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

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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

IARJSET

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

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

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.

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