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Mini Review

Plant Growth Promoting Rhizobacteria: Bioresouce for Enhanced Productivity of Solanaceous Vegetable Crops

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Abstract

Solanaceous vegetables belonging to the nightshade family *Solanaceae* are among the major vegetables used in the world. High nutrient requirement of the crop along with the high vulnerability towards the various bacterial, fungal or viral diseases are among the major causes for their losses in yield and soil health. Plant growth promoting rhizobacteria are the soil bacteria that inhabits root surface and are directly or indirectly promotes plant growth and development via reduction and secretion of various regulatory chemicals in the vicinity of rhizosphere. Generally, plant growth promoting rhizobacteria facilitate the plant growth directly by either assisting in resource acquisition (nitrogen, phosphorus and essential minerals) or modulating plant hormone levels, or indirectly by decreasing the inhibitory effects of various pathogens on plant growth and development in the forms of biocontrol agents. Various studies have documented the increased health and productivity of different plant species by the application of plant growth promoting rhizobacteria under both normal and stressed conditions. The plant-beneficial rhizobacteria may decrease the global dependence on hazardous agricultural chemicals which destabilize the agro-ecosystems. This review accentuates the perception of the rhizosphere and plant growth promoting rhizobacteria under the current perspectives.

Keywords: PGPR; Biostimulants; Biofertilisers; Biocontrol Agents; Solanaceous Vegetables

Plant growth in agricultural soils is influenced by a myriad of abiotic and biotic factors. The thin layer of soil immediately surrounding plant roots in which physical, chemical and biological properties have been changed by root growth, their activities and that provides stimulating growth environment for microbial populations capable of exerting beneficial, neutral or detrimental effects on plant growth is known as rhizosphere [1,2].

Since bacteria are the most abundant microorganisms in the rhizosphere, they influence the plants physiology to a greater extent, especially considering their competitiveness in root colonization. Bacteria that colonize the rhizosphere are referred as plant growth-promoting rhizobacteria [3]. PGPR enhance the plant growth by direct mechanisms such as fixation of atmospheric nitrogen, production of siderophores, solubilization of minerals such as phosphorus, synthesis of phytohormones [4,5] or by indirect mechanism such as induction of disease resistance, stimulation of other beneficial symbiosis, xenobiotics degradation and antagonism against pathogens [6-8]. The search for microorganisms that improve soil fertility and enhance plant nutrition has continued to attract attention due to the increasing cost of chemical fertilizers and some of their ill environmental impacts [9].

Endophytic bacteria have biocontrol and plant growth promoting potential, consistently colonize the internal plant tissue of their host without causing harm to the host [10]. Endophytes are helpful in modifying biochemicals produced by plants and may add to their protection from insect herbivores, fungal pathogens and even grazing by animals [11]. Bacterial endophytes have also been shown to prevent the disease development through endophyte mediated *de novo* synthesis of structural compounds and fungitoxic metabolites [12]. Endophytic bacteria have the advantage of being protected from high physical and chemical stress, competitive environment and induce greater growth promotion than the bacteria restricted to rhizosphere and/or to the root surface [13].

Various species of rhizospheric bacteria like *Pseudomonas, Azospirillum, Azotobacter, Klebsiella, Enterobacter, Alcaligenes, Arthrobacter, Burkholderia, Bacillus* and *Serratia* and endophytic bacteria like *Pseudomonas, Bacillus, Xanthomonas* and *Erwinia* have been reported to be associated with solanaceous vegetable crops. Soil physical and chemical properties (pH, humidity, water availability, temperature, redox, salinity, texture, stability of aggregates, fertility, organic matter content), presence or absence of pesticides and other xenobiotic substances, soil fauna, the nutrient status of rhizosphere, nature of root exudates, photoperiod and plant genotype directly influence PGPR activity and their effect on plant growth and as well as the proliferation of introduced strain to that environment (Curl and Truelovac, 1986) [14-19].

PGPR as Root Colonizers

The rhizosphere is the volume of soil surrounding and under the influence of plant roots and the rhizoplane includes the root surface and strongly adhering soil particles. In the rhizosphere bacteria are most abundant microorganisms. Rhizobacteria are rhizosphere competent bacteria that aggressively colonize plant roots, are able to multiply and colonize all the ecological niches found on the roots at all the stages of plant growth, in presence of competing microflora. During the process of root colonization bacteria multiply in the spermosphere (region around the seed) in response to seed exudates rich in carbohydrates and amino acids, then these get attached to root surface and colonize the developing root system [20,21].

Endophytes enter into the plant roots by three putative pathways i.e. root tips, point of emergence of lateral roots and the axils of emerging or developing lateral roots [22]. [23] reported that endophytes either become localized at the point of entry or are able to spread throughout the plant and can live within cells, in the intercellular spaces or in the vascular system.

PGPR as P-Solubilizers

Phosphorus is among the primary essential nutrient elements required by the plant in optimum amount for its proper growth and development. Although P content in an average soil is 0.05%, only 0.1% of the total P present is available to the plants because of its immobilization, chemical fixation and low solubility [24]. Under such conditions, Phosphate solubilizing microorganisms (PSM) offer a biological rescue system capable of solubilizing the insoluble inorganic P of soil and make it available to the plants through the secretion of various organic acids and enzymes. Further, most of the phosphate solubilizing microorganisms were identified as *Bacillus* spp., *B. pantothenticus, B. megaterium, Flavobacterium* spp., *Klebsiella* spp., *K. aerogenes, Chromobacterium lividum, Enterobacter alvei, E. agglomerans, Pseudomonas* spp., *Proteus* spp. and NFB as *Azotobacter* spp., *A. chroococcum, A. paspalii, Rhizobium* spp. and *Azospirillum* spp [25-28].

PGPR as HCN/Siderophore/IAA Producers

Siderophores, HCN and phytoharmones like IAA are among the major compounds, known to play an important role in plant microbe interaction as well as in microbe-microbe interaction.

Iron is perhaps, the most important micronutrient used by microorganisms and is essential for their metabolism, being required as a cofactor for a large number of enzymes and iron-containing proteins. Siderophores are low molecular weight, iron chelating ligands synthesized by microorganisms [29] that restrict the growth of pathogenic microorganisms by limiting the iron availability as it bind to the available form of iron (Fe^{2+}) in the rhizosphere [30]. Under iron limiting conditions, PGPR produce siderophores to competitively acquire ferric ions [31,32]. However, increased iron concentration in the environment has negative effect on the siderophore production as reported by [33] who observed that the increase of Fe (III) concentration had a negative effect in siderophore production by *Pseudomonas aeruginosa*, especially above 10 μM. Some PGPR strains go one step further and draw iron from heterologous siderophores produced by nearby micro-organisms.

Indole-3-acetic acid (IAA) mediates an enormous range of development and growth responses including embryo symmetry establishment, initiation of cell division, promote vascular differentiation, root initiation and apical dominance. PGPR all over the world have been reported to enhance the plant growth by the production of phytoharmones. [34] studied the ability of 30 isolated PSB to produce both IAA and GA and observed that IAA produced by the PSB strains, ranged from 1.1 μg to 28.0 μg/25 ml broth and GA ranged from 0.6 μg to 9.8 μg/25 ml broth. Similarly, [35] revealed that the strains WPR-51, WPR-42 and WM-3 belonging to *Azotobacter* and *Azospirillum* produced IAA ranged from 19.4 to 30.2 μg/ml. [36] tested *Pseudomonas fluorescens* AK1 and *Pseudomonas aeruginosa* AK2 for their ability to produce indole-3-acetic acid in the presence and absence of tryptophan and revealed that for both strains, indole production increased with increase in tryptophan concentration.

PGPR as Biofertilizers for Enhanced Growth, Yields and Fruit Quality

Solanaceous vegetables crops require high nutrient quantity for growth and yield. PGPR are known to directly promote the plants growth usually by the production of phytohormones and/or by facilitating uptake of nutrients from the soil through different mechanisms such as atmospheric nitrogen fixation, solubilization of phosphorous and synthesis of siderophore [37,38] and/or as biocontrol agent.

[39] reported that three strains IN937a, GBO3 and IPC11 were found to be effective in increasing the seed germination and seedling vigour of tomato plants. [40] reported increased seedling height (ranged from 7.33 to 7.87 cm compared to 6.88 cm) and dry-weight (ranged from 2.7 to 4.3 mg compared to 2.3 mg) of the plants from the seeds treated with chinolytic bacteria. [41] reported that the artificial inoculation of rhizobacteria *Azospirillum* caused a positive effect on tomato plant seedling growth and yields. [42] reported growth promotion and enhanced disease resistance of seedlings inoculated with *Streptomyces* spp. strain S30.

Transplantation is one of the major cultivation techniques especially in case of solanaceous crops. Treatment of seedlings roots with PGPR prior to transplantation have been reported to better nutritional acquisition, yields and disease resistance. [43] evaluated tomato and pepper transplants amended with formulations of several plant growth-promoting rhizobacteria (PGPR) and found improved transplant growth, vigour and survival in the field.

[44] reported that the plant fresh and dry weight as well as root/shoot length increased due to application of fluorescent *Pseudomonas*. [45] isolated *Bacillus* isolates (B1, B3 and B13) and identified them as *B. amyloliquefaciens, B. licheniformis* and *B. subtilis*, respectively. They reported that the application of *Bacillus* spp. results in increased plant height by 20% and yields by 27%, in comparison to check.

PGPR are being tried as consortia and have been found to be more effective than single inoculation. [46] evaluated the efficiency of *Trichoderma* and *Bacillus* genera and reported that, the dual inoculation gave the highest records of growth parameters, fruit yields and plant nutrient content than individual one. [47] worked to check out if the combination of three PGPR, *B. licheniformis, Pseudomonas fluorescens* and *Chryseobacterium balustinum* with LS213 (a combination product of two PGPRs, *Bacillus subtilis* strain GB03 and *B. amyloliquefaciens* strain IN937a and chitosan) would have a synergistic effect on growth promotion on tomato and pepper or not and revealed synergistic effect on growth promotion, with the most effective combination of *B. licheniformis* and LS213. [48] evaluated the impact of inoculating tomato with *Pseudomonas putida, Azotobacter chroococcum, Azosprillum lipoferum* and arbuscular mycorrhiza fungi (AMF) and found that the application of *Pseudomonas* + *Azotobacter* + *Azosprillum* + AMF treatment had the most effect on lycopene, antioxidant activity and potassium contents on tomato. [49] isolated 15 bacteria from chilli rhizosphere and elucidated their morphological, biochemical, plant growth-promoting and biocontrol characteristics. Further, they identified C2 and C25 strains as *Bacillus* spp. and C32 strain as *Streptomyces* spp. and reported that combined inoculation results in remarkable increase in total number of fruits, fruit-weight and yields.

PGPR as works with the plants innate system, they not only enhance the plant growth and yield but also improves the texture, shelf life and fruit quality. [50] reported improved tomato firmness and extended shelf life of tomato plants treated with *Bacillus subtilis* BEB-13bs. [50] further evaluated the effect of tomato roots inoculation with *Bacillus subtilis* BEB-lSbs (BS13) and reported increased yields, fruit weight and length and enhanced texture of fruits.

PGPR as Biocontrol Agents

Solanaceous crops are highly susceptible to phytopathogens attack. The resulting intensive application of pesticides on crops affects the environment and health of humans and animals [51]. Biocontrol is an emerging trend aimed at reducing chemical input while increasing plant fitness, productivity and resistance to diseases in sustainable agriculture [52].

PGPR protects plant against pathogens through number of mechanisms such as production of macromolecules [53] antifungal metabolites, antimicrobial substances [54] HCN, siderophores and indole acetic-acid which could also be involved in biocontrol and growth promotion in crop plants [18]. HCN is released as product of secondary metabolism by several microorganisms and affects sensitive organisms by inhibiting the synthesis of ATP-mediated cytochrome oxidase [55]. Biocontrol activity of IAA involves inhibition of spore germination and mycelial growth of pathogenic fungi [56].

Beside the production of metabolites, production of diffusible or non-diffusible antifungal substances, displacing harmful organisms, competition for nutrients and/or space or the other mechanisms might be the reasons for antagonistic activity [57]. One of important method is the induced systemic resistance (ISR), which results from the specific recognition of (a) bacterial determinant(s) by (a) plant receptor(s) on the roots and is manifested as a reduction of the number of diseased plants or in disease severity upon subsequent infection by a pathogen. ISR is effective against both soilborne and foliar pathogens [8,58] investigated the role of bacterial compounds as elicitors of the induced systemic resistance. They reported that the lipopeptides, especially surfactin and fengycin produced by *Bacillus subtilis* strains are able to stimulate bean and tomato plants and also decreased the impact of subsequent pathogen infection. Cellular changes have also been reported as one of the major phenomenon of restricting fungal development in the plants.

In spite of their direct action, PGPR induce pathogenesis-related proteins in plants such as phenylalanine ammonia lyase, peroxidase, polyphenol oxidase [catechol oxidase], beta -1,3 glucanase and phenolics [59]. PGPR have also been reported to be involved in lowering the ethylene levels [60] malondialdehyde content, superoxide dismutase, peroxidase and catalase activities in the plant that might also enhance anti-disease capability of the plants [61].

i) PGPR against fungal and bacterial pathogens

Many rhizospheric isolates belonging to *Bacillus* spp., *Enterobacter* spp. *Pseudomonas* spp., *Pichia* spp. collected from tomato and pepper growing areas showed antagonistic activity against *Botrytis cinerea, F. graminearum, Colletotrichum capsici, Alternaria solani, P. capsici* and *Mycosphaerella melonis* [62-68] investigated effects of rhizobacteria on the early growth of cucumber and tomato plug seedlings and reported that *Azospirillum* spp., Pseudomonas spp. inhibited the growth of *Fusarium* spp., *Pythium* spp. and *Rhizoctonia* spp. on both plants. Similarly, [69] reported inoculation of tomato plants with *Bacillus 6ubtilis* effective against root fungal pathogen *Pythium* spp.

[40] examined the ability of chitinolytic bacteria as a biocontrol agent of *Fusarium* wilt of red chili (*Capsicum annuum L.*) seedlings and observed relative reduction in disease incidence ranged from 28.57 to 60.71% and further compared different biocontrol agents and ranked BK08 as the most potential candidate for biological control agent of *Fusarium* wilt. [70] evaluated performance of six *Trichoderma* spp. and four *Pseudomonas* spp. isolates for their bio control efficacy against *Fusarium solani* and reported *T. viride* and *Pseudomonas fluorescens* as most efficient antagonists.

[71] tested antagonistic rhizobacteria *Pseudomonas fluorescens, Pseudomonas putida* and *Bacillus subtillis* singly and in combination for their biological control efficacy against *Rhizoctonia solani* and *Sclerotium rolfsii* under greenhouse conditions. And reported that combination of *B. 6ubtilis* with *Pseudomonads* strains can lead to greater plant protection than alone. [72] evaluated the efficacy of antagonistic microorganisms against F*usarium oxysporum f.sp lycopersici* and reported minimum disease incidence with antagonistic microorganisms. Further, they also revealed significant increase in shoot length, root length, biomass and fruit yields with the treatment comprising *T. viride, Pseudomonas fluorescens, Paecilomyces lilacinus* + neem cake. [39] reported *Pseudomonas fluorescens + B. 6ubtilis* + neem + chitin as the best treatment for reducing the fruit rot incidence besides increasing the plant growth and yields parameters.

[18] characterized and identified 28 antagonistic endophytic bacterial isolates associated with eggplant against *Ralstonia solanacearum* causing bacterial wilt and observed that plants treated with *Pseudomonas* isolates (EB9, EB67), *Enterobacter* isolates (EB44, EB89) and *Bacillus* isolates (EC4, EC13) reported reduced wilt incidence by more than 70%. [73] isolated 108 endophytic strains from capsicum plants and reported strains BS-1 and BS-2 (identified as *Bacillus 7ubtilis*) as most effective as exhibited 57.34 - 94.08% control against anthracnose (*Colletotrichum gloeosporioides*).

PGPR against viruses

PGPR all over the world have been reported to reduce the virus attack on the crops. [74] studied the effect of PGPR strains for induction of systemic resistance against cucumber mosaic virus. Similarly, [69] studied their effect on whitefly-transmitted tomato mottle virus in tomato plants. They all concluded that tomatoes treated with PGPR demonstrated a reduction in the incidence of viral infection and significant increase in tomato yields. [53] investigated the biocontrol efficacy of strains of *Pseudomonas fluorescens* against tomato spotted wilt virus (TSWV) in tomato and reported significant reduction in TSWV incidence with a concomitant increase in growth promotion and yields in both the glasshouse and field conditions.

PGPR against root not nematodes

Root not nematodes are among the major causes for losses in yields in various crops, however, biocontrol involving PGPR have been reported by many researchers. [75] reported 65.4%, 68.2%, 53.8% and 53.8% control effect of *B. polymyxa, Bacillus* spp. B697, *B. megaterium* and *Azospirillum* spp., respectively against root not nematode *M. incognita.* [76] evaluated the influence of some bacterial isolates of *Mycobacterium* spp., *Micrococcus* spp., *Escherichia coli, Bacillus subtilis, Serratia marcescens, Pseudomonas aeruginosa* and *Sarcina* spp. as biocontrol agents against the rootknot nematode (*Meloidogyne incognita*) infecting eggplant, under greenhouse conditions and reported that most of the tested bacterial isolates significantly reduced numbers of galls, their developmental stages and egg masses in roots.

Conclusion

Plant growth promoting rhizobacteria (PGPR) benefit the plant growth and development through various direct and indirect means of mechanism like the production of secondary metabolites, i.e. plant growth substances, changes root morphology resulting in greater root surface area for the uptake of nutrients, siderophores production, antagonism to soil-borne root pathogens, phosphate solubilization, and nitrogen fixation. PGPR inoculants though have attracted much attention throughout the world, generally, have resulted in positive responses under controlled (laboratory and greenhouse), however, their result under open conditions is unpredictable. PGPR must be ropagated artificially to optimize their viability and biological activity under field applications.

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Bibliography

1. Bowen GD and Rovira AD. "The rhizosphere and its management to improve plant growth". *Advances in Agronomy* 66 (1999): 1-102.
2. Cook RJ. "Advances in plant health management in the twentieth century". *Annual Review of Phytopathology* 38 (2000): 95-116.
3. Kloepper JW., *et al*. "Free- living bacterial inocula for enhancing crop productivity". *Trends in biotechnology* 7.2 (1989): 39-44.
4. Glick BR. "The enhancement of plant growth by free-living bacteria". *Canadian Journal of Microbiology* 41.2 (1995): 109-117.
5. Barraquio WL., *et al*. "The quest for nitrogen fixation in rice". Los Banos, Philippines (2000): 93-118.
6. Cattelan AJ., *et al*. "Screening of plant growth promoting rhizobacteria to promote early soybean growth". *Soil Science Society of American Journal* 63.6 (1999): 1670-1680.
7. Vessey JK. "Plant growth promoting rhizobacteria as biofertilizers". *Plant and Soil* 255.2 (2003): 571-586.
8. Loon LC van. "Effects of beneficial microorganisms on plants". Bulletin-OILB/SROP 29.2 (2006): 183-192.
9. Adesemoye AO., *et al*. "Plant growth-promoting rhizobacteria allow reduced application rates of chemical fertilizers". *Microbial Ecology* 58.4 (2009): 921-929.
10. Sharma PK., *et al*. "Isolation and characterization of an endophytic bacterium related to Rhizobium/Agrobacterium from wheat (Triticum aestivum L.) roots". *Current Sciences* 89.4 (2005): 608-610.
11. Larran S and Monaco C. "Status and progress of research in endophytes from agricultural crops in Argentina". *Management of fungal plant pathogens* 24 (2010): 149-161.
12. Sturz AV., *et al*. "Bacterial endophytes: potential role in developing sustainable systems of crop production". *Plant Science* 19 (2000): 1-30.
13. Austin MB and Nobel AJP. "The chalcone synthase superfamily of type III poly peptide synthases". *National Production Report* 20.1 (2003): 79-110.
14. Klein DA., *et al*. "Microbial colonization of plant roots". In: biotechnology of plant-microbe interactions. JP Nakas and C Hagedon (editions.). Mc. Graw-Hill, New York (1990): 1989-1225.
15. Vijaypal I., *et al*. "Rhizosphere bacteria for biocontrol of plant diseases". *Indian Journal of Microbiology* 38 (1998): 187-204.
16. Smith KP and Goodman RM. "Host variation for interactions with beneficial plant associated microbes". *Annual Review of Phytopathology* 37 (1999): 473-491.
17. Rangeshwaran R., *et al*. "Isolation of endophytic bacteria for biological control of wilt pathogens". *Journal of Biological Control* 16.2 (2002): 125-133.
18. Ramesh R., *et al*. "Pseudomonads: major antagonistic endophytic bacteria to suppress bacterial wilt pathogen, Ralstonia solanacearum in the eggplant (Solanum melongena L.)". *World Journal of Microbiology and Biotechnology* 25.1 (2009): 47-55.

19. Gadade AS., *et al*. "Studies on phosphate solubilizing isolates from chilli rhizosphere". *Journal of Maharashtra Agricultural Universities* 35.2 (2010): 319-320.
20. Kloepper JW., *et al*. "Effects of rhizosphere colonization by plant growth promoting rhizobacteria on potato plant development and yield". *Phytopathology* 70.11 (1980): 1078-1082.
21. Suslow TV. "Role of root colonizing bacteria in plant growth". In: Mount M S and Lacy G H (eds.). Phytopathogenic prokaryotes. Academic press, New York. 1 (1982): 187-223.
22. James EK and Olivares FL. "Infection and colonization of sugarcane and other graminaceous plants by endophytic diazotrophs". *Critical Review of Plant Science* 17.1 (1998): 77-119.
23. Reinnhold HB and Hurek T. "Life in grasses; diazotrophic endophytes". *Trends in Microbiology* 6.4 (1998): 139-144.
24. Kundu BS., *et al*. "Host specificity of phosphate solubilizing bacteria". *Indian Journal of Microbiology* 42.1 (2002): 19-21.
25. Akhaury P and Kapoor KK. "Solubilization of insoluble phosphate by fungi isolated from compost and soil". *Environmental Ecology* 15.3 (1997): 524-527.
26. Raju RA and Reddy MN. "Effect of rock phosphate amended with phosphate solubilizing bacteria and farmyard manure in wetland rice (Oryza sativa)". *Indian Journal of Agriculture Science* 69 (1999): 524-527.
27. Tilak KVBR., *et al*. "Diversity of plant growth and soil health supporting bacteria". *Current Science* 89.1 (2005): 136-150.
28. Suliasih N and Widawati S. "Isolation and identification of phosphate solubilizing and nitrogen fixing bacteria from Soil in Wamena Biological Garden, Jayawijaya, Papua". *Biodiversitas* 6.5 (2005): 175-177.
29. Ikram A. "Beneficial soil microbes and crop productivity". *Planter* 66.777 (1990): 640-648.
30. Ahmad F., *et al*. "Screening of free living rhizospheric bacteria for their multiple plant growth promoting activities". *Microbiological Research* 163.2 (2008): 173-181.
31. Carson KC., *et al*. "Hydroxamate siderophores of root odule bacteria". *Soil Biology and Biochemistry* 32.1 (2000): 11-21.
32. Whipps JM. "Microbial interactions and biocontrol in the rhizosphere". *Journal of Experimental Botany* 52 (2001): 487-511.
33. Villegas MED., *et al*. "Evaluation of siderophore production by Pseudomonas aeruginosa PSS". *Microbiologia* 44 (2002): 112-117.
34. Vikram A., *et al*. "Production of plant growth promoting substances by phosphate solubilizing bacterial isolates from vertisols". *Journal of Plant Sciences* 2.3 (2007): 326-333.
35. Fatima Z., *et al*. "Antifungal activity of plant growth promoting rhizobaterial isolates against Rhizoctonia solani in wheat". *African Journal of Biotechnology* 8.2 (2009): 219-225.
36. Karnwal A. "Production of indole acetic acid by fluorescent Pseudomonas in the presence of L- tryptophan and rice root exudates". *Journal of Plant Pathology* 91.1 (2009): 61-63.
37. Glick BR., *et al*. "Promotion of plant growth by bacterial ACC deaminase". *Critical Review of Plant Science* 26 (2007): 227-242.
38. Zahir ZA., *et al*. "Improving maize yield by inoculation with PGPR". *Pakistan Journal of Soil Science* 15 (1998): 7-11.
39. Bharathi R., *et al*. "Rhizobacteria based bio-formulations for the management of fruit rot infection in chillies". *Crop-Protection* 23.9 (2004): 835-843.
40. Suryanto D., *et al*. "Control of Fusarium wilt of chili with chitinolytic bacteria". *Hayati Journal of Biosciences* 17.1 (2010): 5-8.
41. Glala AA., *et al*. "Influence of plant growth promoting rhizosphere-bacteria "PGPR" enrichment and some alternative nitrogen organic sources on tomato". *Acta Horticulturae* 852 (2010): 131-138.
42. Cao L., *et al*. "Isolation and characterization of endophytic Streptomyces strains from surface-sterilized tomato (Lycopersicon esculentum) roots". *Letters in Applied Microbiology* 39.5 (2004): 425-430.
43. Kokalis BN., *et al*. "Field evaluation of plant growth-promoting rhizobacteria amended transplant mixes and soil solarization for tomato and pepper production in Florida". *Plant and Soil* 238.2 (2002): 257-266.
44. Bhattacharyya P and Ghosh G. "The fluorescent Pseudomonads as plant growth promoting rhizobacteria in some agricultural crops". *Indian Agriculturist* 51 (2001): 59-62.
45. Guillen CR., *et al*. "Bacillus spp. as biocontrol in an infested soil with Fusarium spp., Rhizoctonia solani Kuhn and Phytophthora capsici Leonian and its effect on development and yield of pepper crop (Capsicum annuum L.)". *Revista Mexicana de Fitopatologia* 24.2 (2006): 105-114.
46. Morsy EM., *et al*. "Efficiency of Trichoderma viride and Bacillus subtilis as biocontrol agents against Fusarium solani on tomato plants". *Egyptian Journal of Phytopathology* 37.1 (2009): 47-57.
47. Domenech J., *et al*. "Combined application of the biological product LS213 with Bacillus, Pseudomonas or Chryseobacterium for growth promotion and biological control of soil-borne diseases in pepper and tomato". *Bio Control* 51.2 (2006): 245-258.
48. Ordookhani K., *et al*. "Influence of PGPR and AMF on antioxidant activity, lycopene and potassium contents in tomato". *African Journal of Agricultural Research* 5.10 (2010): 1108-1116.
49. Datta M., *et al*. "Plant growth promoting rhizobacteria enhance growth and yield of chilli (Capsicum annuum.) under field conditions". *Australian Journal of Crop Science* 5.5 (2011): 531-536.
50. Mena VHG and Olalde PV. "Alteration of tomato fruit quality by root inoculation with plant growth-promoting rhizobacteria (PGPR): Bacillus subtilis BEB-13bs". *Scientia Horticulturae* 113.1 (2007): 103-106.
51. Oliveira MF., *et al*. "Anti-phytopathogen potential of endophytic actinobacteria isolated from tomato plants (Lycopersicon esculentum) in southern Brazil and characterization of Streptomyces spp. R18(6), a potential biocontrol agent". *Research in Microbiology* 161.7 (2010): 565-572.
52. Dong F., *et al*. "Characterization of the endophytic antagonist pY11T-3-1 against bacterial soft rot of Pinellia ternate". *Letters in Applied Microbiology* 50.6 (2010): 611-617.

53. Kandan A., *et al*. "Use of Pseudomonas fluorescens-based formulations for management of tomato spotted wilt virus (TSWV) and enhanced yield in tomato". *Biocontrol Science and Technology* 15.6 (2005): 553-569.

54. Bakker AW and Schippers B. "Microbial cyanide production in the rhizosphere to potato yield reduction and Pseudomonas spp. mediated plant growth stimulation". *Soil Biology and Biochemistry* 19.4 (1987): 451-457.

55. Knowles CJ. "Microorganisms and cyanide". *Bacteriological Review* 40.3 (1976): 652-680.

56. Uneo M., *et al*. "Indole acetic acid related compounds induce the resistance to rice blast fungus, Magnaporthe griesea in Barley". *Phytopathology* 152 (2004): 606-661.

57. Tsomlexoglou E., *et al*. "Biocontrol potential of Bacillus antagonists selected for their different modes of action against Botrytis cinereal". Bulletin-OILB/SROP 24.3 (2001): 137-141.

58. Jourdan E., *et al*. "PGPR-induced systemic resistance: activity of amphiphilic elicitors and structural analogues on different plant species". Bulletin-OILB/SROP 30.6-1 (2007): 123-126.

59. Kumaresan K., *et al*. "Development of bioformulations of antagonistic bacteria for the management of damping off of chilli (Capsicum annuum L.)". *Archives of Phytopathology and Plant Protection* 38.1 (2005): 19-30.

60. Penrose DM and Glick BR. "Methods for isolating and characterizing ACC deaminase-containing plant growth-promoting rhizobacteria". *Physiologia Plantarum* 118.1 (2003): 10-15.

61. Liu F., *et al*. "Mechanism of biological control of Phytophthora blight in pepper by mangrove endophytic bacterium strain RS261". *Acta Phytopathologica Sinica* 40.1 (2010): 74-80.

62. Guo-Jian H., *et al*. "Biocontrol efficiency of three PGPR strains admixture to pepper bacterial wilt". *Bacterial Wilt Newsletter* 17 (2002): 32-47.

63. Rahman MM and Khan AAA. "Antagonist against bacterial wilt pathogen (Ralstonia solanacearum)". *Bangladesh Journal of Plant Pathology* 18(1/2) (2002): 27-31.

64. Yuan SZ and Zhou MG. "Screening and root colonization of biocontrol agents against Phytophthora capsica". *Journal of Yangzhou University Agricultural and Life Sciences* 27.4 (2006): 93-97.

65. Sadfi Z N., *et al*. "Ability of the antagonistic bacteria Bacillus subtilis and B. licheniformis to control Botrytis cinerea on fresh market tomatoes". Bulletin-OILB/SROP 30(6(1)) (2007): 63.

66. Nguyen MT and Ranamukhaarachchi SL. "Soil-borne antagonists for biological control of bacterial wilt disease caused by Ralstonia solanacearum in tomato and pepper". *Journal of Plant Pathology* 92.2 (2010): 395-406.

67. Lin HF., *et al*. "Evaluation of Bacillus subtilis as a bio-control agent against pepper blight under greenhouse and field conditions". *Journal of the Agricultural Association of Taiwan* 11.3 (2010): 210-222.

68. Cho Ja Y and Chung Soon J. "Effect of rhizobacteria on the growth of cucumber and tomato plug seedlings". *Journal of the Korean Society for Horticultural Science* 39.1 (1998): 18-23.

69. Hanafi A and Fellah K. "Does the PGPR Bacillus subtilis induce plant resistance to whiteflies and Pythium spp. in greenhouse tomato?". Bulletin OILB/SROP 29.4 (2006): 105.

70. Rani GSD., *et al*. "Biological control of Fusarium solani causing wilt of chilli". *Indian Phytopathology* 62.2 (2009): 190-198.

71. Saman A. "Efficacy of combine use of biocontrol agents on control of Sclerotium rolfsii and Rhizoctonia solani of Capsicum annuum". *Archives of Phytopathology and Plant Protection* 42.3 (2009): 221-227.

72. Sivakumar T., *et al*. "Bioefficacy of antagonists against for the management of Fusarium oxysporum f. sp. lycopersici and Meloidogyne incognita disease complex of tomato under field condition". *Plant Archives* 8.1 (2008): 373-377.

73. Hong H., *et al*. "Selection of endophytic antifungal bacteria from capsicum". *Chinese Journal of Biological Control* 18.4 (2002): 171-175.

74. Murphy JF., *et al*. "Plant growth-promoting rhizobacterial mediated protection in tomato against tomato mottle virus". *Plant Disease* 84.7 (2000): 779-784.

75. Dai M., *et al*. "Effects of plant growth-promoting rhizobacteria on root-knot nematode in tomato". *Chinese Journal of Biological Control* 25.2 (2009): 181-184.

76. Shalaby MEM and Sedik MZ. "Biocontrol activity of some bacterial isolates against Meloidogyne incognita". *Egyptian Journal of Biological Pest Control* 18.1 (2008): 119-125.

Volume 1 Issue 3 August 2017