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REVIEW PAPER OPEN ACCESS

The use of microbes as biofertilizers

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Abstract

The excessive applications of chemical fertilizer to improve land fertility and to increase crop yield often lead to unanticipated detrimental ecological effects which includes surface overflow in phosphorus, nitrogen and leakage of nitrates into ground water. They are involved in basic activities which make sure the stability and efficiency of both of the natural ecosystem and agriculture system. There is a strong emerging business for microbial inoculants globally now a day's these bacteria mainly belonging to genera *Azospirillium* and Rhizobium flourish within the plant effectively colonizing all parts of plant. Through the union the attacking bacteria provide benefits to the host with a noticeable rise in plant strength, yield and growth. Uses of advantageous microbes as a bio-fertilizer has dynamic significance in agriculture field for their credible role in the food protection and sustainable crop yield. These bio-friendly plant growth promoting rhizobacteria (PGPRs) occurring in rhizosphere can produce growth enhancing substances in large quantities that can directly or indirectly manipulate the general morphology of the plants. They offer a reasonably attractive and ecologically good method for providing nutrient to the plant. Though Chemical fertilizers are easily accessible with good transport facility but extreme and extended use of the chemical fertilizer is a growing problem with some harmful effects on the environment, that is, decreased productivity, soil fertility and soil structure. The nonuseful effects of chemical fertilizer can be reduced by taking up manure or organic fertilizer. Moreover, biofertilizers due to its low cost have attracted small farmers. This review focuses on the useful aspects of biofertilizers in order to promote their use and avoid the detrimental effects of chemical fertilizers.

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Introduction

Environmental stresses are becoming important problems resulting in extraordinary decline in crop yield. Our excessive use of chemical fertilizers and insecticides has supported the progress in manufacturing these lethal chemicals, which are risky for human utilization and also have adverse effects on environmental balance (Bhardwaj *et al*., 2014).

Due to progress in agriculture industry over the past decades producers has become highly dependent on the use of agro-chemicals as a comparatively consistent method of crop protection, to ensure their economics strength. With the increase of world's population, the worldwide rise in rice utilization has exerted an increased pressure on our deteriorating cultivated land (FAO, 2009) however, intensive use of chemical fertilizers to increase crop production has caused some adverse impact, i.e growth of pathogen confrontation to the applied agents and their non-target ecological impact (Compant, 2005). To meet this demand, high yielding varieties are being developed, which requires excessive application of phosphorus (P) and Nitrogen (N) fertilizer (Hazell, 2010). The excessive use of chemical fertilizers to enhance crop yield can have detrimental effects over the natural biogeochemical cycle (Perrott *et al.,* 1992). In past few decades, the degree of phosphorus, potassium (NPK) and nitrogen fertilizer application has risen enormously. In 2006, three countries i.e. India, USA and china were reported to be highest consumers of chemical fertilizers, they are consuming 21.65,20.83,50.15 million tons of NPK fertilizer, correspondingly as reported by the international fertilizer industry association (Ademosoye *et al.,* 2009 a). Fertilizers are vital element of contemporary farming because they are providing essential nutrition to plant. However overuse of this fertilizer can cause unanticipated environmental effect (Malakoof, 1998).

For decrease in poverty and rise of prosperity in developing countries to feed billions of people development in agriculture can be a useful tool. The increased demand for food leads to production of genetically modified crops, elevated transportation rates, biofuel production and climate change, creating high risk of food safety in the population (Singh *et al.,* 2018; Tiwari *et al.,* 2018).

Products based on plant growth-promoting rhizobacteria (PGPR), or plant growth-promoting bacteria (PGPB) for use in agriculture have obtained extensive attention in current years (Pastor-Bueis *et al.,* 2017). When used appropriately these kind of products lead to an increase in crop yields which results in a less need for chemicals (Bhardwaj *et al.,* 2014). This technology is well-matched with, and may be corresponding to, conventional technologies based on mineral, synthetic or organic products. ultimately, microorganism-based products could somewhat or even totally replace conventional agricultural products.

Chemical fertilizer have a high amount of phosphorus and nitrogen, which have large negative effect on ground and surface water and lead to water resources related problems. Draining of elemental composition from the soil level to the ground water contaminates the natural habitat through formation of particulate matter and enhancing unwanted microbial growth (Meena and Busi, 2019).

However, micro-organisms do not possess any toxic effects on the environment and crops, they have specific destruction characteristics of the targeted insects. Through their use the development of immunity has been found to be low in insect, insects which are not destroyed by the normal pesticides can also be controlled using microorganism based products they are safe for the beneficial pest of the cultivation. Agricultural microbiology is concerned with the relationship between microbes and crops with an emphasis on improving yields and minimizing plant diseases. (Sharma *et al.,* 2019) This review aims on highlighting the importance of use of biofertilizers and their significant role in decreasing soil contamination.

Use of Microbes

Organic farming is an eco-friendly strategy ensuring food safety as well as enhancing biodiversity of land (Megali *et al.,* 2013).

The supplementary benefits of bio fertilizers contain longer shelf lives which do not cause opposing effect to environment (Shoo *et al.,* 2014). From last few years a huge range of microbes including species of *Azospirillum, Klebsiella. Enterobacter, Pseudomonas, Arthobacter, Serratia Buekholderia, Azotobacter, Alcaligens*, and *Bacillus* have reported to increase plant growth (Kloepper *et al.,* 1989).

Plant beneficial microorganisms are of concern for application in agriculture as bio fertilizers or as pesticides as well as for phytoremediation applications (Compant, 2010).

Table 1. Beneficial microbial genera.

Symbiotic	Non symbiotic	Free living
Rhizobium sp.	*Azotobacter*	*Azospirillum*
Mesorhizobium	*Azospirillum*	*Enterobacter*
Bradyrhizobium	*Bacillus*	*Klebsiella*
Azorhizobium	*Klebsiella* sp	*Pseudomonas*
Allorhizobium		

Source: (Hayat *et al.,* 2010)

Microbial growth and activity is mainly intense in the rhizosphere. this is indicated by the number of microbes that are present around the roots of plant and they are mostly 10 to 100 times more than in the bulk soil (Weller and Thomashow, 1994). *Rhizobium* and *azospirillum* are well considered example for plant development promotion. *Pseudomonas, Serratia, Streptomyces, Stenotrophomonas, Bacillus* and the fungal genera *Ampelomyces, Trichoderma* and *Coniothyrium* are representative organism to demonstrate effect on plant health (Berg, 2009).

These microorganisms flourish inside the plant, efficaciously inhabiting stem, root and leaf during the connotation, the invading microbes welfares the host with an obvious enhancement in plant growth, yield and vigor (Bhattacharje *et al.,* 2008). The different genetic and functional activities of the widespread bacterial populations havea serious influence on soil function, based on the fact that microbes are pouring forces for essential metabolic processes including specific enzyme activities (Nannipieri *et al.,* 2003). Plant and microbial connections in the rhizosphere are the determinants of plants health and soil productiveness (Hayat *et al.,* 2010).

The concentration of microbes (per gram for soil) that is present adjacent the root of plant is usually more than the microbes population or concentration.in the other part of the soil. (Lynch, 1990). This apparently reflects the existence of elevated level of nutrients that are present in the region just about the root and able to support microbial development and metabolism (Koeppler, 1988)

Among *rhizobacteria* there is an incline of root immediacy and relationship as follows.

- Metabolites released from roots as N and C sources are used by bacteria living in the vicinity of roots
- Bacteria inhabiting the rhizoplane.
- Bacteria dwelling in root tissue, populating spaces among cortical cells.
- Bacteria existing within the cells in specific root structures, or nodules (Gray, 2005)

Table 2. Plants that form symbiotic association with rhizobacteria.

Scientific name	Plant
Pisumsativum	Pea
Medicago sativa	Alfalfa
Phaseolus vulgaris	Beans
Glycine max	Soybean
Lens culinaris	Lentil
Arachis hypogeal	Peanut
Acacia sp	Acacia
Trifolium sp	Clover

Source: (Gray and Smith, 2005)

Microbial V/S Chemical Fertilizers

(Berg *et al.,* 2009) reported that bacterial inoculants have numerous benefits:

- They are harmless.
- They cause potentially smaller hazard wellbeing and cause less ecological harms
- Show more besieged actions.
- They are more powerful and less expensive.
- Reproduce themselves but managed by the other plant and native microbial population.
- Decay rapidly as compared to the usual chemical insecticides.
- Many mechanisms are cause of reduction in resistance development.
- They are used in integrated pest management systems.

PGPR have three basic characteristics

1) The first property should be obliged to inhibit the plant root system.

2) in contrast to other microbiota they must live and develop in microhabitats linked with the root exterior, in any case for the time required to put across their plant enhancing and safety activities

3) they are obliged to encourage plant development.

Mechanism and Advantages of PGPR

seedling growth, nutrient cycling and biological management of plant pathogens are the most important environmental processes that are known to be promoted by PGPR (Persello-Cartieaux *et al.,* 2003) direct promotion by the PGR either supply the plant with the plant development substance processed by the microorganism or help in the absorption of specific plant nutrients from the suurroundings. The indirect promotion of plant development by PGPR involve reducing the harmful outcome of one or morephytopathogenic microbes. (Ahmad *et al.,* 2008) PGPR acts as biocontrol agents in many of the indirect processes of plant growth enhancement. Major mechanisms of biological control through which plant growth promotion occurs are introduction of systemic resistance, antibiosis struggle for nutrients and niches and by dropping the level of disease (Lugtenberg *et al*., 2009).

Enhancement in root growth, belated leaf senescence, germination time, tolerance to famine, increase in yield involving grain, magnesium levels, leaf region, protein content chlorophyll level, nitrogen content, shoot and root mass and hydraulic activity are some of the plant development advantages due to the addition of PGPR. Biocontrol is also a main advantage of PGPR use is disease resistance in the plant. (Lucy *et al.,* 2004).

The exact mechanisms of how PGR enhances the plant development and not fully recognized up till now, however the potential explanation involve 1) The capacity to produce ACC(1-Aminocycloprapane-1-carboxylic acid) deaminase to lessen the ethylene content in roots of the growing plants thus raising the root span and expansion (Dey *et al.,* 2004). The PGR have been spitted into two groups one group indulge in nutrient cyling and phytostimulation. The other one is responsible for biological control of plant parasites (Holguin and Bashan, 1998).

PGR mediated plant growth is done by changing the overall microbial population in rhizophere niche by producing the variety of substances (Parray *et al.,* 2016). Some bacteria goes in the inner part of the root to develop endophytic population along with the power to fiddle with the niche and are helpful for host plants (Compant *et al*., 2005). Some bacteria increase root surface area, thus giving a greater value of nutrients absorption and it successively promote plant production.

Table 3. Plant growth regulators (PGRs) produced by *Rhizobacteria*.

PGPR	PGR	Crop	References
Pseudomonas putida GR12-2	ACC deaminase	Tomato	Patten 2002
Rhizobacterial isolates	Auxin	Rice and wheat	Khalid *et al* 2001
PGPR strain Ha 21	Auxin	Wheat	Khalid *et al* 2004
Azospirillum	Pectinase	Wheat	Kloepper 1989
Azospirillum brasilense	Auxin	Pearl millet	Loon 2007
P fluorescens WCS 365	Auxin	Raddish	Lugtenberg 2009
Bacillus pumilis	Gibberlic acid	Alnusglutinosa	Mohanty 2017
Rhizobium leguminosarum	ACC deaminase	Common bean	Mohanty 2017
Pseudomonas fluorescens	IAA	Black currant cutting	Patten 1996
Azotobacter	Indole 3 acetic acid (IAA)	Maize	Zahir *et al* 2000
Pseudomonad synxantha strain R81	Phosphate solubilization	Litchi	Visen *et al* 2017
Paenibacillus polymyxa L6	Auxin	Lodgepole pine	Weyens *et al* 2009

Table 4. Methods for development of plant microbial symbiotic relationship by free living microbes.

Mechanisms	Example
Plant growth promoters	Increase of plant suspectibility to the symbiont or increasing in the infections caused by symbiont
Nutrition	increasing the accessibility of nutrition that can enhance the effectiveness of the symbiosis
Biocontrol	manageing the plant infections that effect vascular function and root density which can decrease locations or substrate for symbiont infection

Source: (Kloepper *et al.,* 1989)

Table 5. Manufacture of principle organic acids by phosphate solubilizing bacteria.

Phosphate solubilizing bacteria	Acid	References
Enterobacterinter medium	2-ketogluconic acid	Hoon *et al* 2003
Panibacillusmacerans	Isobutyric acid	Vazquez *et al* 2000
Bacillus firmus	Succinic acid and 2-ketogluconic acid	Banick and Dey 1982
Pseudomonas striata	tartaric,fumaric and Succinic acid	Gaur 1990
Phosphobacterins	Glyoxalic and maleic acid	Sundara *et al* 2002
Bacillus polymyxa	Citric, oxalic acid	Gupta *et al* 1994

Table 6. Significant species of phosphate solubilizer.

Microorganisms	References
Bacillus	Illmer and schinner 1992
Burkholderia	Oliveira *et al* 2009
Aspergillus	Motsara *et al* 1995
Penicillium	Motsara *et al* 1995
Rhizobium	Whitelaw 2000
Enterobacter	Whitelaw 2000
Pseudomonas	Illmer and schinner 1992
Bacillus circulans	Mohammadi *et al* 2012
Bacillus subtilis	Mohammadi *et al* 2012
Pseudomonas striata	Mohammadi *et al* 2012

N_2 fixing bacteria

Major metabolic processes like synthesis of proteins, DNA and RNA , chlorophyll and cellular production of enzymes require nitrogen therefore it is considered as critical compound in enhancing the plant development and manufacture of food and feed. Elemental N_2 is fixed by nitrogenize in rhizobialbacteroids through symbiotic fixation to supply nitrogen for modulating legumes. This mechanism of (BNF) biological nitrogen fixation is responsible to supplying 65% of the nitrogen presently consumed by farming and in future it will be considered significant for sustainable crop manufacture method (Mstiru and Dakora, 2004).

Mineralization in organic nitrogen to ammonium (NH4+) by microbial driven processes and its succeeding nitrification to nitrate (NO3-) is an important key to nitrogen accessibility and has manipulated rhizosphere dynamics and root behavior. Although organic forms of Nitrogenare typically known to be rule plant uptake (Richardson *et al.,* 2009).

Examples of free living fixing bacteria are obligate aerobes, cyanobacteria (*Azotobacter*) obligate anaerobes (*Clostridium pasteurianum*) some methanogens photosynthetic bacteria (Rhodobacter) and facultative anaerobes (Mohammadi *et al.,* 2012). In most cases bacteria settle only on the surface of the root and remain defenseless to competition from other rhizosphere micro-organisms, even when the nitrogen-fixing microbes are endophytic advantages to the plant might be a result from enhanced acceptance of soil nutrients and not from endophytic nitrogen fixation (Cocking *et al.,* 2003).

Phosphorus Solubilizing Bacteria

Alternative method recommended for plant growth encouragement by beneficial microbes is conversion of natural phosphorus elements or solubilization of inorganic phosphorus elements (Kloepper, 1989) for plant development and expansion of phosphorus is the highly significant macronutrients (Ehrlich, 1990). It exists at the level of 400-1200mg/kg of soil. Organic and inorganic phosphorus are the two types in which elemental phosphorus occur in soil. A significant characteristic of a PGPR in growing plant productivity is the change of insoluble inorganic and organic phosphorus in the varieties available to the plant (Hayat, 2010) even though organic and inorganic phosphorus is abundant in land.

It is the leading and more important cause for the plant growth in contrast to other chief compounds. Phosphorus is the least transportable and accessible to flora in the most soil situation (Khan *et al.,* 2007).

Plants get P as the source of orthophosphate anions (mainly as $H2PO4^{1-}$ and $HPO4^{2-}$) from the soil solution. The absorption of orthophosphate in solution is little approximately (1 to 5 um) in the majority of the soil and it should be restocked from other pools of soil phosphorus to the suit plant necessity (Richardson *et al.,* 2009) the consumption of PSB in farming would equalize the high cost of manufacturing phosphate fertilizer and also insoluble particle in the fertilizer and soil to which they will be applied. (Chang and Yang, 2009). The manufacture of organic acids is thought to be the primary method for inorganic phosphate solubilization in microbes. That assumption has been reinforced by the replication of two genes involved in gluconic acid production: gabY genes and PQQ synthase (Mariano *et al.,* 2001)

Phytostimulators

Development of plant is directly encourage by the phytostimulators, generally by the manufacturing of hormone (Bloemberg *et al.,* 2001) plant growth promotingrhizobacteria produce phytohormones like cytokinins, ethylene, auxins and gibberllins help to influence cell propagation in root structure due to the excessive production of root hairs and side root and by increasing of the water and nutrient uptake (Gupta *et al.,* 2015) Auxinindole 3 acetic acid (IAA). Most studied phytohormone produced by plant related bacteria, add to the plant growth and expansion (Vessey, 2003). Manufacturing of indole acetic acid is the basic characteristics of PGPR and these bacteria are useful to act against the salinity stress in plant. Change have been observed in the morphology of plant roots repeatedly upon *Azospirillum* inoculation have been credited to the fabrication of plant growth encouraging ingredient, gibberellins and cytokinins with auxin manufacture have been quantitatively the major one (Spaepen *et al.,* 2008).

Conclusions

The consumption of chemical fertilizers and compost cannot be replaced currently without considerably reducing food production. The destructive ecological side-effect of the use of compost, for example the increasing dead region of aquatic system. Globally it may cannot go unabated. Organic fertilizer enhanced agriculture production but it is very expensive and damage ecosystem. It exhausts non-renewable energy through side- effect, devastating microorganisms and friendly insects, leakage and polluting water basins and declining soil productiveness thus causing irreversible damage to the whole system. There is extensive date that certain bacteria have ability to inhabit the root- soil environment where they perform a range of collaborative processes this review specify the expansion and preparations of PGPRs in biological enhancement of various attributes of florae development actions knows to advantage plants augmentation and health. Because it recognized that suitable administration of target obliging bacterial actions can lower the utilization of energy and chemical. The help of bio fertilizer is very important as they solve the difficulties of malnutrition of the growing global population where the farming is passing from very hard time and facing a diversity of environmental pressure.it is necessary to understand the importance of bio fertilizer and execute their usefulness to the current farming practices.

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