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Role of Bio-fertilizers in vegetables production: A review

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Abstract
Bio-fertilizers are considered as an alternative to chemical fertilizers in modern vegetable production. Green revolution was needed at that time because we had to increase the yield of vegetable in any way. This is the reason why we used chemical fertilizers indiscriminately. There is no doubt that the Green Revolution has brought the country out of hunger-like problems. Obviously the chemical fertilizers are expensive, not environment friendly and they are also responsible for water, air and soil pollution. Moreover, they may destroy the fertility of the soil in a long run. In view of these reasons, the scientist has found the option of chemical fertilizers through bio-fertilizers. Bio-fertilizers contain microorganisms which promote the adequate supply of nutrients to the host plants and ensure their proper development of growth and regulation in their physiology.

Keywords: Bio-fertilizers, soil health, crop growth, vegetable production

Introduction
Vegetables are most important component of a balanced diet and act as a protective food. India occupies a prime position in the world in vegetable production and 2nd largest producer of vegetable next to china. India produces about 7905000 million tons of vegetables from an area 465000 million hectares, and productivity 17t/h [1] which are far below to the desired requirement (300g/capita/day) to fulfil the need of the growing population [2]. It is widely accepted that vegetables are important component of a healthy diet, and that their consumption could help prevent a wide range of diseases. Epidemiological data support that protective effect of vegetables against several types of cancers and cardiovascular disease [3]. Talking about human health, studies have shown evidences where farmers exposed to chemical fertilizers were at risk of giving birth to children with limb defect [4-5]. It has been estimated that about 50% of the fertilizer leaches down into the soil and has started showing its effects on human health in the form of diseases such as methemoglobinemia in children [6]. Keeping this challenge in mind there is a need to increase the crop yield from the same land area and that too in an environmentally safe way [7].
For optimum plant growth, nutrients must be available in sufficient and balanced quantities [8]. Beneficial microorganisms in bio fertilizers accelerate and improve plant growth and protect plants from pests and diseases [9]. The role of soil microorganisms in sustainable development of agriculture has been reviewed [10-11]. These are products containing living cells of different types of microorganisms which when, applied to seed, plant surface or soil, colonize the rhizosphere or the interior of the plant and promotes growth by converting nutritionally important elements (nitrogen, phosphorus) from unavailable to available form through biological process such as nitrogen fixation and solubilisation of rock phosphate [12].

Need of Bio-Fertilizers
Fertilizer prices are increasing day by day so becoming unaffordable by small and marginal farmers, depleting soil fertility due to widening gap between nutrient removal and supplies, growing concern about environmental hazards and increasing threat to sustainable agriculture. Besides above facts, the long term use of biofertilizers is economical, eco-friendly, more efficient, productive and accessible to marginal and small farmers over chemical fertilizers [13].

Biofertilizers
Bio fertilizers are mainly constituted of selected living cells of microbes which provide the plants with nutrients through their root system. The microbes in these fertilizers use different mechanisms to provide nutrients to the plants. They are capable of nitrogen fixing, phosphate solubilizing, phosphate mobilizing, and promotion of rhizobacteria [14]. It includes mainly the nitrogen fixing, phosphate solubilizing and plant growth promoting microorganisms.

Biofertilizers benefiting the crop production are Azotobacter, Azospirillum, blue green algae, Azolla, P-solubilizing microorganisms, mycorrhizae and sinorhizobium [15]. The preparation includes selective microorganism that may be useful for the soil. The suitability of the packaging is ensured for a longer shelf life and the safety of the environment and the user [16]. Application of Azotobacter + recommended dose of NPK and Azospirillum + recommended dose of NPK (160:90:90 kg/ha) through chemical fertilizers gave better plant growth and fruit yield [17]. The improvement in yield characters in knol-khol with inoculation of PSB is due to solubilization and increased availability of phosphorus from insoluble or otherwise fixed phosphorus for its plant availability [18]. The beneficial effects of PSB along with other nutrients increased yield of crop might have resulted due to higher rate in partitioning of different reproductive structure and yield attributes which might have ultimately in turned to higher yield of the crop [19-22]. Application of bio-fertilizers not only improved the productivity of knol-khol but also gave maximum monitory benefit [23].

1. Nitrogen-Fixing Bacteria (NFB)

Biological Nitrogen fixing microorganisms also improve the soil microbiological activities. Hence the plants show improved growth and yield. These microorganisms also produce hormones and some other growth factors which are needed for the plant growth and development. Certain plant pathogens are also removed by these nitrogen fixing microorganisms [24-26]. Biological nitrogen fixation is one way of converting elemental nitrogen into plant usable form [27]. Plant growth and productivity is arrested due to the deficiency of certain minerals especially Nitrogen in soil. Free living as well as symbiotic nitrogen fixing bacteria plays an important role to improve the structure of the soil [28-30].

Benefits of using BNF (Biological nitrogen fixation)

- **Economics:** BNF reduces costs of bio fertilizers production. Environment: The use of inoculants as alternatives to N fertilizer avoids problems of contamination of water resources from leaching and runoff of excess fertilizer.
- **Efficiency:** Legume inoculants do not require high levels of energy for their production or distribution. Application on the seed is simple compared to spreading fertilizer on the field.
- **Better yields:** Inoculants increase legume crop yields in many areas. BNF often improves the quality of dietary protein of legume seed even when yield increases are not detected.
- **Increased soil fertility:** Through practices such as green manuring, crop rotations, and alley cropping, N fixing legumes can increase soil fertility, permeability, and organic matter to benefit non-legume crops.
- **Sustainability:** Using BNF is part of the wise management of agricultural systems. The economic, environmental, and agronomic advantages of BNF make it a cornerstone of sustainable agricultural systems [31]. Studies have shown that common combination of lower input costs and favourable price premiums can offset reduced yield and make organic farming equally and often more profitable than conventional farms [32-34].

Rhizobium

The most widely used bio-fertilizer is Rhizobium which colonizes the roots of specific legumes to form tumor like growth called root nodules. These nodules act as factories of ammonia production. The Rhizobium legume association can fix upto 100-300 kg N/ha in one crop season and in certain situation can leave behind substantial nitrogen for following crops [35]. The study shows that there was a significant of synthetic inoculation of Rhizobium on the yield and other growth parameter of French beans. It has been concluded that inoculation of Rhizobium to French beans has significantly increased plant height, pod yield and yielding components [36-37]. Rhizobium depicted a significant influence on legume vegetable crops, resulting increase in yield from 4-13 % [38-40].

Azotobacter

Among the biofertilizers, Azotobacter represents the main group of heterotrophic, non-symbiotic, gram negative, free living nitrogen-fixing bacteria. They are capable of fixing an average 20 kg N/ha/year. The genus Azotobacter includes 6 species, with A. chroococcum most commonly inhabiting in various soils all over the world [41]. Besides nitrogen fixation, Azotobacter also produces thiamin, riboflavin, indole acetic acid and gibberellins. When Azotobacter is applied to seeds, seed germination is improved to a considerable extent, so also it controls plant diseases due to above substances produced by Azotobacter. The exact mode of action by which Azotobacteria enhances plant growth is not yet fully understood. Three possible mechanisms have been proposed: N2 fixation; delivering combined nitrogen to the plant; the production of phytohormone-like substances that alter plant growth and morphology, and bacterial nitrate reduction, which increases nitrogen accumulation in inoculated plants [42]. The incorporation of bio-fertilizers (Azotobacter) plays major role in improving soil fertility, yield attributing characters and thereby final yield of vegetables has been reported by many workers [43-50]. The addition of Azotobacter along with organic sources which is of rich nutrient content narrowed the C: N ratio of the organic manures and this enhanced the rate of mineralization resulting in rapid release of nutrient from the organic source [51]. The research confirmed that incorporation of Azotobacter chroococcum strains into the soil affected the increase in sugar beet production and soil biogenicity. Sugar beet root yield increased after inoculation compared with the control (7.52–8.47 t ha^{-1}). Inoculation increased root yield by 20%, and repeated inoculation caused a 23% increase. Increase in the yield of crystal sugar obtained after inoculation was 21%, while repeated inoculation caused the increase of 22–23% [52]. It can fairly be concluded that the application FYM 50% + Azospirillum 50% and Azotobacter 100% at optimum level is quite effective to promote growth, yield and quality of cabbage. It increased height, leaves, head size, spread and yield per hectare, along with better quality of heads in terms of TSS, acidity and ascorbic acid [53].

Azospirillum

Biological products and especially the use of Azospirillum spp. appeared among the new the technologies for optimizing plant implantation, Azospirillum is growth promoting Rhizobacteria (PGPR) capable of colonizing the root and stimulating root growth thus enhancing mineral and water uptake plants [54]. Number of scientific findings were well documented that application of Azospirillum and other plant growth promoting rhizobacteria improve the plant growth and yield of commercially important crops like tomato, brinjal and chillies [55]. They are called as associative endosymbiont on roots of grasses and similar types of plants. They are also

known to fix atmospheric nitrogen and benefit host plants by supplying growth hormones and vitamins. Generally the nitrogen requirement of non-leguminous crops such as horticultural crops met partly from the activities of associative symbiotic bacteria–Azospirillum as well as increased the yield and nitrogen economy of vegetables [56-68].

2. Phosphous Solublizing Bacteria (PSB)

Soil and seed inoculation with phosphate solubilizing bacteria (PSB) improves solubilization of fixed soil phosphorus and of applied phosphates, resulting in higher crop yields [67-72]. The increase in growth characters might be due to stimulative effect of PSB on P solubilization leading to higher P availability and uptake by plants [73-76]. Microorganisms enhance the P availability to plants by mineralizing organic P in soil and by solubilizing precipitated phosphates [77-79]. Subsequently, PSB become a source of P to plants upon its release from their cells. Similar results were reported in tomato [80-81], Cauliflower [82], turmeric [83], pea [84].

French bean is affected by the inadequate availability of nutrients in the soil; it requires a large quantity of phosphorus for optimum growth and yield. To enhance the plants capacity to utilize such nutrients effectively including in the soil, PSB and VAM inoculation have been considered to be effective. Researchers in the few decades established that PSB Treatment could improve plant growth through increased uptake of phosphorus, especially in the soils of low fertility [85-86]. Tomato growth, yield and quality parameters such as TSS, ascorbic acid and lycopene contents were higher in plants grown with phosphobacteria and Azospirillum [87]. The chilli cultivars (Arkalohit, Arkajwala and Arkaanamika) and Brinjal inoculated with Phosphobacteria found to increase crop growth and yield [88]. Tomato plants were inoculated with culture isolate Bacillus PSB 24 and various morphological growth characters were analyzed at different time intervals. The culture inoculum of Bacillus PSB24 caused an increase in growth parameters over control and showed better growth in shoot as well as root and an enhancement in both root and shoot dry and fresh weight in tomato plants [89]. Increased in the yield of various crops were demonstrated due to inoculation of peat based cultures of phosphobacteria and saving up to 50 per cent of recommended level of P_2O_5 was observed in many experiments [90-93]. Root inoculation with PSB 1:10 solution (1kg PSB:10 litre water) in the presence of 100% P (full recommended P2 O5 dose) significantly increased plant height, leaf area index, number and yield of fruits per plant, fruit weight and yield per hectare. The highest net return and cost: benefit ratio were also recorded [94]

3. Potassium solubilizing bacteria (KSB)

Potassium solubilization is done by a wide range of saprophytic bacteria, fungal strains and actinomycetes [95-98].There are strong evidences that soil bacteria are capable of transforming soil K to the forms available to plant effectively [99-101]. As reported by previous researchers, inoculation with KSB also exerted beneficial effects on growth of eggplant [102], pepper and cucumber [103]. Inoculation of seeds and seedlings of different plants with KSB generally showed significant enhancement of germination percentage, seedling vigor, plant growth, yield, and K uptake by plants under greenhouse and field conditions [104-107]. Inoculation with KSB also exerted beneficial effects on growth of eggplant, pepper, cucumber, Okra, Brinjal and potato [108-113]. These studies indicate that the use of KSB as bio-fertilizers for agriculture improvement can reduce the use of agrochemicals and support eco-friendly crop production [114-115].

4. Vesicular Arbuscular Mycorrhiza (VAM)

The mycorrhizal fungi mobilize phosphates and other micronutrients like zinc, boron and molybdenum from adjacent soil to the root system through hyphal network. Enhanced uptake of phosphorus and increased plant growth due to inoculation of soil with VAM fungi in horticultural crops such chilli, tomato, asparagus, potato, lettuce, Onion and chilli [116-120].

5. Combined inoculation

The highest number of fruits, fruit weight, length of fruits and thickness of fruits were obtained with the application of combination of organic manures together with Azotobacter and PSB in okra crop [121] Seeds inoculation of tomato plants with a mixture of Azotobacter chroococcum, Azospirillum brasilense and Bacillus subtilus results an increase in fresh and dry weight of plants over inoculating plants with Azospirillum brasilense or Azotobacter chroococcum alone [122]. They found that plant dry weight of Capsicum annum cv. California Wonder significantly increased by mycorrhizal inoculation together with different diazotrophs [123]. Inoculation of pigweeds (Amaranthus dubians) with effective microorganisms can improve their growth and yields [124].

Advantage of Bio-Fertilizers

1. They are capable of nitrogen fixing, phosphate solubilizing, phosphate mobilizing, and promotion of rhizobacteria [125].
2. The preparation includes selective microorganism that may be useful for the soil. The suitability of the packaging is ensured for a longer shelf life and the safety of the environment and the user [126].
3. To make the application easier, the microorganisms are mounted on any material before being released into the fields. This material not only helps increase the shelf life of the fertilizer but also facilitates rapid growth upon release [127].
4. Biological fertilizers can mobilize nutrients that favor the development of biological activities in soils.
5. Maintenance of plant health is enhanced by the addition of balanced nutrients.
6. Food supply is provided and growth of microorganisms and beneficial soil worms is impelled.
7. As a result of the good structure provided to the soil, root growth is promoted.
8. The content of organic matter in soil is higher than normal levels.
9. Promotes the development of mycorrhizal associations, which increases the availability of phosphorus (P) on the soil.
10. Help to eliminate plantar diseases and provide continuous supply of micronutrients to the soil.
11. Contribute to the maintenance of stable nitrogen (N) and phosphorus (P) concentrations.
12. Improvements on the capacity of nutrients' exchange in the soil.

Disadvantage of Bio-Fertilizers

1. Compost products have highly variable concentrations of nutrients. In addition, implementation costs are higher than those of certain chemical fertilizers.

2. Extensive and long-term application may result in accumulation of salts, nutrients, and heavy metals that could cause adverse effects on plant growth, development of organisms of the soil, water quality, and human health.
3. Large volumes are required for land application due to low contents of nutrients, in comparison with chemical fertilizers.
4. Main macronutrients may not be available in sufficient quantities for growth and development of plants.
5. Nutritional deficiencies could exist, caused by the low transfer of micro- and macro-nutrients [128].

Conclusion

Application of Bio-fertilizers will play an important role in improving the supply of nutrients, organic carbon, accumulation of soil enzymes, future productivity, directly reflects on soil fertility index, economy of farmers, maintain sustainability in natural soil ecosystem and vegetables crops availability in the coming years.

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