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Biofertilizer Fertilizer And Food Scarcity Removal: A Path Towards Sustainable Agriculture In India: A Review

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Abstract

Food scarcity and security have been longstanding challenges faced by many countries, including India. With a growing population and increasing demand for food, the need for sustainable agricultural practices has become more critical than ever. One of the essential components of modern agriculture is the use of chemical fertilizers, which has significantly contributed to increasing crop yields and addressing food scarcity. However prolonged usage of chemical fertilizer not only degrades soil quality and decreased the agricultural production, but also affects soil, water bodies' atmosphere and finally human health. The easy and eco-friendly solution to this growing issue is traditional organic agricultural process however due to its time consuming characteristics it was not became acceptable method. Biofertilizers are natural or organic substances containing living microorganisms that enhance soil fertility and plant nutrition. Via metabolic processes these microorganisms accelerates nutrient availability for the plants in the soil. Moreover, this is a cheaper and eco-friendly alternative which can develop a sustainable agricultural system. In this review we have discussed regarding the utility of bio-fertilizer usage over chemical biofertilizer and current status in Indian agriculture system to accepting biofertilizer usage for sustainable development.

Keywords: Chemical fertilizer, Bio-fertilizer, soil health, Sustainable agriculture

1. Introduction

The production of crops increased with advent of green revolution but chemical fertilizers in turn have degraded not only the soil texture but also demean the physio-chemical nature of soil and also affected the microorganisms of soil and insects and worms living in soil. With the increase in demand of production of crops the exploitation of chemical fertilizers increased by the farmers which in turn degraded the soil quality and quantity. Thus biofertilizers were used instead. Biofertilizers contain living microorganisms in living or dormant condition. It gets mutually associated with roots and increases the nitrogen, phosphorus and potassium contents and also synthesize plant growth promoting factors. Biofertilizers increases the amount of auxin, cytokianine and gibberellins which are essential factors for growth of plants. The use of biofertilizers increases the quality of the soil so unlike chemical

fertilizers it is cost effective in nature. Biofertilizers not only induces yield of crops but also increases the nutrient availability of the soil. At estimation nitrogen content of soil increased by 20-30% with the use of biofertilizer compared to chemical fertilizers and phosphorus content increased by 25 %. It was recorded by Panda et. al. in 2017 recorded that with the use of biofertilizer production of crops increased within range between 35% to 65%. (Mahmud *et. al* 2021), (Singh *et. al* 2014)

2. Advantages of use of bio-fertilizers

2. 1 Carbon emission: Synthetic fertilizers causes carbon emission while production and transportation. Research conducted by Greenpace Research laboratories at University of Exter and University of Turin conducted a study showed that more than 10 % of CO_2 occurs in agriculture in countries like India, China, U. S and EU28 during 2018. Nitrogen producing research plants produce 1. 13 gigatones of CO_2. When nitrogen is applied to the soil plants take up some nitrogen while micro organisms use some parts of it and by product N_2O is produced as a result of metabolism and the rest end up leaching from the site. (Menegat *et al*,2022). The carbon emission with the use of organic fertilizer were 0. 8 $kg_{CO2,eq}$. /kg for nitrogen and 1. 8 $kg_{CO2,eq}$. /kg for phosphorus, while the carbon emission for chemical fertilizers were1. 9–7. 8 $kg_{CO2,eq}$. /kg for nitrogen and 2. 3–4. 5 $kg_{CO2,eq.}$ /kg for phosphorus. (Havukainen et. al ,2018). The scaling down of green house gas production in between organic and chemical fertilizer ranges between 78% for nitrogen and 41% for phosphorus. (Havukainen et. al ,2018).

2. 2 While studying various roles of plant growth promoting rhizobacteria aiding in plant growth and providing nutrition it was seen that in inoculated maize plants *Azotobacter chroococcum* increased the total nitrogen and phosphorus content than uninoculated maize plants. (Havukainen et. al ,2018). Inoculated *A. chroococcum* increased the ammonium content of soil at seedling stage (+17. 78%) and during germination stage (+34. 48%) and also during germination stage increased nitrate content-N (NO_x-N; −23. 94%) and Phosphorus (Olsen-P; −15. 38%) content of soil. (Song et. al, 2021).

3. Overview of various soil microbes used as bio-fertilizer

The microorganism which are notable in plant growth and development are rhizobacteria,N_2-fixing cyanobacteria, mycorrhiza, beneficial bacteria which aids in healthy plant development, stress tolerance endophytes and microbes which helps in biodegradation. (Song et. al, 2020). Biofertilizers add complimentary elements which assists in protection of soil and increases production of crops *viz* , pest management, soil PH adjustment, restoration of organic matter in soil, preventing soil leaching . There are three main ways through which microbe based bioferlizers help agriculture. (Bhardwaj et. al,2014).

Increases in NPK content of soil production: With the use of rhizobium the legume production increased(Hassen et al,2016). For example plantation of soya bean increases the nitrogen content by about 80% required for the growth of soya bean and also improved the nutrient content of soil. (F. K Mbaka et. al ,2022). It is estimated that organic nitrogen fertilizer increases rice production over inorganic nitrogen fertilizer by 52%. Rhizobium biofertilizers increases the nitrogen content in regions like Kenya, Zimbabwe , Tanzenia where regions are mostly arid and semi arid by 50%. (Li et. al,2018).

Plant hormones production which promotes growth of plants : Soil containing symbiotic bacteria other than increasing nitrogen content of soil produces various plant growth hormones , increases nutrient content of soil for growth , produces organic acids ,actives and compounds which prevent pathogenic attack on plants (Singh JS et. al ,2016)

Crop protection via mitigation of various biotic abiotic stress : Certain microbes not only acts as biofertilizers but also protects plants from specific pests via production of different antagonistic compounds. (Koskey et. al ,2017). Rhizobium when forms symbiotic association with leguminous plants which produces cyanide compounds and provides resistance against herbivores. (like *Bacillus* sp. , *Pseudomonus* sp.)

3. 1 Nitrogen Fixing Bio-fertilizer

Nitrogen fixing biofertilizers are most commonly used biofertilizer and are expected to grow 11. 9% compounding annual growth rate (CAGR). These microorganisms fix biological nitrogen demand in plants. In leguminous plants nitrogen fixing bacteria have been studied and inoculated legumes showed much more growth than un-inoculated legumes. (Thies et. al, 1995). Inoculations of nitrogen in alfalfa, soya bean, pea, and cowpea showed a range from 23 to 335/kgha/year (Ramoneda et. al, 2020). The nitrogen fixation by nitrogen fixing bacteria depends on various factors like the strain of bacteria used, rhizobium-legume symbiotic association, climatic conditions (Melchiorre et. al, 2011). According to (Herridge et al. (2008) (Hungria et.

al,2006), Rhizobium inoculants can replace mineral fertilizers and can be cost effective by USD 29 ha−1 . Trial on new strains needs to be performed and their viability of field experiments needs to be studied. Like leguminious crops more researches need to be conducted on non-leguminous crops and diazotrophs. *Azospirillumsp. , Azotobacter sp. , Gluconaceotobacter sp. , and Burkholderia sp*. requires more focus as the study on asymbiotically fixed nitrogen in crop fields largely remains unestablished. Researches need to be conducted on extensively consumable crops like cereals, vegetables (Adeleke et. al ,2019). Some efficient N-fixing strains such as *Rhizobium sp*. and *Azotobacter sp*. are commercially used as biofertilizer. (Franche et. al, 2009). However, the commercial nitrogen biofertilizers mostly consist of *Rhizobium sp*. and a few other bacteria such as *Azotobacter sp*. , and *Azospirillum* sp. species and are widely used. (Figure:1)

3. 1. 1. Rhizobium group of microbes

Rhizobium belongs to family of Rhizobiceae forms symbiotic association with plants and fixes nitrogen upto 50-100 kg/ha with legumes. It forms association with specific plants and forms nodules and produces ammonia. Rhizobium forms symbiotic association with legumes and certain non-legumes like *Parasponia* sp. There are six groups of rhizobium species based on cross inoculation studies (Tien et. al,1979).

3. 1. 2. *Azospirillum* sp.

Azospirillum belongs to family of spirilaceae, forms associative symbiosis and fixes 20-40 kg/ha of land and produces growth promoting substances. Azospirillum forms symbiosis with planys which particularly haveC_4-dicarboxyliac path way. Azospirillum is usually used for maize, sugarcane etc. as these thrives on organic acid like malic aspartic acid. Theazetobacter is not only present on the surface but also present in the roots. *A. lipoferumand, A. brasilense* are mainly used as bio-fertilizer worldwide (Kalimuthu et. al,2019). The common phytohormones are auxins, gibberellins, and cytokinin. Though PGPR, produces very less quantity of phytohormones but they are crucial for plant growth. The most commonly used PGPs as biofertilizers are *Azospirillum sp. , Bacillus sp*. Due to their importance in production of phyto-stimulators PGPR are considered for PGP as bio-fertilizers, especially if they aid in providing plants nutrition or can fix or can help in fixing organic nutrient in soil. (Sumbul A et. al,2020)

3. 1. 3. *Azetobacter sp.*

These species belongs to azotobacteriacea and are aerobic and free living in nature. Azetobacter thrives generally in neutral or alkaline soil. *A. chroococcum ,A. vinelandii* are some azetobacters which are widely used as biofertilizers. These bacteria produces antifungal antibiotics which prevents pathogenis infections in roots to some level. *Azetobacter* is generally used in rice, maize, bajra etc. The number of *Azotobacter. sp* does not exceeds more tan of 104 to 105/g. (Abdelmoteleb et. al, 2020)

3. 2 Phosphate and potassium solubilizing bio-fertilizer

Besides nitrogen fixation crops also require phosphorus fixation which they cannot uptake from atmosphere. Recently phosphetic bio-fertilizers have gained popularity as they aids in increasing organic phosphorus for soil and also aids in control of pathogens. (Soumare et. al, 2020)Phosphorus deficiency had been reported in various kinds o soils so the demands of phosphorus bio-fertilizers have increased. Though there are numerous literatures and scientific research regarding phosphorus bio-fertilizers but in practice their use is limited. Since mineral Phosphorus bio-fertilizers are limited, Phosphorus bio-fertilizers will open a horizon for sustainable agricultural production. (25) (Figure :2)

Similarly, potassium solubilizing bio-fertilizers are equally important as potassium is limited to soil which is necessary for crop production. The potassium solubilizing ability of PGPR from potassium rocks via acidification have been widely studied and potassium solubilizing bacteria in enhancing plant growth and increase in production in plants like tomato(Goteti et. al,2013) and crops like maize,(Reyes-Castillo et. al,2019) wheat(Akintokun et. al,2019) and many others. The Potassium solubilizing bacteria can increase the rate of germination, uptake of nutrients, growth of plants in controlled and uncontrolled conditions. Though studies show that potassium bio-fertilizer cannot fulfill the potassium requirement of soil like mineral fertilizer but it is an ecofriendly approach for production of crops. NativePottasium solubilizing bacteria has been emerging now a days. Though there are various ongoing studies but the viability of Pottasium solubilizing bacteria in different atmosphere is still uncertain. (Meena et al. 2018) sated though there are many research regarding potassium availability in soil bt field experiments are inadequate so more field experiments are required to enhance usability. (Muthuraja et. al, 2021)

3. 3 ZINC SOLUBILIZING BIOFERTILIZER

Zinc deficiency is present in soil throughout the world due to nutrient deficiency due to over irrigation in aerobic agricultural lands. (Paudyal et. al, 2018) For this reason mineral zinc fertilizers are employed at the rate of 5 kgha−1 Zn approximately but these fertilizers are costly and are not in absorbable form by the plants. (Meena et. al,2018) Recently studies on rhizobacterial zinc solubiliztion showed that the field application of zinc solubilizing bacteria increased the zinc availability of soil and aided in plan growth and increased yield. (Naz et. al) stated that *azetobacter* sp. , *rhizobium* sp. and *azospirillum* sp increased Zn uptake in wheat. (Cakmak et. al, 2017) (Sharma et. al) studied 134 *bacillus sp.* On soya bean and concluded that there are greater concentration of zinc in zinc inoculated crops than that of in inoculated crops. (Aloo et. al, 2022)In wheat, zinc inoculated wheat showed enhance in growth than that of un inoculated plants. (Sharma et. al,2012) *Pesudomus sp.* aid in uptake of zinc has been reported by Goteti et al. (2013*). E. cloacae* showed zinc uptake in sugarcane, wheat by wheat rhizospres , maize by Bacillus, soybean via *B. aryabhattai* and rice by several zinc solubilizing bacteria (Kamran et. al,2017).

3. 4. Iron solubilizing bio-fertilizer

Some bio-fertilizers provide bio-fertilizers via specific metabolism known as siderophores which has higher affinity for iron in low iron containing environment. (Goteti et. al,2013) Fe3 + is formed in microbial siderohores in the membrane of microbes followed by Fe^{3} + is reduction to Fe2+ which is released in the cell via input mechanism. via this process, plants directly assimilate the Fe^{2}+ from siderophore of bacteria from the iron siderophore complexe or via ligand exchange process. Siderophore is a typical example of iron production via rhizobacterial inoculants. (Wang et. al, 2022)

4. Discussion and future of bio-fertilizer

There are about 170 establishments in 24 countries which produce biofertilizers in industrial scale. Research on rhizobial inoculants have been conducted for several years and practically can replace chemical fertilizers Though bio-fertilizers have several advantages but somehow the global market is relatively low, as chemical fertilizers are way more cheaper than that of bio-fertilizers. (Yamazaki et. al, 2021). Bio-fertilizers use is exponentially is increasing in countries like India, China, USA and many others due to tax exemptions, incentives etc. (Bharti et. al,2017). Such approach techniques have popularized in the global bio-fertilizer market, but further approach is still required. With progress in research activities there has been a huge development in native bio-fertilizers and bio-fertilizer market has shown comparative growth. With the increase in requirement of organic food products bio-fertilizer market has shown cooperative growth. . The Plant growth promoting hormones have little to no use in agriculture as the available inoculants are of poor quality or are sufficient literature not available (Paudya et. al l, 2018).

The most extensively used bio-fertilizer is nitrogen fixing biofertilizer. *Rhizobial* sp. inoculants are the most widely used bio-fertilizer potassium, phosphorus ,zinc bio-fertilizers occupies 30% of the bio-fertilizer market altogether. Though the rest of the bio-fertilizer market is increasing nowadays . It is reported India is the fourth largest consumer of potassium biopesticides and China, Brazil ,USA are top consumers of microbial bio-pesticides. *Azospirillium sp.* and *Bacillus sp.* are the most widely used non-rhizobial bio-fertilizers. (Bashan et. al,1998)

Bio-fertilizers increases the number of micro organisms in the soil in much faster rate which increases the nutrient availability of the soil, can be up taken by the plants . The use of biofertilizers leads to separate accumulation of N, P and K in the soil, thereby maintaining soil nutrient balance Sugar cane production increased with the inoculation of PSB bacteria. A microbe with cheap rock phosphate increases the production of crops by about 74% at a very cheaper price. With the use of organic fertilizer the net earrings are Rs. 1,88,100 while it was Rs 1,54,350 with the use of chemical fertilizers (Biofertilizers market. (n. d.). , 2023). Thus a favorable expenditure to profit ratio should encourage frmers towards using biofertilizers . Due to the ecofriendly nature of biofertilizers it can be used for a long period of time and the soil fertility won't be affected. Crop yield can be increased by 10-40% with the use of biofertilizers (Adesemoye et. al, 2013)

Uses of bio-fertilizers are gaining momentum quickly. Microbial bio-fertilizers are already in use in many countries but the increasing demand of sustainable food production will further expand the global bio-fertilizer market. With the demand of production of organic crops and agricultural products, protection of soil and other factors increased the demand of bio-fertilizers. Bio-pesticide market will grow CAGR of 10. 9% to escalate by 2028 (Rosa et. al, 2022). Various researches are being conducted on the inoculation, identification and use of PGPRs (Vantage Market Research. (2022, April 1)). So it can be expected there with extensive research work there would be development in bio-fertilizer market. Regulatory authorities are also supporting alternative form

of existing bio-fertilizer which is cost effective. Rhizobacteria are chosen based on the function of particular strain but with the development of genetically modified strain bio-fertilizers will be more effective, which will not cause harm to the environment or crops. Bio-fertilizers have shorter shelf life so further research needs to be conducted on increasing the self-life of bio-fertilizers. Micro-encapsulation is a process which is adopted to increase the self-life of bio-fertilizer (Vatsyayan et. al, 2013). Also researches need to be conducted so that inoculants can survive environmental stress, heavy metal stress , cold stress and other unfavorable climatic factors(Jain et al. ,2021)

5. CONCLUSION

Due to continuous irrigation and use of chemical fertilizers soil quality have continuously degraded. This can be achieved with use of microbial biofertilizers. The review is based on use of rhizobacterial biofertilizers and their usefulness in development of sustainable agriculture. Though the use of biofertilizer has been practiced for several decades but their demand in market is low. With time and extensive research biofertilizer market will grow further. Researcher, institutions, and universities can aid in increase in speed in production of biofertilizer at a faster rate. If there are issues regarding acceptance, method-development and acceptability of biofertilizers these points can be clearly addressed as bio-fertilizers aids towards sustainable agriculture.

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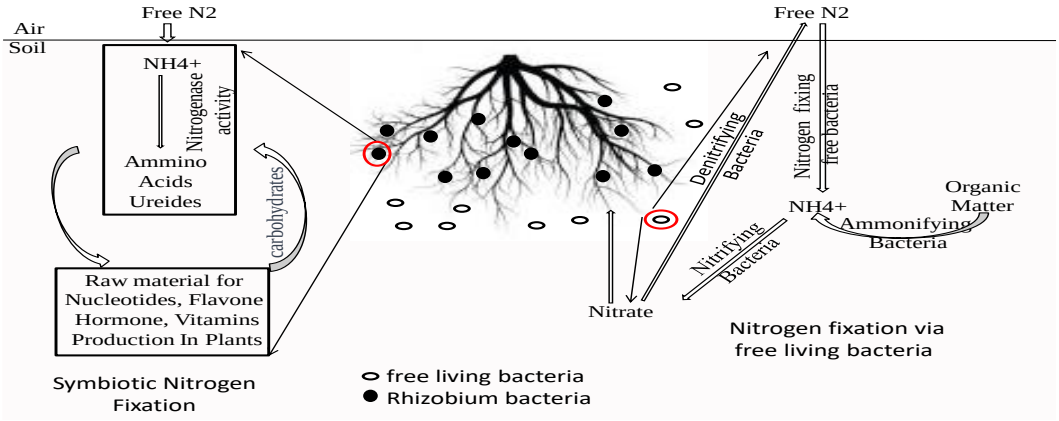

FIGURE:1: Nitrogen fixation mechanism by bacteria

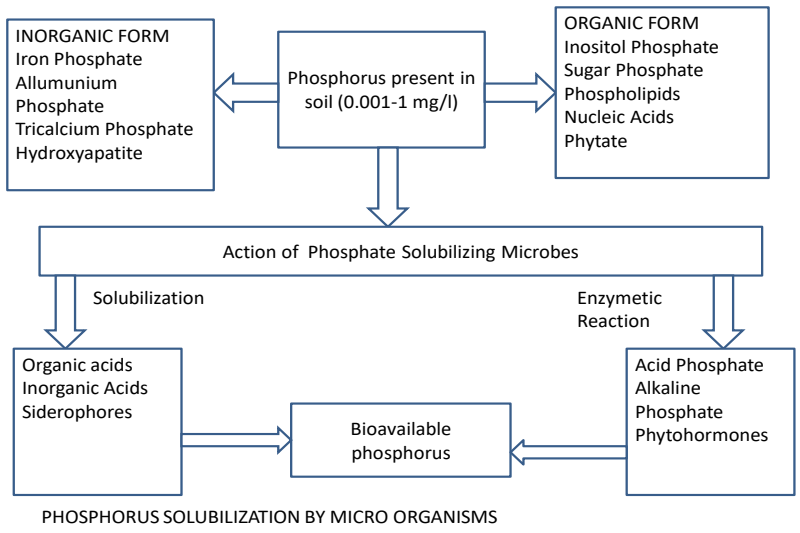

FIGURE 2: Phosphorus solubilizing mechanism by microorganisms