IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 3, Issue 5, May 2016

Potential of Biofertilizers to Replace Chemical Fertilizers

Meenakshi Suhag

Assistant Professor, Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana

Abstract: The use of chemical fertilizers (e.g. urea, calcium nitrate, ammonium sulphate, diammonium phosphate etc.) have a great importance for the world's food production as it works as a fast food for plants causing them to grow more rapidly and efficiently. While adverse effects are being noticed due to the excessive and imbalanced use of these synthetic inputs. Moreover, persistent use of conventional chemical fertilizers subverts the soil ecology, disrupt environment, degrade soil fertility and consequently shows harmful effects on human health and contaminates ground water. For these reasons, biofertilizers, the organic substances, which make use of microorganisms to increase the fertility of soil, has been identified as harmless input help in safeguarding the soil health and also the quality of crop products. Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilising phosphorus, and stimulating plant growth through the synthesis of growth promoting substances. They are also environment friendly and responsible for continuous availability of nutrients from natural sources. This paper will review the facts and observations regarding biofertilizers, types and their potential for crop production based on relevant literature and research work carried out by many researchers.

Keywords: Nutrients, Chemical fertilizers, Biofertilizers, Microorganisms, Growth promoting substances,

INTRODUCTION

The importance of 16 essential plant nutrients (such as N, P, K, Ca, Mg and S are called macronutrients, while Fe, Zn, Cu, Mo, Mn, B and Cl are called micronutrients) in required quantities to achieve the maximum yield in crop production is well-established. N, P and K are required in enhancing the natural ability of plants to resist stress from drought and cold, pests and diseases (Tsai et al., 2007). Current soil and agriculture management strategies are mainly dependent on continuous use of inorganic chemical-based fertilizers which are industrially manipulated substances, largely water-soluble and contain high available nutrient concentrations.

However, excessive use of chemical fertilizers not only cost intensive but also creates the problem of environmental pollution. Sustainable agriculture offers the potential to meet our agricultural needs as it encompasses advances in agriculture by using special farming, management practices and technology at the same time ensuring that no harm done to the same. Chemical fertilizers and their exploitation cause air and ground water pollution by eutrophication of water bodies (Youssef et al., 2014). Conventional, chemically processed fertilizers also subvert the soil ecology, disrupt environment, degrade soil fertility and consequently shows harmful effects on human health (Ayala and Rao, 2002). Hence, the practice of chemical farming put the long-run sustainability of agriculture and the survival of the farming community at risk. In this context, biofertilizers have emerged as an important component of the integrated nutrient supply system and have great potential to improve crop yields through environmentally better nutrient supplies (Das et al. 2007). This review highlights the role of biofertilizers in modern agriculture, future prospects and aspects based on relevant literature.

BIOFERTILIZERS

Biofertilizers most commonly referred to as the fertilizer that contains living soil micro-organisms to increase the availability and uptake of mineral nutrients for plants (Vessey, 2003). It is expected that their activities will influence the soil ecosystem and produce supplementary substance for the plants. Biofertilizers also include organic fertilizers (manure, etc.), which are rendered in an available form due to the interaction of micro-organisms or due to their association with plants (Sujanya and Chandra, 2011). When biofertilizers are applied as seed or soil inoculants, they multiply and participate in nutrient cycling and benefit crop productivity (Singh et al., 2011).

Biofertilizers keep the soil environment rich in all kinds of micro- and macro-nutrients via nitrogen fixation, phosphate and potassium solubilisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Sinha et al., 2014; Sivakumar et al., 2013) providing better nutrient uptake and increased tolerance towards drought and moisture stress. Biofertilizers differ from chemical and organic fertilizers in the sense that they do not directly supply any nutrients to crops and are cultures of special bacteria and fungi, relatively simple and having low installation cost. Biofertilizer overall produced higher growth rates, yield development of rice production compared with Chemical fertilizer (Alam and Seth, 2012). Therefore, biofertilizers can solve the problem of feeding an increasing global population at a time when agriculture is facing various environmental stresses and changes.

Types of Biofertilizers

Biofertilizers are live formulates of microorganisms (useful bacteria and fungi) that are ready to be used and

improve the quality and the health of the soil and the plant species by increasing the nutrient availability for the soil and plants (Abbasniayzare et al., 2012). The common microorganisms (Table 1.) which use as microbial inoculants (biofertilizer) can be divided in two groups, containing symbiotic system such as *Rhizobium* spp., *Frankia* spp. and *Azolla* spp. and non symbiotic system such as *Azotobacter* spp., *Azospirillum* spp. and blue green algae (Bashan and Holguin, 1997). Biofertilizers thus include the following, symbiotic nitrogen fixers *Rhizobium* spp. asymbiotic free nitrogen fixers (*Azotobacter*, *Azospirillum*, etc.), algae biofertilizers (blue green algae or BGA in association with *Azolla*), phosphate solubilising bacteria, *mycorrhizae*, organic fertilizers (Goel et al., 1999). **Biological nitrogen (N) fixers** include members of genus *Rhizobium*, *Azospirillum*, and blue-green algae. The most striking relationship that these have with plants is symbiosis, in which the partners derive benefits from each other. The use of biological nitrogen fixation by living nitrogen fixers will help minimize use of chemical nitrogen fertilizer and to improve plant growth to decrease the production cost and environmental risk (El-Hawary et al., 2002). Rhizosphere associated N_2-fixing *Paenibacillus* species have increasingly been used in non-legume crop species such as sugar beet and conifer species (Bent et al., 2002). Bio-fertilization strategy using selected rhizobial strains to promote rice production capacity maintain agricultural sustainability and acceptable
production economy (Yanni and Dazzo, 2010).
Microorganisms involved in phosphorus acquisition include *mycorrhizal* fungi and Phosphate solubilizing Micro-organisms (PSMs). Most plants form symbiotic associations with the arbuscular mycorrhizal fungi (AMF) acting as bio-ameliorators, has the potential to enhance the rhizospheric soil characteristics considerably thereby improves soil structure so as to promote plant growth under normal as well as stressed conditions (Rabie and Almadini, 2005). Results revealed that AMF induced enhancement in nutrient uptake promotes various biologically important metabolites such as plant hormones including GA and auxin have an irreplaceable role in plant growth regulation under normal as well as stress conditions. Microorganisms are central to the soil P cycle and play a significant role inmediating the transfer of P between different inorganic and organic soil P fractions, subsequently releasing available P for plant acquisition (Oberson et al., 2001). Phosphate solubilization takes place through various microbial processes / mechanisms including organic acid production and proton extrusion (Dutton and Evans, 1996). P uptake by plants can be enhanced by inoculation of phosphate solubilizing fungi (PSF) mainly *Aspergillus* species because of their strong ability to provide available P and had strongest growth-promoting effects in chickpea plants (Mittal et al., 2008). The example of K-solubilizer is *Bacillus mucilaginous* while for P-solubilizer are *Bacillus megaterium*, *Bacillus circulans*, *Bacillus subtilis* and *Pseudomonas straita* (Mohammadi and Sohrabi, 2012). Microbial fertilizers like *Rhizobium* and phosphate-solubilizing bacteria (PSB) are highly beneficial in enhancing nitrogen (N) and phosphorus (P) content because of added nitrogen fixation by *Rhizobium* and the solubilization of native P by PSB, thus making the two essential nutrients available to the plant by their synergistic effect (Singh et al., 2011). Many marketable biofertilizers are mainly based on plant growth-promoting rhizobacteria (PGPR) that induce plant growth by several processes including biological N_2 fixation, increase of nutrient availability in the rhizosphere, enlargement of root surface area, enhancement of beneficial symbioses for the host (Vessey, 2003) providing iron that has been sequestered by bacterial siderophores, and soluble phosphate (Hayat et al., 2010).

Table1. Types of Biofertilizers

Sr. No	Types of Biofertilizers	Characteristics	Micro-organisms
1	Nitrogen fixing biofertilizers	Obtain Nitrogen from the atmosphere and convert this into organic forms usable by plants	*Rhizobium, Azospirillum, Azotobacter*
2	Phosphorous solubilizing biofertilizers (PSB)	Solubilize insoluble inorganic phosphate compounds	*Bacillus, Pseudomonas* and *Aspergillus*
3	Phosphate mobilizing biofertilizers	symbiotic association between host plants and certain group of fungi at the root system	*Mycorrhiza*
4	Plant growth promoting biofertilizers	Increasing the growth and yield of plant	*Pseudomonas* sp.

Potential of Biofertilizers in crops production

Biofertilizer could be used as a nutrient source or to ameliorate soil microbiology by maintaining fruit yield and quality and promoting nutritionally supplied plants with lower production costs (Cavalcante et al., 2012). Nitrogen fixing microorganisms plays an important role in increasing yield by converting atmospheric nitrogen into organic forms usable by plant. *Rhizobia* are symbiotically associated with legumes and nitrogen fixation occurs within root or stem nodules where the bacterium resides (Saikia and Jain, 2007). *Rhizobium* inoculation helps to improve nodulation, plant growth and produces higher grain yield by 10-15% under farmed condition than a crop that has not been inoculated. Nitrogen fixation by different annual legumes has been reported to vary from 35-270 kg^{-1} ha^{-1} yr^{-1}(Nutman, 1969). The most likely candidates for biological N fixation in rice are species of *Alcaligenes*, *Azospirillum*, *Bacillus*, *Herba spirillum*, *Klebsiella*, *Pseudomonas* and *Rhizobium* (Malik et al., 1997). Being resistant to different temperature ranges *Rhizobium* normally enters the root hairs, multi-plies there and forms nodules (Nehra et al., 2007). Result showed that the number of nodules per root system was significantly

IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology
Vol. 3, Issue 5, May 2016

higher in chickpea plants inoculated with *Rhizobium* sp. compared to control (Akhtar and Siddiqui, 2009). Use of biological N_2-fixation technology can contribute as much as 75 kg N ha^{-1}per crop cycle with means of 8 to 30 kg N ha^{-1}(Irissarri and Reinhold-Hurek, 2001) decrease N fertilizer application and reduce environmental risks (Raimam et al., 2007).

Azotobacter and *Azospirillum* are the two most important non-symbiotic N-fixing bacteria in non-leguminous crops. These N-fixing bacteria may be free-living or naturally associated to rice plants. Under appropriate conditions, *Azotobacter* and *Azospirillum* can enhance plant development and promote the yield of several agricultural important crops in different soils and climatic regions (Okon and Labendera-Gonzalez, 1994). *Azotobacter* plays an important role in the nitrogen cycle in nature as it possesses a variety of metabolic functions (Mrkovacki and Milic 2001). Besides playing role in nitrogen fixation, *Azotobacter* has the capacity to synthesizes and secretes considerable amounts of biologically active substances like vitamins such as thiamine and riboflavin (Revillas et al., 2000), nicotinic acid, pantothenic acid, biotin, heteroxins, gibberellins, secretion of ammonia in the rhizosphere in the presence of root exudates, which helps in modification of nutrient uptake by the plants (Narula and Gupta, 1986). Similarly, *Azospirillum* is free-living, motile, gram variable and aerobic bacterium also have the ability to produce plant growth regulatory substances which stimulate plant growth, changes in the plant roots that help in transport of minerals and water (Sarig et al., 1988) and thereby productivity. *Azospirillum* are reported to fix atmospheric nitrogen, produce plant growth-promoting substances Indole Acetic Acid (IAA) and Indole Butyric Acid (IBA) and increase the rate of mineral uptake by plant roots, resulting in the enhancement of plant yield (Gadagi et al., 2004). These beneficial effects of *Azotobacter* and *Azospirillum* on plants are attributed mainly to an improvement in root development, an increase in the rate of water and mineral uptake by roots, displacement of fungi and plant pathogenic bacteria and, to a lesser extent, biological nitrogen fixation (Okon and Itzigshohn, 1995. Study suggested, when the biofertilizers were inoculated with combined treatment of *Azotobacter* and *Azospirillum* than singly inoculated plants results in significantly higher growth and grain yields in pearl millet (Tilak, 1995), black pepper (Bopaiah and Khadeer, 1989) and tomato plants (Ramakrishnan and Selvakumar, 2012). Similar results in growth improvement and nutritional quality were also found in case of *Moringa oleifera* using combination of different biofertilizers such as *Azotobacter chroococcum*, *Azospirillum brazilense*, *Bacillus megatherium*, *Bacillus circulans*, *Pseudomonas fluorescens* and *Saccharomyces cerevisiae* (Zayed, 2012). Kloepper and Beauchamp (1992), reported increased wheat yield up to 43% and 30% with the inoculation of *Azotobacter* and *Bacillus* respectively.

Several soil bacteria and a few species of fungi possess the ability to bring insoluble phosphate in soil into soluble forms by secreting inorganic or organic acids and/or by reducing the pH and freeing available phosphate (He et al., 1996). Organic acids produced by PSB solubilize insoluble phosphates by lowering the pH, chelation of cations and competing with phosphate for adsorption sites in the soil (Nahas, 1996). Plant growth promoting Bacteria (PGPB) represent a wide variety of soil bacteria (such as *Azospirillum*, *Azotobacter*, *Bacillus* and *Pseudomonas* genus) which, when grown in association with a host plant play an important role in plant rhizosphere (Ghosh et al., 2010). Studies and surveys reported plant growth promotion, increased yield, uptake of N and some other elements through PGPR inoculations (Sheng and He, 2006) which significantly promote growth and increased shoot and root growth of canola and sugar beet (Bertrand et al., 2001). Plant growth-promoting rhizobacteria (PGPR) such as *Bacillus* and *Pseudomonas* (able to produce indolacetic acid (IAA) and gibberellins) are able to exert a beneficial effect upon plant growth, and therefore may be used as biofertilizers for agriculture (Broughton et al., 2003). Results shows that *Pseudomonas* not only degrades organic nitrogenous compounds but also improves circulation of N and P in soil (Hayat et al., 2010) and in wheat significantly increases root dry weight and harvest index (Walley & Germida, 1997). According to field visual observations, the plant growth regulators resulted in vigorous development of greener and larger leaves, despite the unfavourable, very dry climatic conditions (Nagy and Pinter, 2015). Inoculations with PGPR protecting the plant against soil-borne diseases through suppression of plant disease-causing organisms (Veerubommu and Kanoujia, 2011), most of which are caused by pathogenic fungi (Lutgtenberg and Kamilova, 2009).

Seaweed (brown marine alga *Stoechospermum marginatum*) extracts enhanced the shoot and root length, total fresh and dry weight, leaf area and the content of moisture, photosynthetic pigments, protein, amino acids, reducing sugar, ascorbic acid and nitrate reductase activity in the leaves of brinjal plants (Ramya et al., 2015). Organic wastes from animal production and agriculture and by products of agricultural and food processing industries cause substantial environmental and social problems could be act as good carrier material for nutrient and microorganisms (Hong-yuan et al., 2015). The use of organic matter such as sawdust, rice bran, rice husk and shredded paper to meet the requirements of a biofertilizer carrier is economical also.

CONCLUDING REMARKS

In modern agriculture, chemical fertilizers have degraded the fertility of soil making it unsuitable for raising crop plants. In addition the intensive use of these inputs has also led to severe health and environmental hazards such as soil erosion, water contamination, pesticide poisoning, falling ground water table, water logging and depletion of biodiversity. Biofertilizers naturally activate the microorganisms found in the soil being cheaper, effective and environmental friendly are gaining importance for use in crop production, restoring the soil's natural fertility and protecting it against drought, soil diseases and therefore stimulate plant growth. For the success of biofertilizer technology, further research and development is needed to understand the mechanisms of action of various biofertilizers and to find out more competent rhizobacterial strains and carrier materials to make agriculture practices more sustainable and economical.

BIBLIOGRAPHY

1. Abbasniayzare, S.K., Sedaghathoor, S. and Dahkaei, M.N.P. 2012. "Effect of Biofertilizer Application on Growth Parameters of *Spathiphyllum* illusion". American-Eurasian Journal of Agricultural & Environmental Sciences, 12 (5): 669-673.
2. Akhtar M.S. and Siddiqui., Z.A. 2009. "Effects of phosphate solubilizing micro organisms and *Rhizobium* sps. On the growth, nodulation, yield and root-rot disease complex of Chick pea under field condition". African Journal of Biotechnology, 8(15): 3489-3496.
3. Alam, S. and Seth, R.K. 2014. "Comparative Study on Effect of Chemical and Bio-Fertilizer on Growth, Development and Yield Production of Paddy crop (Oryza sativa)". International Journal of Science and Research, 3(9): 411-414.
4. Ayala, S. and Rao, E.V.S.P. 2002. "Perspective of soil fertility management with a focus on fertilizer use for crop productivity". Current Science, 82: 797–807.
5. Bashan, Y. and Holguin, G. 1997. "*Azospirillum*-plant relationships: environmental and physiological advances (1990-1996)". Canadian Journal of Microbiology, 43:103-121.
6. Bent, E., Breuil, C., Enebak, S., and Chanway, C.P. 2002. "Surface colonization of lodgepole pine (*Pinus contortavar*.*latifolia* (*Dougl. Engelm.*) roots by *Pseudomonas fluorescens* and *Paenibacillus polymyxa* under gnotobiotic conditions". Plant and Soil, 241: 187-196.
7. Bertrand, H., Nalin, R., Bally, R. And Cleyet-Marel, J.C. 2001. "Isolation and identification of the most efficient plant growth-promoting bacteria associated with canola (*Brassicanapus*)". Biology and Fertility of Soils, 33: 152-156.
8. Bopaiah, B.M. and Abdul Khader, K.B. 1989. "Effect of biofertilizers on growth of black pepper (*Piper nigrum*)". Indian Journal of Agricultural Sciences, 59: 682-683.
9. Broughton, W.J., Zhang, F., Perret, X., and Staehelin, C. 2003. "Signals exchanged between legumes and *Rhizobium*: agri-cultural uses and perspectives". Plant and Soil, 252: 129-137.
10. Cavalcante, I.H.L., Cavalcante, L.F., Santos, G.D., Beckmann-Cavalcante, M.J. and Silva, S.M. 2012. "Impact of Biofertilizers on Mineral Status and Fruit Quality of Yellow Passion Fruit in Brazil". Communications in Soil Science and Plant Analysis, 43:15, 2027-2042.
11. Das, K., R. Dang, T. N. Shivananda, and N. Sekeroglu. 2007. "Influence of bio-fertilizers on the biomass yield and nutrient content in *Stevia rebaudiana Bert*. grown in Indian subtropics". Journal of Medicinal Plant Research, 1:5–8.
12. Dutton, V.M. and Evans, C.S. 1996. "Oxalate production by fungi: its role in pathogenicity and ecology in the soil environment". Canadian Journal of Microbiology, 42: 881-895.
13. El-Hawary, M.I., Hawary talman, I.E.I., El-Ghamary, A.M. and Naggar, E.El. 2002. "Effect of application of biofertilizer on the yield and NPK uptake of some wheat genotypes as affected by the biological properties of soil". Pakistan Journal of Biological Sciences, 5 (11): 1181–1185.
14. Gadagi, R.S., Krishanraj, P.U., Kulkarni, J.H. and Sa, T. 2004. "The effect of combined *Azospirillum* inoculation and nitrogen fertilizer on plant growth promotion and yield response of the blanket flower *Gaillardia pulchella*. Scientia Horticulturae, 100:323–332.
15. Ghosh, P. K., Das, A., Saha, R., Kharkrang, E., Tripathi, A. K., Munda, G., and Ngachan, S. V. 2010. "Conservation agriculture towards achieving food security in north-east India". Current Science, 99(7): 915–21.
16. Goel, A.K., Laura, R.D.S., Pathak, G., Anuradha, G. and Goel, A. 1999. "Use of bio-fertilizers: potential, constraints and future strategies review". International Journal of Tropical Agriculture, 17 1–18.
17. Hayat, R., Ali, S., Amara, U., Khalid, R., and Ahmed, I. 2010. "Soil beneficial bacteria and their role in growth promotion: a review". Annual Review of Microbiology, 60: 579–598.
18. He, Z.L., Baligar, V.C., Martens, D.C., Ritchey, K.D and Kemper, W.D. 1996. "Factors affecting phosphate rock dissolution in acid soil amended with liming materials and cellulose". Soil Science Society of America Journal's, 60:1596–160.
19. Hong-yuan, W., Shen, L., Li-mei, Z., ZHANG Ji-zong, Tian-zhi R, Bing-quan F, LIU Hong-bin L. 2015. "Preparation and utilization of phosphate biofertilizers using agricultural waste". Journal of Integrative Agriculture, 14(1): 158–167.
20. Irissarri, P. and Reinhold-Hurek, B. 2001. "*Azoarcus sp*. strain BH72 as a model for nitrogen-fixing grass endophytes". Journal of Biotechnology, 106:169-178.
21. Kloepper, J.W. and Beauchamp, C.J. 1992. "A review of issues related to measuring of plant roots by bacteria". Canadian Journal of Microbiology, 38: 1219 -1232.
22. Lutgtenberg, B. And Kamilova, F. 2009. "Plant-growth-promoting rhizobacteria". Annual Review of Microbiology, 63: 541–556.
23. Malik, K.A., Rakhshanda, B., Mehnaz, S., Rasul, G., Mirza, M.S. and Ali S. 1997. "Association of nitrogen-fixing plant-growth-promoting rhizobacteria (PGPR) with kallar grass and rice". Plant and Soil, 194:37-44.
24. Mittal, V., Singh, O., Nayyar, H., Kaur, J. and Tewari, R. 2008. "Stimulatory effect of phosphate-solubilizing fungal strains (*Aspergillus awamori* and *Penicillium citrinum*) on the yield of chickpea (*Cicer arietinumL*. *cv*. GPF2)". Soil Biology & Biochemistry, 40: 718-727.
25. Mohammadi, K. and Sohrabi, Y. 2012. "Bacterial Biofertilizers for sustainable crop production: A review". Journal of Agricultural and Biological Science, 7:307–316.
26. Mrkovacki, N. and Milic, Y. 2001. "Use of Azotobacter *chroococcum* as potentially useful in agricultural application". Annual Review of Microbiology, 51:145–158.
27. Nagy, P.T. and Pinter, T. 2015. "Effects of Foliar Biofertilizer Sprays on Nutrient Uptake, Yield, and Quality Parameters of *Blaufrankish* (*Vitis viniferaL.*) Grapes. Communications in Soil Science and Plant Analysis, 46(S1): 219–227.
28. Nahas, E. 1996. "Factors determining rock phosphate solubilization by microorganism isolated from soil". World Journal of Microbiology and Biotechnology, 12: 18-23.
29. Narula, N. and Gupta, K.G. 1986. "Ammonia excretion by *Azotobacter chroococcum* in liquid culture and soil in the presence of manganese and clay minerals". Plant and Soil, 93: 205-209.
30. Nehra, K., Yadav, S.A., Sehrawat, A.R. and Vashishat, R.K. 2007. "Characterization of heat resistant mutant strains of *Rhizobium sp*. [*Cajanus*] for growth, survival and symbiotic properties". Indian Journal of Microbiology, 47:329–335.
31. Oberson, A., Friesen, D.K., Rao, I.M., Buhler, S. and Frossard, E. 2001. "Phosphorus transformations in an oxisol under contrasting land-use system: The role of the microbial biomass". Plant Soil, 237: 197-210.
32. Okon, Y. and Itzisohn, R. 1995. "The development of *Azospirillum* as a commercial inoculant for improving crop yields". Bio technology Advances, 13: 414-424.
33. Okon, Y. and Labandera-Gonzalez, C. 1994. "Agronomic applications of Azospirillum: an evaluation of 20 years worldwide field inoculation". Soil Biology & Biochemistry, 26: 1591-1601.
34. Rabie, G.H. and Almadini, A.M. 2005. "Role of bioinoculants in development of salt-tolerance of *Vicia faba* plants under salinity stress". African Journal of Biotechnology, 4: 210–222.
35. Raimam, M.P., U. Albino, M.F. Cruz, G.M. Lovato, F. Spago, T.P. Ferracin et al. 2007. Interaction among free-living N-fixing bacteria isolated from *Drosera villosavar*. *villosa* and AM fungi (*Glomus clarum*) in rice(*Oryza sativa*). Applied Soil Ecology, 35:25-34.
36. Ramakrishnan, K. and Selvakumar, G. 2012. "Effect of biofertilizers on enhancement of growth and yield on Tomato (*Lycopersicum esculentum Mill.).* International Journal of Research in Botany, 2(4): 20-23.
37. Revillas, J.J., Rodelas, B., Pozo, C., Martinez-Toledo, M.V., Gonzalez, L.J. 2000. "Production of B-Group vitamins by two Azotobacter strains with phenolic compounds as sole carbon source under diazotrophic and adiazotrophic conditions". Journal of Applied Microbiology, 89:486–493.

38. Saikia, S.P. and Jain, V. 2007. "Biological nitrogen fixation with non-legumes: an achievable target or a dogma?" Current Science, 92: 317–322.
39. Sarig, S., Blum, A. and Okon, Y. 1988. "Improvement of water status and yield of grown grain sorghum by inoculation with *A. brasiliense*. Journal of Agricultural Science, 110: 271-278.
40. 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". Canadian Journal of Microbiology, 52: 66–72.
41. Singh, G., Sekhon, H.S. and Sharma, P. 2011. "Effect of irrigation and biofertilizer on water use, nodulation, growth and yield of chickpea (*Cicer arietinum L.*)". Archives of Agronomy and Soil Science. 57(7): 715–726.
42. Singh, J.S., Pandey, V.C. and Singh, D.P. 2011. "Efficient soil microorganisms: a new dimension for sustainable agriculture and environmental development". Agriculture, Ecosystems & Environment,140: 339–353.
43. Sinha, R.K., Valani, D., Chauhan, K. 2014. "Agarwal S: Embarking on a second green revolution for sustainable agriculture by vermiculture biotechnology using earthworms: reviving the dreams of Sir Charles Darwin". International Journal Of Agriculture And Biology, 1:50–64.
44. Sivakumar, T., Ravikumar, M., Prakash, M. 2013. "*Thamizhmani R*. Comparative effect on bacterial biofertilizers on growth and yield of green gram (*Phaseolus radiataL*.) and cow pea (*Vigna siensisEdhl.*)". International Journal of Current Research and Academic Review., 1(2) 20-28.
45. Sujanya, S. and Chandra, S. 2011. "Effect of part replacement of chemical fertilizers with organic and bio-organic agents in ground nut, *Arachis hypogeal*". Journal of Algal Biomass Utilization, 2 (4): 38– 41.
46. Tilak, K.V.B.R. 1995. "Vesicular-arbuscular *mycorrhizae* and *Azopirillum brasilense* rhizocoenosis in pearl millet in semi-arid tropics In: Adholeya A & Singh S (Eds.) Proceedings of Third National Conference on Mycorrhiza (pp. 177-179). Tata Energy Research Institute, New Delhi.
47. Tsai, S.H., Liu, C.P. and Yang, S.S. 2007. "Microbial conversion of food wastes for biofertilizer production with *thermophilic lipolytic* microbes". Renewable Energy, 32(6), 904-915.
48. Veerubommu, S. and Kanoujia, N. 2011. "Biological management of vascular wilt of tomato caused by *Fusarium oxysporum f.sp. lycospersici* by plant growth-promoting rhizobacterial mixture". Biological control, 57: 85–93.
49. Vessey, J.K. 2003. "Plant growth promoting rhizobacteria as biofertilizers". Plant Soil, 255:571-586.
50. Walley, F.L. and Germida, J.J. 1997. "Response of spring wheat (*Triticum aestivum*) to interactions between *Pseudomonas* species and *Glomus clarum* NT4". Biology and Fertility of Soils, 24: 365-371.
51. Yanni, Y.G. and Dazzo, F.B. 2010. "Enhancement of rice production using endophytic strains of *Rhizobium leguminosarum bv. trifolii* in extensive field inoculation trials within the Egypt Nile delta". Plant Soil, 336:129-142.
52. Youssef, M.M.A. and Eissa, M.F.M. 2014. "Biofertilizers and their role in management of plant parasitic nematodes. A review". E3 Journal of Biotechnology and Pharmaceutical Research, 5:1–6.
53. Zayed, MS. 2012. "Improvement of growth and nutritional quality of *Moringa oleifera* using different biofertilizers". Annals of Agricultural Science, 57(1): 53–62.