Role of Microbial Biofertilizers in Vegetable Production- A Review

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Abstract

Biofertilizers comprises living microorganisms symbiotically associated with plants, when applied to soil or a propagule intends to increase the soil fertility, seed germination and plant growth by encouraging the efficient supply of nutrients to the plants. Since past 50-60 years, soil management practices are mostly reliant on inorganic fertilizers, which has invited serious fortune to the environment (ruining soil fertility and increased pollution) and human health problems (disease risk). Heeding to it researchers have found an eco-friendly alternative by the way of incorporating microbial biofertilizers to supersede chemical fertilizers. Microbial biofertilizers has been analysed as substitute in procuring soil fertility and expanding vegetable production. Microbial fertilizers are promising enough to outstand the chemical fertilizers ensuring sustainable agriculture without disrupting the environment.

Keywords
Azotobacter, Biofertilizers, Nitrogen fixing biofertilizers, PSB, Vegetables

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Introduction

Biofertilizer term refers to substances containing effective strains of living microorganisms such as fungi, algae, bacteria that can expedite soil microbial activities to enhance the active supply of nutrients in a way that plants can easily incorporate. Inorganic fertilizers indeed played a significant role in enhancing agricultural productivity, but they overstretched the use of renewable sources. Although, farmers are still applying over dosage of chemical fertilizers in lieu of high production nevertheless their excess has cost us soil contamination, soil toxicity, water table contamination etc. causing environmental pollution (Mahdi et al., 2010) as well as causing several types of cancers and cardiovascular disease in humans (Engel et al., 2000). Their quick action or contribution towards high yield and low price had brought them promptly into the prime focus of the marginal farmers. Among agricultural crops, vegetable crops being short-duration, flexible provided with high productivity accompanying health benefits plays a significant role in food trade especially in India. Vegetables are important for human nutrition in terms of bioactive nutrient molecules such as dietary fibre,
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mins and minerals, and non-nutritive phytochemicals (phenolic compounds, flavonoids, bioactive peptides, etc.). They are packed with vitamins (C, A, B1, B6, B9, E) and anti-oxidants which can help in growth, repairing of body cells and reduce risk of dreadful diseases like cancers. These nutrient and non-nutrient molecules reduce the risk of chronic diseases such as cardiovascular diseases, diabetes, certain cancers, and obesity (Pennington et al., 2009; Malaterreb et al., 2018).

A high vegetable diet has been associated with reduced risk of human cardiovascular disease (Mullie and Clarys, 2011). Owing to health benefits and high productivity, area under vegetable production is constantly rising, and so is the chemical fertilizers application. Marginal farmers need to improvise their farming skills and incorporate organic farming or at least organic fertilizers and microbial biofertilizers. Organic farming contributes to quality vegetables therefore adoption and application of the microbial biofertilizer is mandatory for modern agriculture to flourish sustainably.

Biofertilizers are the essential component of organic farming as they help in maintaining soil fertility for longer time period. The microbes present in these fertilizers provide nutrient to plants by using different mechanism and also encourage immunity of plants to protect their selves from the attack of diseases and pests as well as abiotic stresses. Biofertilizers add nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth promoting substances. Some biofertilizers are viz. symbiotic nitrogen fixing biofertilizers, free-living biofertilizers, associative symbiotic nitrogen fixing biofertilizers etc. Biofertilizers can be applied directly to the crop or also with the combination of chemical fertilizers and have different mode of action. If the microbial inoculant is not applied properly, the benefits from the biofertilizer may not be obtained. The biofertilizer can be synthesized in solid or in liquid form for spraying on the plants. Bio-fertilizers are usually amended with carrier material to increase effectiveness of the bio-fertilizers and also enhance the water retention capacity.

The incorporation of microorganisms into carrier materials enables easy handling, long term storage, and effectiveness of the biofertilizer. Carrier material such as saw dust, talcum dust, manure, earthworm cast can be used. There is lot of work done by many researchers to know the effects of biofertilizers and they have achieved many successful results. Keeping in mind the above key points, narrating the potential key role biological fertilizers could play if incorporated towards vegetable productivity and sustainable agriculture, we are presenting hereby a review of all researches done in this field exaggerating the fact how microbial biofertilizers could help in safeguarding the environment and prove as an eco-friendly and cost effective input for the farmers.

**Nitrogen fixing microbes**

Nitrogen fixing microbes comprises of symbiotic nitrogen fixing biofertilizers (including Rhizobium, Azolla etc.), free living nitrogen fixing biofertilizers [Azotobacter, Cyanobacteria (blue green algae) etc.] and associative symbiotic nitrogen fixing biofertilizers (Azospirillum). Along with these there are microbes which fix phosphorus or solubilize the phosphorus like Phosphorus Solubilizing Bacteria (PSB). Various studies done regarding the application of microbial fertilizers among vegetables and their beneficial effect towards yield and quality parameters have been provided in Table 1.
Symbiotic nitrogen fixing biofertilizers

Rhizobium

These are the widely recognized symbiotic nitrogen fixers that belong to the Rhizobiaceae family and typically consist of various genera, such as Mesorhizobium, Sinorhizobium, Allorhizobium, Azorhizobium, Bradyrhizobium, and Rhizobium. Rhizobium are motile, gram-negative, non-sporulating rod type which tend to symbiotically fix atmospheric nitrogen. Rhizobium helps reduce the molecular N2 to NH3 in the root nodules, which is then readily absorbed by the plant roots.

The N-fixation is carried out by a complex enzyme nitorgenase consisting of dinitrogenase reductase with iron as its cofactor and dinitrogenase with molybdenum and iron as its cofactor (Mahanty et al., 2016). Rhizobium can fix 50-200 kg N ha\(^{-1}\) which helps to meet up to 80 to 90% nitrogen need of the crop as their natural presence in nodulating legume crops makes them less dependent on inorganic nitrogen (Kour et al., 2020).

Azolla

It is a symbiotic diazotroph which has the capacity to fix nitrogen in the atmosphere found in temperate and tropical environments. There is a symbiotic relationship between Azolla and Anabaena cyanobacteria. Azolla helps to provide the anabaena with a carbon source and its nitrogen requirement is met by cyanobacteria's atmospheric nitrogen fixation. The benefit of growing Azolla as a biofertilizer helps provide N and K requirements to the plant. Anabaena azollae is considered to be the most dominant biofertilizers and commonly used for the wetland rice in South-east Asia and estimated to fix around 40-60 Kg N/ha in rice crop (Kannaiyan, 1993).

Free living nitrogen fixing biofertilizers

Azotobacter

Azotobacters are free living nitrogen fixing bacteria which belongs to azotobacteriaceae family and mostly found in alkaline and neutral soils. It does not require any host and fixes the atmospheric nitrogen especially in non-leguminous plants without any symbiotic relationship (Jaga and Singh, 2010). Application of Azotobacters bio-inoculants may increase 10-12% crop productivity leading to synthesis of ample amount of biologically active substance like nicotinic acid, biotin, heteroauxins, vitamin B and gibberellins etc, which increase root growth and uptake of the minerals (Jaga and Singh, 2010).

Azotobacter sp. has the ability to produce antifungal antibiotics and fungi static compounds against pathogens like Fusarium sp., Alternaria sp., Trichoderma etc.

Cyanobacteria

Cyanobacteria referred as "blue-green algae" or BGA, are free living, aquatic, small, unicellular bacteria and possess photosynthetic property i.e. they can manufacture their own food. They are one of the largest bacterial species and the dominant nitrogen fixers among them are Calothrix, Nostoc, Anabaena and Aulosira (Sahu et al., 2012). By building up soil fertility, they help to increase yield along with excretion of various substances that promote growth, e.g. amino acids, phytohormones, vitamins (Rodríguez et al., 2006), soil salinity reduction, weed growth prevention, soil P content increase (Wilson, 2006) etc. When inoculated with cyanobacteria, vegetables such as chilli, spinach, radish, tomato have shown the beneficial effects (Thajuddin and Subramanian, 2005). Nostoc and Anabaena are have been found to fix about 20–25 Kg of N/ha (Kour et al., 2020).
Table 1: Application of microbial biofertilizers among various vegetables and their effects on growth and production

| S. no. | Biofertilizer | Plant             | Description                                                                 | Inorganic fertilizer used | References           |
|--------|---------------|-------------------|-----------------------------------------------------------------------------|---------------------------|----------------------|
| 1.     | PSB           | Asparagus         | All growth characters in asparagus were maximum when PSB was applied with organic fertilizers. | Applied                   | Palande et al., (2017) |
| 2.     | Azotobacter, PSB | Bottlegourd    | Application of 2.5kg dose of Azotobacter and PSB each found highly profitable resulting high C:B ratio. | Applied                   | Patle et al., (2018)   |
| 3.     | Azospirillum, Phosphobacteria | Brinjal    | Combined application of microbial fertilizers and chemical fertilizers enhanced growth and yield. | Applied                   | Latha et al., (2014)   |
| 4.     | Azotobacter, Azospirillum, PSB | Brinjal    | Growth and yield attributes increased with Azotobacter+Azospirillum+PSB application. | Applied                   | Solanki et al., (2010) |
| 5.     | Azotobacter and PSB | Brinjal    | Morphological and yield characters of the plant were maximum by the application of Azotobacter and PSB alone provided with biotic stress resistance. | Applied                   | Doifode et al., (2014) |
| 6.     | Azospirillum, PSB | Brinjal    | Growth and yield components were maximum with root dipping treatment of 125g Azospirillum and PSB. | Applied                   | Kiran (2006)           |
| 7.     | Azospirillum, PSB, VAM, Azotobacter | Broccoli | Curd size, yield, protein, lipid, sulphate contents of broccoli curd was maximized after applying 50% Azospirillum and Azotobacter. | Applied                   | Singh et al., (2014)   |
| 8.     | Azotobacter, Azospirillum | Cabbage | Azotobacter and Azospirillum were used as the organic source of nitrogen. | Applied                   | Gupta et al., (2004)   |
| 9.     | Azospirillum | Carrot            | Morpho-physiological, yield, biochemical components increased with Azospirillum application. | Applied                   | Mog.B. (2007)          |
| 10.    | Azospirillum, PSB, VAM, Azotobacter | Cauliflower | The application of Azotobacter, Azospirillum, VAM and PSB significantly increased growth parameters when PSB was followed by Azospirillum. VAM followed by PSB gave better leaf width. PSB significantly increased curd size and curd weight. | Applied                   | Kachari et al., (2009) |
| 11.    | Azotobacter and Azospirillum | Chilli       | Azotobacter along with RDF gave the high yield. Azospirillum treatment gave high growth parameters. Azospirillum was found better over Azotobacter. | Applied                   | Khan & Pariari (2012)  |
| 12.    | PSB, Rhizobium | Frenchbean       | Pod yield/ha maximized with Rhizobium+ PSB+ Organic matter.                  | Applied                   | Thakur et al., (2018)  |
| 13.    | VAM and PSB   | Frenchbean       | Growth and yield characters of French bean were enhanced due to application of 2kg VAM and 2.5kg PSB per ha. | Applied                   | Ramana et al., (2010)  |
| 14.    | Rhizobium     | French bean      | Seeds inoculated with synthetic Rhizobium gave the maximum growth, yield and seed quality components. | Not applied               | Ahmed et al., (2016)   |
| No. | Microorganism | Crop | Description | Application | Reference |
|-----|---------------|------|-------------|-------------|-----------|
| 15. | Azospirillum, Azotobacter, PSB | Knol-khol | PSB, Azotobacter and Azospirillum inoculation lead to yield and biochemical parameters. | Applied | Choudhary et al., (2017) |
| 16. | Azotobacter, Azospirillum, Pseudomonas | Lettuce | Plant height, no. of leaves, leaf area index and yield was maximum in seed inoculation with Azospirillum. | Not applied | Chamangasht et al., (2012) |
| 17. | Azospirillum | Lettuce | Azospirillum inoculated lettuce seeds yield a higher number of transplanted plants with superior quality than non-inoculated ones. | Not applied | Fasciglione et al., (2012) |
| 18. | Azotobacter, PSB | Okra | The highest yield parameters were obtained with the application of combination of organic manures together with Azotobacter and PSB in okra crop. | Applied | Bairwa et al., (2009) |
| 19. | Azospirillum | Onion | The application of Azospirillum, increased the yield of onion and also enhanced the nitrogen level in soil. | Applied | Yadav et al., (2004) |
| 20. | Azospirillum, VAM, PSB | Onion | Seed yield of onion was maximum when treated with GA$_3$ along with Azospirillum+PSB+ VAM | Not applied | Waghmode et al., (2010) |
| 21. | Microbein | Onion | Highest yield of total bulbs and increase in N, P, K, Fe, Mn, Zn, Cu, Pb, NO$_3$ and NH$_4$ was obtained. | Organic manure applied | Shaheen et al., (2007) |
| 22. | Azotobacter, PSB | Potato | Application of Azotobacter along with combination of PSB and organic manure enhanced the high yield of potato. | Organic manure applied | Kumar et al., (2013) |
| 23. | Azotobacter | Potato | Azotobacter along with the 75% RDF of nitrogen and phosphorus resulted in higher yield per hectare. | Applied | Kumar et al., (2006) |
| 24. | Azotobacter | Potato | Azotobacter increased the yield of tuber by 4-24% along with nitrogen. | Applied | Singh,K.(2001) |
| 25. | Rhizobacterin, Microbein and Phosphorein | Potato | Cultivar diamond gave the high yield when treated with phosphorein whereas rhizobacterin treatment gave the highest tuber weight. | Not applied | Farag et al. (2013) |
| 26. | Nitrobin, PSB | Pumpkin | Application of biofertilizer along with 50% chemical fertilizers gave the maximum seed yield, fruit yield, photosynthesis rate and chlorophyll content. | Applied | Habibi et al., (2013) |
| 27. | Azospirillum, PSB, Azotobacter | Radish | Growth, yield, and nutritional quality of radish maximized when one fourth quantity of Azotobacter, Azospirillum, PSB along with RDF were applied. | Applied | Shani et al., (2017) |
| 28. | Azotobacter | Tomato | Application of Azotobacter with RDF (150kg N + 60kg P + 60 Kg/ha) increased the growth and yield parameters of the plant. | Applied | Gabhiye et al., (2003) |
| 29. | Azotobacter, Azospirillum and PSB | Tomato | Fruit yield maximized when treated with RDF + PSB whereas, fruit quality increased with RDF+ azospirillum+PSB. | Applied | Kadlag et al., (2007) |
| 30. | Nitrobin | Tomato | Nitrobin biofertilizer enhanced tomato growth and yield characters. | Applied | Gmaa.(2015) |
Associative symbiotic nitrogen fixing biofertilizers

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food will produce to feed burgeoning population. Biofertilizers will gradually help soil to regain its fertility for long term health. Biofertilizers application will reduce the use of chemical fertilizers and thus it reduces the additional cost of farmers. They are ecofriendly in nature and reduce the environmental pollution. Biofertilizers are only at the starting phase still need more efforts to bring changes in modern agriculture. Microbial extraction, their colonization, production, marketing, application, good knowledge among farmers etc. are necessary for more and more utilization of biofertilizers in modern agriculture aiming at the reduction of chemical fertilizer application in the field for high productivity. More studies in the field of plant and microbes interaction are required so that more efficient technology is used to get more production without disturbing the environment. Biofertilizers like Azotobacter, Azospirillum, Phosphobacter, Rhodobacter etc. can help plant to survive in stress conditions and to perform well. The application of biofertilizers not only will benefit the agricultural ecosystem but it also contributing to a holistic and sustainable environment.

In conclusion the modern agriculture, the excessive use of chemical fertilizers and pesticides is disturbing the sustainability of our agricultural land. These chemicals are becoming threat to human health because of consumption of chemically produced food by humans resulting dreadful diseases. These chemicals also have atrocious impacts on air, water and soil, thus disturbing the ecological balance. Use of biofertilizers is becoming a big challenge to ensure the food safety and environment protection. Now attention is shifting towards organic production of food because of the harmful effects of the chemical fertilizers. The application of bio-fertilizers having beneficial microbes is gaining importance in promoting the crop productivity to a large extent and can help to solve the food need problem of increasing population of world. Soil erosion, water logging, accumulation of toxic elements are the main reasons which diminished the soil fertility in India. Biofertilizers are helpful in solving such kinds of problems and make the soil more productive as they are eco-friendly in nature.

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