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Review Article

ROLE OF BIOFERTILIZERS IN AGRICULTURE- A REVIEW

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ABSTRACT

With the increase in population, the demand for the crop has significantly increased which has led to extensive use of inorganic fertilizers without least consideration for soil health, which is a critical factor for realizing sustainable high yield. Besides this, the residual effects of inorganic fertilizers on environment, underground water resources and soil micro-flora, is a matter of great concern. The beneficial plant microbe interactions in the rhizosphere are the primary determinants of plant health and soil fertility and improve long term sustainability of soil. The lost biological activity in the soil, due to excess use of chemical fertilizers, can be restored slowly by incorporating artificially multiplied cultures of beneficial microorganisms in the form of biofertilizers. They produce growth promoting substances and vitamins and help to maintain soil fertility and suppress the incidence of pathogen and control diseases which ultimately results in improved yield and yield components. As a cost effective supplement to chemical fertilizers, biofertilizers can help to economize the high investment needed for fertilizer use. Biofertilizers are carrier based micro-organisms which help to enhance productivity by biological nitrogen fixation or solubilization of insoluble phosphate or by producing hormones, vitamins and other growth promoters required for plant growth.

INTRODUCTION

Biofertilizers are preparations containing living or latent cells of efficient strains of microorganisms that accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants.

Table 1 Types of Biofertilizer

1	Nitrogen fixers	Symbiotic Nodulating (*Rhizobium)*; Non- nodulating (*Anabaena* in association with water fern *Azolla)* Asymbiotic *Azotobacter; Azospirilium; Acetobacter*; Blue green algae (*Nostoc* or *Anabaena* or *Tolypothrix* or *Aulosira*)
2	Phosphorus biofertilizer	Phosphorus solubilizer Bacteria *(Bacillus polymyxa*, *Pseudomonas striata)*; Fungi *(Aspergillus spp., Penicillium spp.)* Phosphorus mobilizer *(Glomus spp*., *Scutellospora spp.*)
3	Potassium solubilizer	*Acidothiobacillus ferrooxidans, Paenibacillus spp., Bacillus mucilaginosus, B. edaphicus,* and *B. circulans*
4	Silicate and zinc solubilizer	*Bacillus spp.*
5	Compost biofertilizer	Cellulolytic (*Trichoderma spp.)*; Lignolytic (*Agaricus spp.)*
6	PGPRs	*Psedomonas fluorescence*

Bio-fertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances.

Biofertilizers importance in crop growth, yield, nutrient availability and stress tolerance

N Fixers

Rhizobium

Rhizobium species are group of bacteria that fix atmospheric nitrogen symbiotically and stimulate the growth of plants. The enzyme system of bacteria supplies constant source of reduced nitrogen to the host plant and the plant in turn provides nutrients and energy for the activities of the bacteria (Singh *et al.,* 2008). *Rhizobium* inhibited the growth of pathogenic fungi which indicates that *Rhizobium* may secrete antifungal compounds (Panwar *et al*., 2014). PGPR and Rhizobia strain can promote seed emergence and seedling attributes which benefits the early seedling establishment and consequently the crop growth and development (Mia, 2012). *Rhizobium* increases plant growth by various ways such as production of plant growth hormones, vitamins, siderophores, by

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solubilisation of insoluble phosphates, induction of systemic disease resistance and enhancement in stress resistance (Hussain *et al.,* 2009).

Azospirillum

The promotion of plant growth inoculated with resulting in significant changes in several characteristics of the plants. The *Azospirillum* inoculation increase germination rate, dry weight accumulation of nitrogen and grain yield and also changes duration of the plants growth stages (Boddey and Döbereiner, 1988; Fages, 1994; Fallik and Okon, 1996; Nur *et al*., 1980; Pandey *et al* 1998 and Sumner, 1990). Better plant root development due to *Azospirillum* inoculation is caused by production of growth promoters substances of plants (Bashan and Holguin, 1997; Boddey *et al*., 1986 and Dobereiner, 1992).The beneficial effects caused by the inoculation with *Azospirillum* are not only due to N fixation in the rhizosphere, but mainly, for the best efficiency in the absorption of water and nutrients, which happens due to a more developed root system, increasing the soil area explored by the roots. Biofertilizers like *Azospirillum* release phytohormones like auxin which enhance root branching and also root elongation which is beneficial for plants in dry areas (Dobbelaere *et al*., 1999 and Steenhoudt and Vandereyden, 2000).

Azotobacter

Azotobacter is able to produce other plant hormones like gibberellins and cytokinins (Bhardwaj *et al*., 2014) and reduce stress in the plants and stabilizing their yields. Vargas *et al*. and Nur *et al*. stated that positive plant growth responses after inoculation with associated N_2 fixing bacteria were found under water stress conditions.

Azolla

Azolla is a floating pteridophyte, which contains as endosymbiont the nitrogen-fixing cyanobacterium *Anabaena azollae* (Bhuvaneshwari and Singh, 2015). *Azolla* can supply more than half of the required nitrogen to the rice crop and it is beneficial in wetland rice fields for bringing number of changes which include preventing rise in pH, reducing water temperature, curbing NH_3 volatilization, suppressing weeds and mosquito proliferation (Pabby *et al.,* 2004). Azolla could be utilized as an alternative source of N-fertilizer for higher production of crops in rice-wheat cropping system (Kohle and Mitra, 1989).The use of *Azolla* also increased organic matter and potassium contents of the soil (Bhuvaneshwari and Singh, 2015).

Phosphorus Mobilizers

Large amount of P applied as fertilizer enters into the immobile pools through precipitation reaction with highly reactive Al^{3+} and Fe^{3+} in acidic soil and Ca^{2+} in calcareous or normal soils (Gyaneshwar *et al*., 2002 and Hao *et al*., 2002). Although total P pool is high, only a part is available to plants. So, the release and mobilization of insoluble and fixed forms of P is an important aspect of increasing soil P availability. Mycorrhizae are the root-symbionts which obtain their nutrients from the plant and provide mineral elements like N, P, K, Ca, S and Zn to the host plant (Abbasi *et al*., 2015). Mycorrhiza inoculation significantly increased cucumber seedling survival, fruit yield; P and Zn shoot concentrations (Ortas, 2010). Colonization by arbuscular mycorrhizal fungi can provide multiple functions, such as increased nutrient uptake, drought tolerance and resistance to pathogens (Newsham *et al*., 1995). Arbuscular mycorrhiza, which forms symbioses with majority of plants, influence plant community development, nutrient uptake, water relations, and above-ground productivity. Arbuscular mycorrhizas also act as bioprotectants against pathogens and toxic stresses (Vander Heijden *et al*., 1998). Under water stress conditions, the hyphal of Mycorrhiza play as an additional lateral root system providing the water from long distances away from the root system to the plants.

P Solubilizers

Out of added phosphorus fertilizer only 10-20% is available for the plants; remaining P converts into as insoluble phosphate form like rock phosphate and tri-calcium phosphate. Phosphate solubilizing bacteria (PSB) significantly helps in the release of this insoluble inorganic phosphate and makes it available to the plants (Gupta *et al*., 2014). NPK application along with PSB had a higher germination index than the control as well as in NPK treated soil without PSB (Duarah *et al*., 2011). Inoculation of PSB together with rock phosphate fertilization increased the crop growth in terms of shoot height, shoot and root dry biomass, grain yield and total P uptake in both maize and wheat crops (Kaur and Reddy, 2015). Phosphorus solubilizing bacteria aid the growth of plants by stimulating the efficiency of biological nitrogen fixation, synthesizing phytohormones and enhancing the availability of some trace elements such as zinc and iron (Wani *et al*., 2007). Root length, shoot length and the total biomass of the plants of each treatment containing the PSB with or without NPK fertilizer after 15th day was significantly higher ($p \leq 0.05$) than that of the control and the NPK alone (Duarahet *et al*., 2011). Some phosphate solubilizing bacteria can accumulate heavy metals and eradicate heavy metal phytotoxicity and promots growth in plants (Katiyar and Goel, 2004). Soil fertility *viz*. available P, enzyme activities and PSB population in both maize and wheat crops was significantly improved with combine application of PSB inoculation and rock phosphate fertilization compared to DAP treatment. (Kaur and Reddy, 2015). Phosphorus solubiliziing bacterial cultures viz., *Agrobacterium radiobacter* and *Bacillus megatherium* and fungus *e.i. Aspergillus awamori* have positive influence on various growth and yield parameters and P uptake (Shankaraiah *et al*., 2000). Phosphate solubilizing microorganisms' technology improves the fertility and agricultural use of saline-alkaline soil without causing any environmental or health hazard that accompanies the continuous use of synthetic fertilizers (Alori *et al*., 2017). *Kushneria* sp. YCWA18, a strain that is capable of solubilizing both inorganic phosphorus and organo-phosphorus moderate halophilic properties and can be used in the development of saline-alkaline based agriculture (Zhu *et al*., 2011). *Aerococcus* sp. strain PSBCRG1-1, *Pseudomonas aeruginosa* strain PSBI3-1, *A. terreus* strain PSFCRG2-1 and *Aspergillus* sp. strain PSFNRH-2 solubilize tricalcium phosphate at different NaCl concentrations (Srinivasan *et al*., 2012). The PSM *Burkholderia cepacia* promoted the growth of maize plants in the presence of NaCl concentrations of up to 5% (Zhao *et al*., 2014). Combined use of PSB inoculation and rock phosphate was more economical due to minimal cost and maximum returns (Kaur and Reddy, 2015). Application of fungus cultures *Aspergillus awamori* in ratoon crop improves cane yield (8 to 10%), economy in fertilizer P (25%) and increased net returns (Shankaraih *et al*., 2000). Phosphate solubilizing microorganisms can positively have effect on the increase of plant growth and phosphorus absorption in maize plant, leading to plant tolerance improving under drought stress conditions (Zarabi *et al*., 2011).

K Solubilizers

With the introduction of high yielding crop varieties and the progressive intensification of agriculture, the soils are getting exhausted in K stock at a faster rate. Many bacteria such as *Acidothiobacillus ferrooxidans, Paenibacillus* spp., *Bacillus mucilaginosus, B. edaphicus,* and *B. circulans* dissolve silicate minerals (e.g., biotite, feldspar, illite, muscovite, orthoclase, and mica) and release K through the production of organic and inorganic acids, acidolysis, polysaccharides, complexolysis, chelation, and exchange reactions (Etesami *et al*., 2017). Inoculation of seeds and seedlings of different plants with KSB showed significant enhancement of germination percentage, seedling vigor, plant growth, yield, and K uptake by plants under greenhouse and field conditions (Anjanadevi *et al.*, 2016; Awasthi *et al.,* 2011; 2013; Meena *et al.*, 2015a and Meena *et al.*, 2014). Inoculation with KSB exerted beneficial effects on growth of pepper and cucumber (Sangeeth *et al.*, 2012), maize (Singh *et al.,* 2010), wheat (Sheng and He, 2006), Sudan grass (Basak and Biswas, 2012; Basak and Biswas, 2010) and Okra (Prajapati *et al.*, 2013). Use of KSB as bio-fertilizers for agriculture improvement can reduce the use of agrochemicals and support ecofriendly crop production (Archana *et al.,* 2013; Archana *et al.,* 2012; Prajapati *et al.,* 2013).

Si Solubilizers

Silicon is present in very large quantities in the soil as silicates and silicon dioxide, but the actual concentration of bio-available ortho-silicic acid is very less. Silicate Solubilizing Bacteria (SSB) dissolve various soil silicates into plant available ortho silicic acid thereby playing a major role in increasing crop yield & improving plant health. Several microbes like *Bacillus caldolytyicus*, *Bacillus mucilaginosus* var *siliceous*, *Proteus mirabilis*, *Pseudomonas spp.* and *Penicillium* spp. were found to release silica from natural silicates (Lauwers and Heien, 1974; Avakyan *et al*., 1986). The solubilized silicon has a larger interaction with other nutrients particularly phosphorus. Si in solution increase phosphorus availability to plants by reversing its fixation as Si competes for phosphorus fixation sites in the soil thus application of silicates released more of phosphorus in soil system (Chinnasami and Chandrasekaran, 1978). Besides silicon, silicate minerals contain potassium, calcium, magnesium, iron and zinc and therefore inoculation of SSB to soil benefit the crop by releasing several of these nutrients (Muralikannam, 1996).Simultaneous application of ‘Azotobacterin’ and ‘Silicabacterin’ increased the yields of raw cotton up to 34 % (Ciobanu, 1961). Field inoculation of silicate bacteria enhanced yield of maize, wheat, potato and tomatoes (Alkeksandrow, 1958); lucerne and maize (Vintikova, 1964).

Zn Solubilizers

Exogenous application of Zn sources causes transformation of 96-99% Zn into unavailable forms (Vidyashree, 2015). Microbial transformation of unavailable Zn to plat available form is an important to combat Zn malnutrition problem. Ramesh *et al.* (2014) reported that the strains MDSR7 and MDSR14 substantially influenced mobilization of zinc and its concentration in edible portion, yield of soybean and wheat, and can be utilized as bio-inoculants for bio-fertilization and biofortification. Arbuscular mycorrhizal fungi (AMF) can take up nutrients, including Zn and transfer them to the plant, thereby enhancing plant nutrition (Timothy and Cavagnaro, 2008). Further, under high soil Zn concentrations the formation of AM can also ‘protect’ against the accumulation of Zn in plant tissues to high concentrations. PGPR application alleviated the deficiency symptoms of Zn and invariably increased the total biomass (23%), grain yield (65%) and harvest index as well as Zn concentration in the grain (Tariq *et al.,* 2007). Further, the PGPR colonized rice plants were more efficient in acquiring Zn from either added or indigenous source, than non-colonized plants.

Plant Growth Promoting Rhizobacteria (PGPR)

The plant growth promoting rhizobacteria are suitable alternative to the chemical fertilizers and fungicides and hence may ensure sustainable agriculture production, environmental safety and lower production cost. PGPRs, colonize roots, modified root architecture (increased root branching, root number) and enhanced growth through production of phytohormones, siderophores, HCN, Nitrogen fixation and phosphate solubilization mechanisms (Kumar *et al*., 2015). Further, PGPR also modify root functioning, improve plant nutrition and influence the physiology of the whole plant. (Kumar *et al*., 2015). PGPRs improve plant growth by two mechanisms (Glick, 2012): (i) direct action mechanisms by providing essential plants nutrients (e.g., N, P, Fe etc.) or regulating plant hormone levels (cytokinins, gibberellins, indole-3-acetic acid, and ethylene); and (ii) indirect action (bio-control) mechanisms by decreasing the deleterious effects of various pathogens on the growth and yield of plants. PGPRs enrich soil with major plant nutrients such as nitrogen (by fixing it from the atmosphere), phosphorous and potassium (by solubilizing them from the soil) (Patel *et al*., 2015). They also assist in bioavailability of Zn by solubilizing it from various ores like $Zn_3(PO_4)_2$, $ZnCO_3$, and ZnO (Sirohi *et al*., 2015). They suppress the activity of pathogens by producing numerous antifungal metabolites like siderophores, hydrolytic enzymes, and antibiotics (Chowdhury *et al*., 2015). Several workers reported the improvement of germination of plants while growing through inoculation of PGPR (Vessey 2003 and Poonguzhali *et al*. 2006). The PGPR are reported to be involved in seed germination and in the induction of α-amylase, which helps to provide energy for the growth of roots and shoots (Beck and Ziegler 1989 and Kaneko *et al*. 2002) and biosynthesis of phytohormones such as gibberellins that stimulates the plant growth (Fincher 1989 and Kaneko *et al*. 2002).Soil bacteria such as *Azotobacter spp., Pseudomonas spp., Rhizobium spp., Enterobactor spp., Bacillus spp.* etc. produce amino acids, vitamins and growth promoting substances like indole acetic acid and gibberellic acid, which results in better growth of plants. Application of microbial inoculants enhanced the bioavailability of phosphate to crops, stimulated roots and shoots growth, fresh and dry shoot weights, P-labeled phosphate uptake, and s improved grain and dry matter yields (Rodríguez and Fraga, 1999). *Pseudomonas spp*. is reported to suppress several major plant pathogens. (Gupta *et al*., 2014). PGPR are reported to secrete some extracellular metabolites called siderophores. The presence of siderophore-producing PGPR in rhizosphere increases Fe^{3+} supply to plants and also enhance the plant growth and productivity. Siderophores are commonly referred to as microbial Fe-chelating low molecular weight compounds. This compound after chelating Fe^{3+} makes the soil Fe^{3+} deficient for other soil microbes and consequently inhibits the activity of competitive microbes. PGPR may protect plants against pathogens by direct antagonistic interactions between the biocontrol agent and the pathogen, as well as by induction of host resistance. In recent years, the role of siderophore-producing PGPR in biocontrol of soil-borne plant pathogens has created great interest.

Compost Biofertilizer

Microorganisms that are capable of decomposing organic matter at a faster rate can be used as a fertilizer for quick release of nutrients. *Aspergillus*, *Penicillium*, *Trichoderma* are cellulolytic fungi which break down cellulose of plant material. The natural process of decomposition is accelerated and composting time is reduced by 4 to 6 weeks by the use of inoculants of these organisms.

References

Abbasi, Hisamuddin, Akhtar, A. and Sharf, R. 2015. Vesicular arbuscular mycorrhizal (VAM) Fungi: A tool for sustainable agriculture. *American Journal of Plant Nutrition and Fertilization Technology,* 5 (2): 40-49.

Aleksandrov, V.G. 1958. Organo-mineral fertilizers and silica bacteria. *Dokl Akad-S Kh Nauk* 7:43-48.

Alori E., Fawole O. and Afolayan A. 2012. Characterization of arbuscular mycorrhizal spores isolated from Southern Guinea Savanna of Nigeria. *J. Agric. Sci.* 4: 13-19.

Alori, E.T. Glick, B.R. and Babalola, O.O. 2017. Microbial phosphorus solubilization and its potential for use in sustainable agriculture*. Front Microbiol*, 8: 971.

Anjanadevi, I.P., John, N.S., John, K.S., Jeeva, M.L. and Misra, R.S. 2016. Rock inhabiting potassium solubilizing bacteria from Kerala, India: characterization and possibility in chemical K fertilizer substitution. *J. Basic Microbial*. 56:67-77.

Archana, D., Nandish, M., Savalagi, V. and Alagawadi, A. 2013. Characterization of potassium solubilizing bacteria (KSB) from rhizosphere soil. *Bioinfolet-A Quarterly J. Life Sci*. 10:248-257.

Archana, D.S., Nandish, M.S., Savalagi, V.P. and Alagawadi, A.R. 2012. Screening of potassium solubilizing bacteria (KSB) for plant growth promotional activity. *Bioinfolet-A Quarterly J. Life Sci*. 9: 627-630.

Avakyan, Z.A., Pavavarova, T.A. and Karavako, G.I. 1986. Properties of a new species, *Bacillus mucilaginous*. *Microbiol,* 55:477-482.

Awasthi, R., Tewari, R. and Nayyar, H. 2011. Synergy between plants and P-solubilizing microbes in soils: effects on growth and physiology of crops*. Int. Res. J. Microbiol*, 2:484-503.

Basak, B. and Biswas, D. 2012. Modification of waste mica for alternative source of potassium: evaluation of potassium release in soil from waste mica treated with potassium solubilizing bacteria (KSB). *LAP LAMBERT Academic Publishing*.

Basak, B.B. and Biswas, D.R. 2010. Co-inoculation of potassium solubilizing and nitrogen fixing bacteria on solubilization of waste mica and their effect on growth promotion and nutrient acquisition by a forage crop. *Biol. Fertil. Soil,* 46: 641-648.

Bashan, Y. and Holguin, G. 1997. *Azospirillum*-plant relationships: environmental and physiological advances (1990-1996). *Can. J. Microbiol.*, 43: 103-121.

Beck, .E and Ziegler, P. 1989. Biosynthesis and degradation of starch in higher plants. *Annu Rev Plant Physiol Mol Biol.* 40:534-542.

Bhardwaj D., Ansari M.W., Sahoo R.K. and Tuteja N. 2014. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microb. Cell Fact*., 13:66.

Bhuvaneshwari, K. and Singh, P.K. 2015. Response of nitrogen-fixing water fern *Azolla* biofertilization to rice crop. *Biotech,* 5(4): 523-529.

Boddey, R.M. and Döbereiner, J. 1988. Nitrogen fixation associated with grasses and cereals: Recent results and perspectives for future research. *Plant Soil*, 108: 53-65.

Boddey, R.M., Baldani, V.L.D., Baldani, J.I. and Döbereiner, J. 1986. Effect of inoculation of *Azospirillum* spp. on nitrogen accumulation by field grown wheat. *Plant Soil*, 95: 109-121.

Chinnasami, K.N. and Chandrasekaran, S. 1978. Silica status in certain soils of Tamil Nadu. *Madras Agric J.* 65:743-746.

Chowdhury, P.S., Hartmann, A., Gao, X., and Borriss, R. 2015. Biocontrol mechanism by root-associated *Bacillus amyloliquefaciens* FZB42-a review. *Front. Microbiol*, 6:780.

Ciobanu, I. 1961. Investigation on the efficiency on for biocontrol of *Macrophomina phaseolina* bacterial fertilizers applied to cotton. *J Biol Cent Exp Control* 8:41-44.

Dobbelaere, S., Croonenborghs, A., Thys, A., Broek, A.V. and Vanderleyden, J. 1999. Phytostimulatory effect of *Azospirillum brasilense* wild type and mutant strains altered in IAA production on wheat. *Plant Soil* 6: 155-164.

Duarah, I., Deka, M., Saikia, N. and Deka Boruah, H.P. 2011. Phosphate solubilizers enhance NPK fertilizer use efficiency in rice and legume cultivation. *Biotech.,* 1(4): 227-238.

Etesami, H., Emami, S. and Alikhani, H.A. 2017. Potassium solubilizing bacteria (KSB): Mechanisms, promotion of plant growth, and future prospects A review. *J. Soil Sci. Plant Nutr*., 17 (4).

Fages, J. 1994. *Azospirillum* inoculants and field experiments, In: Okon, Y. (Ed.). *Azospirillum Plant Associations*. USA : CRC Press. pp. 88-105.

Fallik, E. and Okon, Y. 1996. The response of maize (*Zea mays*) to *Azospirillum* inoculation in various types of soils in the field. *World J. Microb. Biot*., 12: 511-515.

Fincher, G.B. 1989. Molecular and cellular biology associated with endosperm mobilization in germinating cereal grains. *Ann Rev Plant Physiol Plant Mol Biol*., 40:305-345.

Gupta, G.N., Srivastava, S., Khare, S.K and Prakas, V. 2014. Role of phosphate solubilizing bacteria incrop growth and disease management. *Journal of Pure and Applied Microbiology*, 8(1): 461-474.

Gyaneshwar, P., Kumar, N.J., Pareka, L.J. & Podle, P.S. 2002. Role of Soil Microorganisms in Improving P Nutrition of Plants. *Plant and Soil*, 245(1):83-93.

Hao, X., Cho, C.M., Racz, G.J. and Chang, C. 2002. Chemical Retardation of Phosphate Diffusion in an Acid Soil as Affected by Liming. *Nutrient Cycling in Agro ecosystems*, 64(3): 213-224.

Hussain, M.B., Mehboob, I., Zahir, Z.A., Naveed, M. and Asghar, H.N. 2009. Potential of *Rhizobium* spp. for improving growth and yield of rice (*Oryza sativa* L.). *Soil Environ*. 28(1): 49-55.

Kaneko, M., Itoh, H., Miyako, U.T., Ashikari, M. and Matsuka, M. 2002. The α-amylase induction in endosperm during rice seed germination is caused by gibberellin synthesized in epithelium. *Plant Physiol.*, 128:1264-1270.

Katiyar,V. and Goel, R. 2004. Improved plant growthfrom seed bacterization using siderophoreoverproducing cold resistant mutant of *Pseudomonas fluorescens*. *J. Microbiol.Biotechnol*., 14: 653-657.

Kaur, G. and Reddy, M.S. 2015. Effects of phosphate-solubilizing bacteria, rock phosphate and chemical fertilizers on maize-wheat cropping cycle and economics. *Pedosphere*, 25(3): 428-437.

Kohle, S. and Mitra, B.N. 1987. Effect of Azolla as an Organic Source of Nitrogen in Rice-Wheat Cropping System. *Journal of Agronomy and Crop Science,* 159(3):212-215 ·

Kumar, A.I., Bahadur, B.R., Maurya, R. and Raghuwanshi 2015. Does a plant growth promoting rhizobacteria enhance agricultural sustainability? *Journal of Pure and Applied Microbiology* 9(2):715-724.

Lauwers, A.M. and Heinen, W. 1974. Biodegradation and utilization of silica and qurtz. *Arch Microbiol* 95:67-78.

Meena, V.S., Maurya, B.R., and Bahadur, I. 2015a. Potassium solubilization by bacterial strain in waste mica. *Bangladesh J. Bot*. 43:235-237.

Meena, V.S., Maurya, B.R., and Verma, J.P. 2014. Does a rhizospheric microorganism enhance K^+ availability in agricultural soils?. *Microbiol. Res*., 169:337-347.

Mia, M.A.B. 2012. Effects of rhizobia and plant growth promoting bacteria inoculation on germination and seedling vigor of lowland rice. *African Journal of Biotechnology*, 11 (16).

Muralikannan, N. 1996. Biodissolution of silicate, phosphate and potassium by silicate solubilizing bacteria in rice ecosystem. *M Sc (Ag) thesis submitted to Tamil Nadu Agricultural University*, Coimbatore, pp 125.

Muralikannan, N. and Anthomiraj, S. 1998. Occurrence of silicate solublising bacteria in rice ecosystem. *Madras Agric J.,* 85 (1):47-50.

Newsham, K.K., Fitter, A.H and Watkinson. A.R. 1995. Multi-functionality and biodiversity in arbuscular mycorrhizas. *Trends Ecol. Evol.,* 10:407-411.

Nur, I., Okon, Y. and Henis, Y. 1980: An increase in nitrogen content of *Setaria italica* and *Zea mays* inoculaited with *Azospirillum*. *Can. J. Microbiol*., 26: 482-485.

Nur, I.Y., Okon, Y. and Henis, Y. 1980.Comparative studies of nitrogen-fixing bacteria associated with grasses in Israel with *Azospirillum brasilense*. *Can. J. Microbiol*., 26: 714-718.

Ortas, I. 2010. Effect of mycorrhiza application on plant growth and nutrient uptake in cucumber production under field conditions. 10.5424/sjar/201008S1-1230.

Pabby, A., Prasanna, R. and Singh, P.K. 2004. Biological significance of *Azolla* and its utilization in agriculture. *Proc Indian Natl. Sci. Acad*. 70:299-333.

Pandey, A., Sharma, E. and Palni, L.M.S. 1998. Influence of bacterial inoculation on maize in upland farming systems of the Sikkim himalaya. *Soil Biol. Biochem.*, 30: 379-384.

Parmar, P., and Sindhu, S.S. 2013. Potassium solubilization by rhizosphere bacteria: influence of nutritional and environmental conditions. *J. Microbiol. Res.,* 3: 25-31.

Patel, R.R., Thakkar, V.R. and Subramanian B.R. 2015. A *Pseudomonas guariconensis* strain capable of promoting growth and controlling collar rot disease in *Arachis hypogaea* L. *Plant Soil*, 390: 369-381.

Pawar,V.A., Pawar, P.R., Bhosale, A.M. and Chavan, S.V. 2014. Effect of *Rhizobium* on Seed Germination and Growth of Plants. *Journal of Academia and Industrial Research*. 3(2).

Poonguzhali, S., Madhaiyan, M. and Sa, T.M. 2006. Cultivation-dependent characterization of rhizobacterial communities from field grown Chinese cabbage *Brassica campestris* ssp. pekinensis and screening of traits for potential plant growth promotion. *Plant soil* 286:167-180.

Prajapati, K., Sharma, M.C. and Modi, H.A. 2013. Growth promoting effect of potassium solubilizing microorganisms on okra (*Abelmoscus Esculantus*). *Int. J. Agri. Sci. Res.* 1:181-188

Ramesh, A., Sharma, S.K., Sharmaa, M.P., Yadava, N. and Joshi, O.P. 2014. Inoculation of zinc solubilizing *Bacillus aryabhattai* strains forimproved growth, mobilization and biofortification of zinc in soybean and wheat cultivated in vertisols of central India. *Appl. Soil. Ecol.,* 73: 87-96.

Rodríguez, H., and Fraga, R. 1999. Phosphate solubilizing bacteria and their role in plant growth promotion. *Biotechnol. Adv.* 17: 319-339.

Sangeeth, K.P., Bhai, R.S. and Srinivasan, V. 2012. Paenibacillus glucanolyticus, a promising potassium solubilizing bacterium isolated from black pepper (*Piper nigrum* L.) rhizosphere. *J. Spic. Aromatic. Crop*. 21.

Shankaraiah, C., Hunsigi, G. and Nagaraju, M.S. 2000. Effect of levels and sources of phosphorus and phosphate solubilizing microorganisms on growth, yield and quality of sugarcane. *Sugar Tech* 2: 23.

Sheng, X.F. and He, L.Y. 2006. Solubilization of potassium-bearing minerals by a wild-type strain of *Bacillus edaphicus* and its mutants and increased potassium uptake by wheat. *Can. J. Microbiol.,* 52: 66-72.

Singh, B., Kaur, R. and Singh, K. 2008. Characterization of *Rhizobium* strain isolated from the roots of *Trigonella foenumgraecum* (fenugreek). *Afri. J. Biotechnol*., 7(20): 3671-3676.

Singh, G., Biswas, D.R. and Marwaha, T.S. 2010. Mobilization of potassium from waste mica by plant growth promoting rhizobacteria and its assimilation by maize (*Zea mays*) and wheat (*Triticum aestivum* L.): a hydroponics study under phytotron growth chamber. *J. Plant Nutr*., 33: 1236-1251.

Sirohi, G., Upadhyay, A., Srivastava, P.S. and Srivastava, S. 2015. PGPR mediated Zinc biofertilization of soil and its impact on growth and productivity of wheat. *J. Soil Sci. Plant Nutr*., 15: 202-216.

Srinivasan, R., Yandigeri, M.S., Kashyap S. and Alagawadi, A.R. 2012. Effect of salt on survival and P-solubilization potential of phosphate solubilizing microorganisms from salt affected soils. *Saudi J. Biol. Sci.,* 19: 427-434.

Steenhoudt, O. and Vandereyden, J. 2000. *Azospirillum*, free-living nitrogen fixing bacterium closely associated with grasses: genetic, biochemical and ecological aspects. *FEMS Microbiol. Rev*., 24: 487-506.

Sumner, M.E. 1990. Crop responses to *Azospirillum* inoculation. In: Stewat, B. A. (Ed.). *Advances in Soil Science*. New York : Springer-Verlag. pp. 52-123.

Tariq, M., Hameed, S., Kauser, A., Mali and Hafeez, Y.F. 2007. Plant root associate bacteria for mobilization in rice. *Pak. J. Bot*., 39 (1): 245-253.

Timothy, R. and Cavagnaro, R.T. 2008. The role of Arbuscular mycorrhizae in improving plant zinc nutrition under low soil zinc concentrations: a review. *Plant Soil*., 304: 315-325.

Uzma, I., Iftikhar, A., Nazia, J. and Shahida, H. 2010. Effect of Zinc phpsphate solubilizing bacteria on growth of *Vignaradiata. Annals. microbiol*.

Marcel, G.A., Klironomos, J.N., Ursic, M., Moutoglis, P., Streitwolf-Engel, R. Boller, T., Wiemken, A. and Sanders, I.R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature*., 396: 69-72.

Vargas, L., Santa Brigida, A.B., Mota Filho, J.P., de Carvalho, T.G. and Rojas, C.A. 2014. Drought tolerance conferred to sugarcane by association with *Gluconacetobacter diazotrophicus*: A transcriptomic view of hormone pathways. *Plos One,* 9.

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

Vidyashree, 2015. MSc. thesis. Evaluation of zinc solubilizing bacterial strain on zinc uptake of tomato Bengaluru, Karnataka.

Vintikova, H .1964. A contribution to study on efficiency of silicate bacteria. *Rostl. Vyr.,* 37:1219-1228.

Wani, P.A., Khan, M.S. and Zaidi, A. 2007. Co-inoculation of nitrogen fixing and phosphate solubilizing bacteria to promote growth, yield and nutrient uptake in chickpea. *Acta Agron. Hung.*

Zarabi, M., Alahdadi, I., Akbari, G.A. and Akbari, G.L. 2011. A study on the effects of different biofertilizer combinations on yield, its components and growth indices of corn (*Zea mays* L.) under drought stress condition. *African Journal of Agricultural Research,* 6(3): 681-685.

Zhao, K., Penttinen, P., Zhang, X., Ao, X., Liu M., Yu X. 2014. Maize rhizosphere in Sichuan, China, hosts plant growth promoting *Burkholderia cepacia* with phosphate solubilizing and antifungal abilities. *Microbiol. Res.,* 169: 76-82.

Zhu, F., Qu, L., Hong, X., and Sun, X. 2011. Isolation and Characterization of a Phosphate-Solubilizing Halophilic Bacterium *Kushneria sp*. YCWA18 from Daqiao Saltern on the Coast of Yellow Sea of China.

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