and antioxidant status of maize under drought stress*: J Plant Interact. 6:1 ±14.

Vargas, L. Carvalho, T.L.G.D. Ferreira, P.C.G. Baldani, V.L.D. and Baldani, J.I. (2012). *Early responses of rice (Oryza sativa) seedlings to inoculation with beneficial diazotrophic bacteria are dependent on plant and bacterial genotypes*: *Plant Soil,* 356:127-137.

Vartanian, N. Hervochon, P. Marcotte, L. and Larher, F. (1992). *Proline accumulation during drought rhizogenesis in Soybean var. oleifera*: J. Plant Physiol. 5: 623-628.

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

Vinocur, B. and Altman, A. (2005). *Recent advances in engineering plant tolerance to abiotic stress: achievements and limitations*: Curr Opin Biotechnol. 16:123-132.

Vivas, A. Marulanda, A. Ruiz-Lozano, J.M. Barea, J.M. and Azcon, R. (2003). *Influence of a Bacillus sp. on physiological activities of two arbuscular mycorrhizal fungi and on plant response to PEGinduced drought stress*: Mycorriza. 13:249 ±256.

Wang, W. Vinocur, B. and Altman, A. (2003). *Plant responses to drought, salinity and extreme temperatures: towards genetic engineering for stress tolerance*: Planta. 218:1 ±14.

Webber, M. Barnett, J. Finlayson, B. and Wang, M. (2006). *Pricing China's Irrigation Water*: Working Paper, School of Anthropology, Geography and Environmental Studies, The University of Melbourne, Victoria, Australia.

Wery, J. Silim, S.N. Knights, E.J. Malhotra, R.S. and Cousin, R. (1994). *Screening techniques and sources and tolerance to extremes of moisture and air temperature in cool season food legumes*: Euphytica. 73: 73 ±83.

Westgate, M.E. and Peterson, C.M. (1993). *Flower and pod development in water–deficient soybean (Glycine max L. Merr.)*: J. Exp. Bot. 44, 109 ±117.

Whipps, J.M. (2001). *Microbial interactions and biocontrol in the rhizosphere*: Journal of Experimental Botany. 52:487-511.

Worrall, V. S. and Roughley, R. J. (1976). *The effect of moisture stress on infection of Trifolium subterraneum L. by Rhizobium trifolii Dang*: J. Exp. Bot. 27:1233 ± 1241.

Wright, J. et al., (2006). *Predicting the last irrigation for corn and soybeans in Central Minnesota*: University of Minnesota, Minnesota C3rop e News.

Wu, Q.S. Xia, R.X. and Zou, Y.N. (2008). *Improved soil structure and citrus growth after inoculation with three arbuscular mycorrhizal fungi under drought stress*: European J. Soil Biol. 44: 122 ±128.

Yadegari, M. Rahmani, H. A. Noormohammadi, G. and Ayneband, A. (2010). *Plant growth promoting rhizobacteria increase growth, yield and nitrogen fixation in Phaseolus vulgaris*: J. Plant Nut. 33: 1733-1743.

Yancey, P.H. Clark, M.E. Hand, S.C. Bowlus, R.D. and Somero, G.N. (1982). *Living with water stress: evolution of osmolyte system*: Science. 217:1214-122.

Yang, J. Kloepper, J.W. and Ryu, C.M. (2009). *Rhizosphere bacteria help plants tolerate abiotic stress*: TrendsPlant Sci.14:1-4.

Yanni, Y.G. Rizk, R.Y. Corich,V. Squartini, A. and Ninke, K. (1997). *Natural endophytic association between Rhizobium leguminosarum bv. Trifolii and rice roots and assessment of its potential to promote rice growth*: Plant Soil. 194: 99-114.

Yasmin, F. Othman, R. Saad, M.S. and Sijam, K. (2007). *Screening for beneficial properties of Rhizobacteria isolated from sweet potato rhizosphere*: Journal of Biotechnology. 6:49-52.

Yogesh, K. Vamsi, K.K. Amol, B. Nikhil, G. and Soham, T. (2009). *Study of pectinase production in submerged fermentation using different isolates of Aspergillus Niger*: Int.J. Microbiol. Res., 1:13-17.

Yuwono, T. Handayani, D. and Soedarsono, J. (2005). *The role of osmotolerant rhizobacteria in rice growth under different drought conditions*: Aust J Agr Res. 56: 715-721.

Zahir, Z.A. Munir, A. Asghar, H.N. Arshad, M. and Shaharoona, B. (2008). *Effectiveness of rhizobacteria containing ACC-deaminase for growth promotion of peas (Pisum sativum) under drought conditions*: J. Microbiol Biotechnol. 18:958 ±963.

Zahir, Z.A. Ghani, U. Naveed, M. Nadim, S.M. and Asghar, H.N. (2009). *Comparative effectiveness of Pseudomonas and Serratia sp. containing ACC deaminase for improving growth and yield of wheat (Triticum aestivum L.) under salt stress conditions*: Arch. Microbiol. 191: 415-424.

Zahran, H.H. (2001). *Rhizobia from wild lequmes: diversity, taxonomy, ecology, nitrogen fixation and biotechnology*: J. Biotechnol. 91:143-153.

Zaidi, A. Khan, M.S. Ahemad, M. and Oves, M. (2009). *Plant growth promotion by phosphate solubilizing bacteria*: Acta Microbiol. Immunol. Hung. 56:263-284.

Zeiher, C. Egli, D.B. Leggett, J.B. and Reicosky, D.S. (1982). *Cultivar differences in N redistribution in soybeans*: Agronomy Journal. 74:375 ±379.

Zhang, J.X. and Kirkham, M.B. (1994). *Drought stress induced changes in activities of superoxide dismutase, catalase, and peroxidase in wheat species*: Plant Cell Physiol. 35: 785-791.

Zhang, F. Dashti, N. Hynes, R. K. and Smith, D. L. (1996). *Plant growth-promoting rhizobacteria and soybean (Glycine max L. Merr.) nodulation and nitrogen fixation at suboptimal root zone temperatures*: Ann. Bot. 77: 453 ±459.

Zhang, M. Duan, L. Zhai, Z. Li, J. Tian, X. Wang, B. He, Z. and Li, Z. (2004). *Effects of plant growth regulators on water deficit-induced yield loss in soybean*: Proceedings of the 4th International Crop Science Congress, Brisbane, Australia.

Zgallai, H. Steppe, K. and Lemeur, R. (2006). *Effects of different levels of water stress on leaf water potential, stomata resistance, protein and chlorophyll content and certain anti-oxidative enzymes in tomato plants*: Journal of Integrative Plant Biology. 48: 679-685.