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Review Paper

Assess Effect of Phosphorus Biologic Fertilizer to Improve Crop Production under Warm and Dry Climate Condition

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RESEARCH ARTICLE

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ABSTRACT

Chemical fertilizers have several negative impacts on environment and sustainable agriculture. Therefore, bio fertilizers are recommended in these conditions and growth prompting bacteria uses as a replacement of chemical fertilizers. Symbiotic bacteria have positive role in the production of bio-fertilizers and hormones which play a significant role in regulating plant growth while mixing them with chemical fertilizers as a supplement the level and depth of the roots. This combination also increases the rate of water and nutrient absorbance which raise the rate of growth and photosynthesis. The inoculation of soil or crop with phosphate solubilizing/mineralizing microorganisms is therefore a promising strategy for the improvement of plant absorption of phosphorus and thereby reducing the use of chemical fertilizers that have a negative impact on the environment. This review has shown that phosphate-solubilizing microorganisms (PSM) have tremendous potential as Bio-fertilizers. Mobilizing soil inorganic phosphate and increasing its bioavailability for plant use by harnessing soil PSM promotes sustainable agriculture, improves the fertility of the soil, and hence increases crop productivity. The use of PSM as microbial inoculants is a new horizon for better plant productivity. PSM technology can contribute to low-input farming systems and a cleaner environment. However, there is need to develop PSB technologies specific to various regions and this should be communicated to farmers in a relatively short time. By using phosphate solubilizing microorganisms in crop root zone and soil, the capability of phosphate availability through insoluble phosphate resources will increase and the efficiency of phosphate fertilizers such as superphosphate will improve. Biological phosphorus fertilizers are good substitutes for phosphate chemical fertilizers. They contain two phosphate solubilizing bacteria which dissolve the soil phosphorus using two mechanisms of organic acid and phosphatase acid secretion.

KEYWORDS: *Microorganism, Nutrition, Organic farming, Symbiotic bacteria, Yield.*

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1. BACKGROUND

Fertilizer management is one of the most important factors in successful cultivation of crops affecting yield quality and quantity (Tahmasbi *et al.,* 2011). A great attention has recently directed towards the application of bio-organic farming to avoid the heavy use of agrochemicals that result in enormous environmental troubles (Abd El-Ghany, 2007). Chemical fertilizers have several negative impacts on environment and sustainable agriculture. Therefore, bio fertilizers are recommended in these conditions and growth prompting bacteria uses as a replacement of chemical fertilizers (Wu *et al*., 2005). Chemical fertilizers quickly perk up the development and yield of crops and are hence gaining fame around the world. Conversely, extensive use of such fertilizers causes serious ecological problems. Nitrate leaching and contamination of ground water are due to increased exploitation of fertilizers. Inorganic fertilizers like calcium nitrate, ammonium chloride, and sodium nitrate produce greenhouse gases that results in pollution. Elevated levels of greenhouse gases and heavy metal uptake by plants are major causes of environmental damage. Eutrophication of freshwater is also due to chemical fertilizers. Furthermore, chemical fertilizers can eradicate the advantageous microbial or insect community of the soil (Liu and Golden 2002). Organic farming has emerged as an important priority area globally in view of the growing demand for safe and healthy food and long term sustainability and concerns on environmental pollution associated with indiscriminate use of agrochemicals. Though the use of chemical inputs in agriculture is inevitable to meet growing demand for food in world, there are opportunities in selected crops and niche areas where organic production can be encouraged to tape the domestic export market (Venkatash-Warlu, 2008). Compare organic fertilizer and chemical fertilizer was mentioned in table 1 and figure 1. (Unknown A).

Table 1. Compare organic fertilizer and chemical fertilizer

Parameter	Organic	Inorganic / Synthetic
Soil Health	Helps by improving soil texture and structure, which increase water holding capacity and beneficial microbial activities	Known to deteriorate soil health in long run. Leads to pollution.
Nutrient Content	Nitrogen and Phosphorus content is often substantially lower. Nutrient content also vary with type of feedstock.	High or configured nutrient content.
Release of Nutrients	They need to be broken down by soil organisms in order for their nutrients to be released and takes time. Because they work slowly, nothing is wasted. Slow and steady	Faster and immediate, but nutrients are vulnerable to run off, which is potential hazard for water bodies.
Volume and Transportation	Requires high volume, thus ineffective cost of transportation. But use of locally available sources with enrichment is perfectly reasonable if its use is consistent with the production strategy.	Less volume compared to Organic fertilizers creates a toxic concentration of salts if over-applied.
Nutrient quantity	Difficult to have control as nutrient quantity varies with feedstock	Easy to manage the quantity
Output	Healthy and sustainable food for population	Known to contain toxic chemicals

Soil microorganisms enhance plant nutrient acquisition. They are involved in a wide range of biological processes including the transformation of insoluble soil nutrients (Babalola and Glick, 2012). Some are capable of solubilizing and mineralizing insoluble soil phosphorus for the growth of plants. Apart from chemical fertilization, microbial P-solubilization and mineralization is the only possible way to increase plant available phosphorus. In the natural environment numerous microorganisms in the soil and rhizosphere are effective at releasing phosphorus from total soil phosphorus through solubilization and mineralization (Bhattacharyya and Jha, 2012).

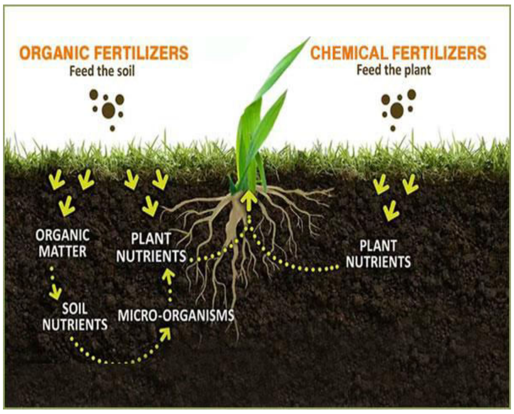

Fig. 1. Compare fertilizer and biofertilizer for feed soil and crop.

Biofertilizers aid plants in accessing the nutrient present in its surroundings. The microbes frequently employed as the biofertilizers include *Rhizobium*, *Azotobacter*, *Anbaena* (nitrogen fixers), *Pseudomonas putida*, mycorrhizal fungi, etc. Likewise, phytohormone/auxin-producing bacteria could also be utilized as biofertilizers (Somasegaran and Springer 1994). These microbes enhance growth and development in plants. The grievance from agriculturalists regarding the effectiveness of biofertilizer is their improper storage and the larger time period between field application and production (Youssef and Eissa 2014). This restricts their employment due to compatibility and constancy issues under diverse soil environments. For this reason, improved shelf life is the basis for the popularization of biofertilizers (Adesemoye and Kloepper, 2009). This group of microorganisms are referred to as Phosphorus Solubilizing Microorganisms (PSM). Many species of soil fungi and bacteria are able to solubilize phosphorus in vitro and some of them can mobilize phosphorus in plants. PSM increases the bioavailability of soil insoluble phosphorus for plant use (Zhu *et al*., 2011). They solubilize insoluble inorganic (Mineral) phosphorus and mineralize insoluble organic phosphorus (Sharma *et al*., 2013). The salt-tolerant or halophilic soil microorganisms that also exhibit the ability to solubilize insoluble phosphorus facilitate the development of saline-alkali soil-based agriculture (Zhu *et al*., 2011). Performance of biofertilizer in improve growth and developments of crop production was mentioned in figure 2. Symbiotic bacteria have positive role in the production of bio-fertilizers and hormones which play a significant role in regulating plant growth while mixing them with chemical fertilizers as a supplement the level and depth of the roots. This combination also increases the rate of water and nutrient absorbance which raise the rate of growth and photosynthesis (Nouraki *et al*. 2016). Beyranvand *et al*. (2013) suggested that effect of nitrogen and phosphate bio-fertilizers were evaluated the positively, there were an increase in plant height, ear weight, number of grain per cob, grain yield and biomass yield.

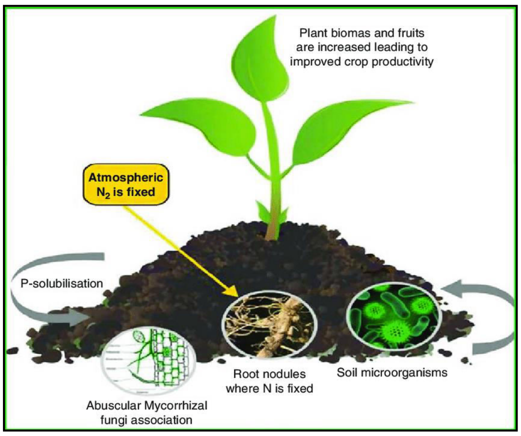

Fig. 2. Biofertilizer technology utilizes plant-microbe interactions in influencing plant growth and development (Rohaya *et al*., 2020).

Kazemi *et al*. (2005) investigated the effect of seeds inoculation with growth promoting bacteria on yield and yield components of two soybean cultivars and reported that inoculation significantly increased number of pod per plant, number of grain per plant, 1000-grain weight and grain yield of soybean. Consumption of phosphate fertilizers in soil supplies the need of crops to phosphorus. However, the problem of such fertilizers is their fixation with soil complex which makes about two-thirds of them unusable for plants (Yilmaz, 2008). Zhang *et al*. (2020) to help minimize the negative impact of chemical fertilizers on the environment, recycle nitrogen and phosphorus nutrients of anaerobic digestate and reduce loss of nutrients via leaching, an eco-friendly slow-release fertilizer was prepared through recovery of nitrogen and phosphorus nutrition from digestate using superabsorbent fibers extracted from soybean curd residue as an adsorbent reported The successful incorporation of N and P into the fiber composite-based adsorbent via adsorption was confirmed by results of these analyses. The prepared fertilizer showed a relatively high N content (3.65 wt%) and a limited P content (0.14 wt%). Also, the swelling capacity as well as water retention capability of the obtained fiber composite-based adsorbent were evaluated. The release behavior of N and P from impregnated fiber composites was examined and was found to be partially in good accordance with the standard of the Committee of European Normalization, showing good slow-release and water-retention properties. Furthermore, in order to assess the fertilizer quality of the prepared materials, the effects of different fertilizers (commercially available fertilizer and prepared slow-release fertilizer) on tomato plant growth and soil microbial communities were investigated. The obtained results demonstrated the potential of fiber composite-based slow-release fertilizer system for recycling N and P nutrition from digestate, improving the effectiveness of fertilizer as well as protecting the environment (Fig .3). Studies have shown that long-term use of fertilizers reduces crop yields. This decrease is due to the acidification of the soil, the reduction of biological activity of the soil and the inappropriate physical properties of the soil (Alexandratos, 2003). Inoculation with Azospirillum and Azotobacter increases the absorption of K, NO_3^-, H_2PO_4, so the root to stem ratio seems to increase. This makes the plant better deployed in the soil and access to limited resources of water and essential nutrients.

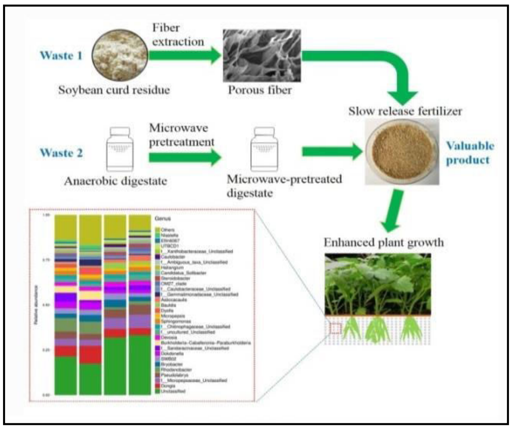

Fig.3. Effect of fertilizer on soil microbial communities

Increasing the absorption of ions by inoculation can play an important role in increasing leaf growth. Also, the release of various phytohormones, such as auxin, cytokinin, gibberellin, and unknown compounds by strains of these bacteria, increase the cell proliferation and cell division, thus increasing the leaf area index can be justified (Yazdani *et al.,* 2009). Fig. 4. depicts various pathways for processing and administering P-based fertilizers to soils and directly to plants as foliar treatments. In spite of the considerable addition of phosphorus to soil, the amount available for plant is usually low. Phosphate dissolving bacteria and soil microorganisms can play an important role in improving plant growth and phosphate uptake efficiency by releasing phosphorus from rock or tri-calcium phosphate. Many researchers showed positive effect of phosphorus fertilization on faba bean (El-Gizawy and Mehasen, 2009). By using phosphate solubilizing microorganisms in crop root zone and soil, the capability of phosphate availability through insoluble phosphate resources will increase and the efficiency of phosphate fertilizers such as superphosphate will improve (Gad *et al.*, 2012). Biological phosphorus fertilizers are good substitutes for phosphate chemical fertilizers. They contain two phosphate solubilizing bacteria which dissolve the soil phosphorus using two mechanisms of organic acid and phosphatase acid secretion (Fedotova *et al.*, 2009). Hamed (2003) showed that consumption of phosphate bio-fertilizer in maize, soybean, and wheat revealed that phosphate biological fertilizer significantly increased the yield. Jadhav *et al.* (1998) observed increasing to 68.4 percent dry weight of corn plants by using phosphate solubilizing bacteria. Abd-Alrahman Rehab *et al.* (2002) stated that use of phosphorus bio-fertilizer in wheat, compared with chemical fertilizers, led to reduction of chemical fertilizer consumption, increase of product, uniformity of the farm, thickness of stems, increase of spikes length, plant resistance to diseases and frost, increase of tillering and ultimately decrease of environmental damage. Phosphorus is essential for helping plants to build healthy root system, but its availability in the soil is highly affected by soil pH and temperature (Fig. 5) (Unknown B). Plants need nutrients to grow which they absorb from the soil via the plant's root system. Fertilizers provide the major nutrients (nitrogen, phosphorus and potassium and important secondary elements) that plants need (Fig. 6) (Unknown B). Phosphate biofertilizers play an important role in improving the P acquisition efficiency (PAE) of plants growing in P-deficient agricultural soils (Arif *et al.*, 2017).

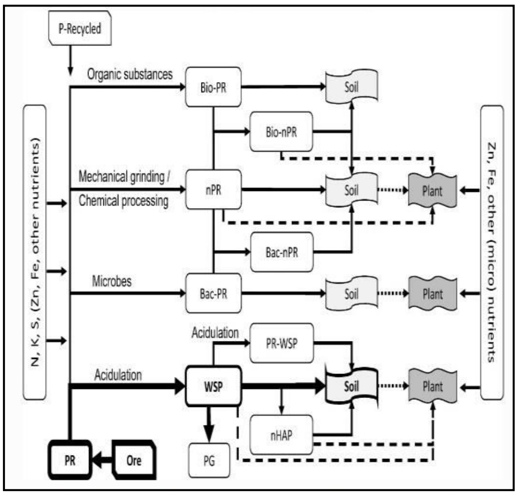

Fig .4. Overview of pathways for P-based fertilizer production and modes of application (the conventional path of production and application are in bold letters and thick lines; continuous lines for processing and soil application; dotted lines indicate uptake from soils by plants; dashed lines indicate foliar application that bypasses the soil. PR= phosphate rock, PG = phosphogypsum, WSP = water soluble P, nHAP = nano hydroxyapatite, PR-WSP = phosphate rock water aoluble P mixtures, Bac = microbial, Bio = organic substances, nPR = nano-size phosphate rock (Bindraban *et al*., 2020).

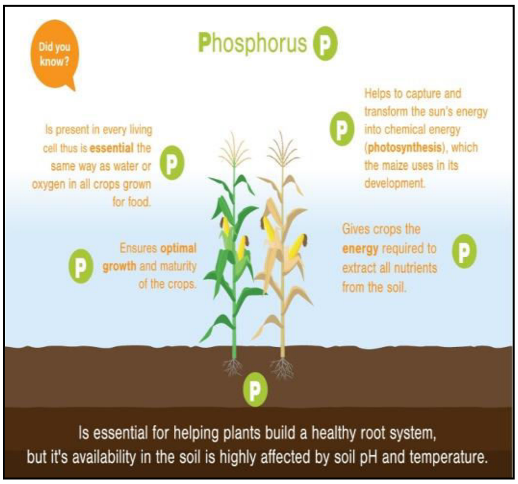

Fig.5. Role of phosphorus in crop

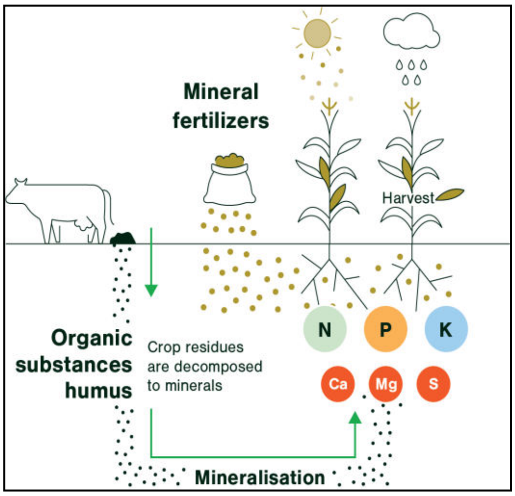

Fig.6. Compare mineral fertilizer and organic matter in crop production

2. OBJECTIVES

Current research was carried out to assess the role of phosphorus biological fertilizer to increase effective traits on cereal yield.

3. EVIDENCE ACQUISITION

Current research was conducted according evaluate results of valid researcher.

4. RESULT AND DISCUSSION

Qing-Fang *et al.* (2020) reported combination of organic and inorganic fertilization maintained high rice yield, and also produced a more complex and stable phosphate mobilizing bacterial community, which contributed to phosphatase activities more than their gene abundances in the model analysis. Compared with the conventional mineral fertilization, organic-inorganic fertilization with the reduced P input slightly increased *pqqC* gene abundance while significantly enhanced the abundance of *phoD*-harboring bacteria, especially the genera *Bradyrhizobium* and *Methylo-*

bacterium known as potential organic P mineralizers which can maintain high rice production. Moreover, the increased pH was the most impactful factor for the *phoD*- and *pqqC*-harboring bacterial communities, by promoting microbial P turnover and greatly increasing bioavailable P pools (H_2O-Pi and $NaHCO_3$-Pi, NaOH-Pi) in this P-deficient paddy soil. Hence, our study demonstrated that the partial replacement of mineral P with organic manure could reshape the inorganic phosphate solubilizing and alkaline phosphomonoesterase encoding bacterial communities towards more resilient and effective to the high P utilization and productivity over intense cultivation, providing insights into the potential of soil microbes in the efficient management of agricultural P fertilization (Fig.7).

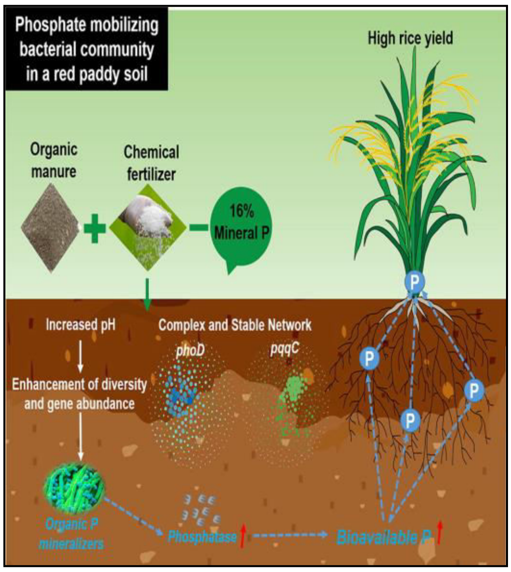

Fig. 7. Soil phosphorus cycle. This figure illustrates the sources of phosphorous inputs in the soil, pathways through which phosphorus becomes available/ unavailable for plant uptake, and phosphorus outputs/ loss pathways.

For example, inoculation of P biofertilizers, Pseudomonas (rhizosphere P solubilizer), and Bacillus (endophyte P solubilizer) increased the P-efficiency (PE) index by 29.5% and 18.7% in two wheat cultivars (Marvdasht and Roshan, respectively) grown under greenhouse conditions (Emami *et al*., 2020). The co-inoculation of rhizospheric bacteria with endophytic bacteria increased the PAE of wheat cultivars relative to inoculation with single bacterial culture or un-inoculated plants. Moreover, the rhizospheric and endophytic bacterial formulations applied alone or in consortium synergistically improved the root and shoot dry matter, plant height, grain yield, length, surface area, and volume of roots of the two cultivars. A notable effect was for coculture application suggesting that the PGPR acted additively with plant growth-promoting endophytes. A similar increase in P uptake and grain yield of wheat due to inoculation with P-solubilizing Pseudomonas and Bacillus species has been reported (Walpola and Yoon, 2012). Saleh *et al.* (2015) inoculation of *Pseudomonas striata* (P.S.B.) + V.A.M. fungi + *Azotobacter* recorded significantly higher chlorophyll content in leaf, as compared to PSB + *Azotobacter* and V.A.M + *Azotobacter* inoculation. Zhang *et al.* (2014) reported that adding small amounts of inorganic phosphorus to the rhizosphere could drive phytic acid mineralization by bacteria and thereby improve plant phosphorus nutrition. Lime and compost, used as a soil improver, also had positive effects on phosphate solubilizers. Phosphorus Solubilizing Bacteria population richness and diversity, according to Azziz *et al.* (2012), were more abundant and diverse following crop rotation. Soil rich in organic matter will favor microbial growth and therefore favors microbial phosphorus solubilisation. Soil pH values between 6 and 7.5 are best for P-availability, this is because at pH values below 5.5 and between 7.5 and 8.5 limits P from becoming fixed by aluminum, iron, or calcium, and hence, not being available for plant use. A negative correlation was observed between the amount of phosphate solubilized by B. cepacia SCAUK0330 and the pH drop that is associated with this process. The pH drop leads to an increase in phosphate solubilization. At pH 3.12, 452 $mg.mL^{-1}$ of phosphorus was solubilized, and when 154 $mg.m.L^{-1}$ of P was solubilized the pH value was 4.95 (Zhao *et al*., 2014). Research has also shown that microbial phosphate solubilization largely depends on the kinds of metabolite produced and its rate of release (Zhu *et al*., 2011). For better utilization of the phosphorus accumulated in soils, PSMs that are capable of transforming insoluble phosphorus to soluble forms can function as biofertilizers. This increases the soluble phosphorus content (Zhu *et al*., 2012). The use of phosphorus biofertilizers is a promising approach to improving food production through enhancing agricultural yield as it is better to use an environmentally friendly approach (that is, a paradigm that emphasizes the use of biological soil amendments in place of chemicals) to solve the problems of infertile soil (Babalola and Glick, 2012). Fig.8 shows the effect of inoculation with a PSM (*Pseudomonas sp*.) on a maize plant. The growth of maize that was inoculated with PSM was improved compared to the control that was not inoculated. PSM act as biofertilizers by making otherwise unavailable P available to growing plants. Phosphorus solubilizing bacteria may also aid the growth of plants by stimulating the efficiency of biological nitrogen fixation, synthesizing phytohormones and enhancing the availability of some trace elements such as zinc and iron (Wani *et al*., 2007).

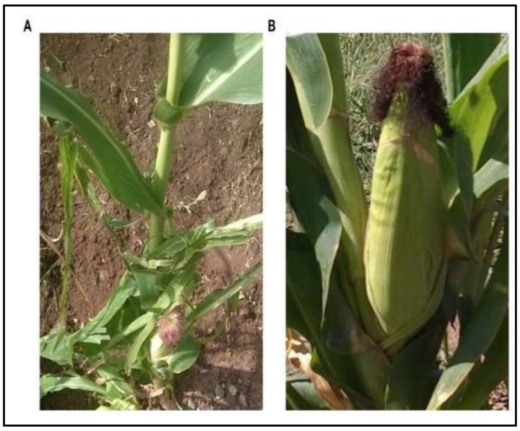

Fig. 8. Biofertilizer effect of Pseudomonas sp. on maize. (A) Maize not inoculated with a PSM. (B) Maize inoculated with a PSM Pseudomonas sp.

The studies by Mattos *et al.* (2020) revealed that the inoculation effect of PSB (Bacillus strains) on two sorghum (*Sorghum bicolor*) genotypes with different P responses (BR007-efficient and responsive and SC283-efficient and nonresponsive) grown in soil fertilized with RP and triple superphosphate (TSP) was variable. The results showed that the inoculation response was influenced by sorghum genotype, P source and microbial strain. Inoculation of the genotype BR007 significantly increased root biomass and P content under greenhouse while yield and grain P content were found maximum in the field but no effect was observed for genotype SC283. The application of PSB in combination with RP is therefore, a promising alternative to reduce the use of synthetic fertilizers in agro-ecosystems contributing toward the sustainable sorghum production. Barley plants bacterized with P-solubilizing Enterobacter ludwigii and A. brasilense and grown in open field conditions showed a beneficial effect on the dry weight, P assimilation and yield, especially in E. ludwigii-inoculated plants (Ribaudo *et al*., 2020). The plant P estimated at 60 DAS was 38%–56% greater in *E. ludwigii*-inoculated barley plants relative to non-inoculated plants. The application of bacteria in the absence of fertilizer caused a substantial increase in biological yields (3795 $kg.ha^{-1}$) and 1000-seed weight which was comparable to those recorded for the maximum dose of chemical fertilizer. The inoculation of bacteria with the intermediate fertilizer dose significantly increased the grain size. These results clearly demonstrated a promising increase in P due to *E. ludwigii* inoculation. In a field experiment, the P solubilizers *Kosakonia radicincitans* (PSB1) and *B. subtilis* (PSB2) applied with DAP and RP had variable impact on sugarcane (Pyone, 2021). The ability to withstand high metal concentrations by P solubilizers is advantageous in agriculture and serves as a good option to develop bioinoculants for augmenting crop production in contaminated soils (Rizvi *et al*., 2020). The ability to withstand stress could be chromosomal or plasmid mediated. The metal-tolerant phosphate solubilizing bacteria, for example, Pseudomonas putida Ws3, have been reported to promote the growth of maize through the synthesis of IAA while decreasing the metal concentration in plants exhibiting largest effects on metal accumulation in roots and shoots (Marzban *et al*., 2016). A detailed description of importance of P to crops, mechanism of P solubilization, and how different active biomolecules secreted by phosphate biofertilizers augment crop production in different agrosystems is given in Fig. 9.

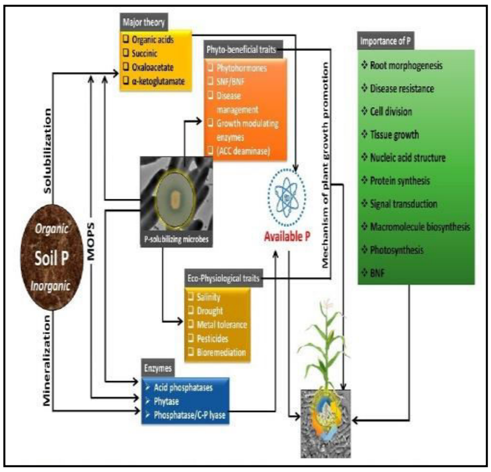

Fig. 9. Description of the importance of phosphate biofertilizers in augmenting crop production in different agrosystems. MOPS, mechanism of phosphate solubilization; SNF, symbiotic nitrogen fixation; BNF, biological nitrogen fixation.

5. CONCLUSION

This review has shown that phosphate-solubilizing microorganisms (PSM) have tremendous potential as Bio-fertilizers. Mobilizing soil inorganic phosphate and increasing its bioavailability for plant use by harnessing soil

PSM promotes sustainable agriculture, improves the fertility of the soil, and hence increases crop productivity. The use of PSM as microbial inoculants is a new horizon for better plant productivity. PSM technology can contribute to low-input farming systems and a cleaner environment. However, there is need to develop PSB technologies specific to various regions and this should be communicated to farmers in a relatively short time.

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FOOTNOTES

CONFLICT OF INTEREST: Author declared no conflict of interest.

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