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Review

Biofertilizers: a natural input of soil fertility management for vegetable production: a review

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ABSTRACT

Sustainable vegetable production is the need of the hour for optimum plant growth, development, higher productivity and balanced and sufficient availability of nutrients. In order to maintain soil fertility and higher vegetable production, chemical fertilizers are being used widely. However incessant use of fertilizers causes decline in soil quality, health as well as productivity of the crop. Continuous use of nitrogen (N) and phosphorus (P) fertilizers leads to soil acidity. The potential biological N_2-fixing *Azotobacter* and *Azospirillum* and P-solubilizing bacteria such as *Bacillus* and *Pseudomonas* and the vesicular arbuscular mycorrhizae play a vital role in nitrogen and phosphorus nutrition of horticultural crops. Application of biofertilizers is greatly involved in the accumulation of soil enzymes which directly reflects on soil fertility index. The effective biofertilizers for crops not only provide economic benefits to the farmers but also improve and maintain the soil fertility.

Keyword: Biofertilizers; soil fertility; vegetable production

INTRODUCTION

Vegetables are most important component of balanced diet and act as a protective food. India occupies a prime position in the world in vegetable production and is 2nd largest producer of vegetables next to china. Chemical fertilizers are industrially manipulated substances composed of known quantities of nitrogen (N), phosphorus (P) and potassium (K) and their exploitation causes air and ground water pollution by eutrophication of water bodies (Youssef and Eissa 2014). In this regard, recent efforts have been channelized more towards the production of nutrient rich high quality food in sustainable compartment to ensure bio-safety. The innovative view of farm production attracts the growing demand of biological-based organic fertilizers exclusive of alternative to agro-chemicals (Raja 2013). In agriculture, encouraging alternate means of soil fertilization relies on organic inputs to improve nutrient supply and conserve the field management (Araujo et al 2008).

Biofertilizers keep the soil environment rich in all kinds of macro and micronutrients via N_2-fixation, phosphate and K-solubilization or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil (Megali et al 2014). When biofertilizers are applied as seed or soil inoculants, they multiply and participate in nutrient cycling and benefit crop productivity (Singh et al 2011). In general 60 to 90 per cent of the total applied fertilizer is lost and the remaining 10 to 40 per cent is taken up by plants. In this regard, microbial inoculants have paramount significance in integrated nutrient management systems to sustain agricultural productivity and healthy environment (Adesemoye and Kloepper 2009).

For optimum plant growth, nutrients must be available in sufficient and balanced quantities (Chen 2006). Beneficial microorganisms in biofertilizers accelerate and improve plant growth and protect plants from pests and diseases (El-Yazeid et al 2007). The role of soil microorganisms in sustainable development of agriculture has been reviewed (Lee and Pankhurst 1992, Wani et al 1995). 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 promote growth by converting nutritionally important elements (N, P) from unavailable to available form through biological process such as N_2-fixation and solubilisation of rock phosphate (Rokhzadi and Toashih 2011). This review is intended to cater to the needs of agriculturists and plant biologists whose work focuses on creating clean and efficient means to improve the quality of soil by nourishing and maintaining the useful and natural flora of microorganisms. Current costs of synthetic fertilizers are so high that farmers in many developing countries cannot afford them and must find alternative nutrient inputs. But biofertilizers are no substitute for synthetic fertilizers. Biofertilizers are known to make a number of contributions in crop production such as they supplement fertilizer supplies for meeting the nutrients need of crops; they can add 20-200 kg N_2/ha (by fixation) under optimum conditions and solubilize/mobilize 30-50 kg P_2O_5/ha; they liberate growth promoting substances, organic acids and vitamins and help maintain soil fertility; they suppress the incidence of pathogens and control diseases; they increase crop yield by 10-15 per cent, N_2-fixers reduce depletion of soil nutrients and provide sustainability to the farming system; they improve soil physical properties, tilth and soil health in general.

Characteristics of biofertilizers

***Rhizobium*:** *Rhizobium* is a rod-shaped, gram negative, non-spore forming aerobic, typically mobile bacterium measuring 0.5 to 0.9 µm wide and 1.2 to 3.0 µm long. A soil habitat bacterium is capable of colonizing the legume roots and fixes the atmospheric N_2 symbiotically into plant usable form. It can fix up to 50-100 kg N/ha/ year especially important for legumes and oilseeds. Process of nodulation occurs in the roots of the plant. The growth promoting chemicals excreted by plants into the root zone stimulate the microorganisms growth (rhizobia) which then aggregate at distinct sites near roots. Little or no adhesion is evident between rhizobia and plants of heterologous cross inoculation group (Dazzo and Hubbel 1975). Invasion of rhizobia occurs through root hairs which curl under the influence of some chemicals. *Rhizobium* excretes one or more compounds probably including nucleic acid and polysaccharide or protein which may be involved in deformation of root hair (Solheim and Raa 1973). A hypha like infection thread is formed due to rhizobial penetration into the root hair. The structure finally consists of central core containing the rhizobia and a surrounding cortical area in which is found the plant vascular system and thus the bacterium establishes contact with host bundles. Kothyari et al (2017) studied the influence of biofertilizers on plant growth and seed yield of pea (*Pisum sativum* L). Based on the mean performance of different treatments, it was observed that recommended dose of chemical fertilizers + *Rhizobium* culture seed inoculation @ 200 g/kg seed was found best for plant growth and seed yield.

***Azotobacter*:** It belongs to Azobacteriaceae and is aerobic, chemoheterotrophic and free living. The application of *Azotobacter* reduces the use of 10-20 kg N/ha. It produces growth promoting substances that enhance seed germination and extend root growth. It produces polysaccharides which give better soil aggregation. *Azotobacter* suppresses the growth of saprophytic and pathogenic microorganisms near the root system of crop plants. *Azotobacter* helps in maintaining better plant population, growth and yield of crops. This organism is present in the rhizosphere of a number of crop plants viz rice, maize, sugarcane, bajra, vegetables and plantation crops (Arun 2007). Mahato et al (2009) evaluated the response of biofertilizers and inorganic fertilizers on germination and growth of tomato plant. Nitrogen was used as inorganic fertilizer and *Azotobacter* was used as biofertilizer. The germination was observed higher in soil application of *Azotobacter* as compared to other treatments.

***Azospirillum*:** They belong to the family Spiriliaceae, are chemoheterotrophic and associative in nature. They fix atmospheric N_2 @ 15-30 kg/ha and secrete growth regulating substances. Initial observations of Dobereiner and Day (1975) gave the indication that *Azospirillum* is confined to the root system of those tropical grasses where C_4 is operative. However *Azospirillum* has been isolated from the soils and roots of a variety of plants both from the temperate and tropical regions (Okon et al 1977). Besides C_4 plants, several C_3 plants including weeds also showed abundant distribution of the organism in the roots. However they do not produce any visible nodules or outgrowth on root tissue. Anisa et al (2016) reported the effect of different biofertilizers and their combination on yield and yield attributing parameters of okra. Among different treatments, treatment combination FYM (double dose) +*Azospirillum* + AMF + *Frateuria* showed best results for all the parameters.

Phosphate solubilizing microorganisms (PSMs): PSMs include different groups of microorganisms particularly fungi and bacteria that have been reported to solubilize inorganic phosphates. Such bacteria and fungi grow in medium where insoluble phosphates such as tricalcium, ferric, aluminium, rock phosphate and bone meal are present. PSMs in addition of assimilating phosphorus for their own requirement, release sufficient quantities in excess of their needs. The genera of bacteria such as *Psuedomonas*, *Bacillus*, *Asperigillus* and *Pencillium* have been reported being active in the solubilization process (Gaur 1990). The production of organic acids by microorganisms is one of the important mechanisms but other products such as CO_2, H_2S and alkalinity production may be mechanisms of solubilization. PSM produces monocarboxylic acid (acetic, formic), monocarboxylic hydroxy (lactic, gluconic, glycolic), monocarboxylic keto (2-keto gluconic), dicarboxylic (oxalic, succinic), dicarboxylic hydroxyl acids (malic, maleic) and tricarboxylic (citric) in liquid medium from simple carbohydrates (Sperber 1957).

Chelating substances have also an important role in solubilization of insoluble phosphates. 2-ketogluconic acid is produced by many aerobic bacteria and is very effective in solubilization of insoluble phosphates such as hydroxyapatite, fluorapatite and aluminium phosphate. PSM also produces phosphatase enzyme along with acids which are involved in the solubilization of phosphate in aquatic conditions. Another mechanism is the proton extrusion ie solubilization without acid production. It could be due to release of protons accompanying respiration or ammonium assimilation (Kucey 1983). Insoluble phosphates in this manner are directly solubilised at the microbial cell surface.

Mycorrhizae: Most of the plant roots are colonized by fungi and transformed into fungus root organ which are known as mycorrhizae. Mycorrhizae result from a mutualistic symbiosis between plant roots and certain fungi. These fungi are omnipresent in soil and are found in the roots of many angiosperms, gymnosperms, Pteridophyta and Thallophyta. The mycorrhizal fungi carry out the role of root hair. The fungus takes carbohydrates from the plants and in turn supplies the plants with nutrients, hormones and protects it from root pathogens. They are essential in increasing plant growth and nutrient uptake (Bagyaraj 1992). They enhance plant growth by improving mineral nutrition. The hyphae extend beyond root zone and directly translocate nutrients from the soil to root cortex (Hayman 1983) in arbuscules where exchange of carbon and phosphorus is done. The beneficial effects of VAM fungi have also been reported in the drought and saline conditions. The important feature is that in drought conditions a mycorrhizal root has ability to get additional water sources unavailable to non-mycorrhizal plant roots (Allen and Boosalis 1983).

Application of biofertilizers on vegetables

For vegetables, the biofertilizers commonly used are *Rhizobium, Azotobacter, Azosprillum,* phosphate solubilizers and mycorrhizae through following methods:

Seed treatment: Each packet (200 g) of inoculant is mixed with 200 ml of rice gruel or jaggery solution. The seeds required for one ha are mixed in the slurry so as to have uniform coating of the inoculants over the seeds and then shade-dried for 30 minutes. The treated seeds should be used within 24 hours. One packet of inoculant is sufficient to treat 10 kg seed. *Rhizobium, Azospirillum, Azotobacter* and *Phosphobacteria* are applied as seed treatment.

Set treatment: A culture suspension is prepared by mixing 1 kg of culture in 50-60 liters of water. The cut pieces of planting material required for 1 acre are kept immersed in the suspension for 10-15 minutes. These cut pieces are allowed to dry for some time before planting. The cut-pieces method is applicable for crops like potato.

Seedling treatment: Seedling treatment is recommended for transplanting crops like tomato, chilli pepper, onion etc. The suspension is prepared by mixing 1 kg of culture in 10-15 liters of water. Seedlings required for 1 acre are made in small bundles. The seedlings are dipped in the suspension for 15-20 minutes and transplanted immediately. Generally the ratio of inoculants and water is 1:10 approximately ie a 1 kg packet in 10 liters of water.

Soil application: A culture of 3-4 kg is prepared and mixed in 40-60 kg of moist soil/compost. The mixture is broadcast in one acre of land either at sowing time or 24 hours before sowing.

Use of VAM biofertilizer: The inoculum is applied 2-3 cm below the soil at the time of sowing. The seeds are sown or cuttings planted just above the VAM inoculum so that the roots may come in contact with

Table 1. Effect of biofertilizers on increase in vegetable yield on farmers' fields at different locations

Location	Treatment	Crop	Yield		Increase in yield over control (%)
			Control (q/ha)	Treatment (q/ha)	
Umri Nagpur	*Azotobacter*	Okra	24.8	26.0	8.3
Ambada Narkhed	PSM	Brinjal	125.0	137.5	10.0
Tivara Amravati	*Azotobacter*	Brinjal	190.0	220.0	15.8
Nagapur Sweagram	*Azotobacter*	Chilli	14.5	16.0	10.3
Bopapur Nagpur	PSM	Cauliflower	34.0	36.5	7.35
Chikhali Katol	*Azotobacter*	Cauliflower	32.5	34.5	6.2
Chicholi Parshivani	*Azotobacter*	Okra	23.4	25.5	8.97

Source: RBDC, VCA Complex, Nagpur, Maharashtra, India (1997-98)

the inoculum and cause infection. Bulk inoculum of 100 g is sufficient for one m^2 area. Seedlings raised in the polythene bags need 5-10 g of bulk inoculum for each bag. At the time of planting of seedlings, VAM inoculum is applied @ of 20 g/seedling in each spot.

Response of different biofertilizers to vegetable yield

The Regional Biofertilizers Development Centre, Nagpur, Maharashtra conducted experiments at farmers' fields during 1997-98 and reported the increase in yield by application of biofertilizers in vegetables (Table 1).

CONCLUSION

The overdependence on the use of chemical fertilizers has encouraged industries to produce chemicals that are toxic to human health as well as soil fertility. These drawbacks are combined with a high cost of production that is beyond the reach of many farmers. The application of locally available organic manures and biofertilizers in different combinations improve soil fertility, growth and yield of vegetables which can improve the economics of farming community. The biologically potential N_2-fixing organisms like *Azotobacter*, *Azospirillum*, phosphorus-solubilizing bacteria such as *Bacillus* and *Pseudomonas* and the vesicular arbuscular mycorrhizae play a vital role in nitrogen and phosphorus nutrition of horticultural crops. Application of biofertilizers is greatly involved in the accumulation of soil enzymes which directly reflects on soil fertility index. The effective biofertilizers for crops not only provide economic benefits to the farmers but also improve and maintain the soil fertility.

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