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Importance of Azotobacter and P-Solubilizer Microorganisms in Agriculture

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Abstract
Application of efficient Azotobacter and phosphate-solubilizing microbial inoculants in agriculture opens up new insight for future crop productivity besides sustaining soil health. Development in the use of phosphate solubilizing bio-inoculants are one of the recently promising options for meeting agricultural challenges imposed by the still growing demand for food. Soil management strategies today are mainly dependent on inorganic chemical-based fertilizers, which cause a serious threat to human health and the environment. Bio-fertilizer has been identified as an alternative for increasing soil fertility and crop production in sustainable farming. The exploitation of beneficial microbes as bio-fertilizers has become of paramount importance in agricultural sector due to their potential role in food safety and sustainable crop production. Microorganisms that are commonly used as bio-fertilizer components include; nitrogen fixers (Nfixer), potassium and phosphorus solubilizers, growth promoting rhizobacteria (PGPRs), endo and ecto-mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. The use of bio-fertilizers leads to improved nutrients and water uptake, plant growth and plant tolerance to abiotic and biotic factors. These potential biological fertilizers would play a key role in productivity and sustainability of soil and also in protecting the environment as eco-friendly and cost effective inputs for the farmers. So this review would provide broad spectrum information for the various roles of Azotobacter and phosphate Solubilizer and its impact in sustainable agriculture.
Keywords: Azotobacter, P Solubilizer, Bio-fertilizer, Microorganisms, Importance
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1. Introduction

Improving soil fertility is one of the most common practices in agricultural productivity for all crops. Nowadays the practice of boosting yield by inorganic fertilizer is conventional but the impact on long-term soil health and productivity is not promising, so using environmentally friendly soil microbes is gaining momentum. Moreover, intensive cultivation due to population growth has seriously depleted the macro and micronutrients in our soil (Getachew A. and Tilahun A., 2017). A part of rhizospheric bacteria is considered plant growth-promoting bacteria (PGPB) due to their positive effect on plant growth and development. Plant growth promoting bacteria based on their metabolic activity can be grouped into biofertilizers, phytostimulants, or biopesticides. These efficient bacteria due to various direct or indirect effects exerted on plants have a crucial role in agricultural sustainability. Recently were reported diverse genera as PGPB like *Acetobacter, Achromobacter, Arthrobacter, Azoarcus, Azospirillum, Azotobacter, Bacillus, Burkholderia, Frankia, Phyllobacterium, Pseudomonas, Serratia, and Rhizobium* (Ashok K and Vijay SM, 2019).

In Ethiopia, only a few studies on tef root-associated microorganisms have been undertaken. Accordingly, the effects of PGPR on growth and yield of tef were evaluated by (Delelegn W and Fassil A, 2011). Microbial inoculum of two Bacillus species (*Bacillus megatherium and Bacillus mucilaginous*) improved the growth of the plant as well as the nutritional assimilation of the plant (Saida A et al., 2015). There are around six species in the genus Azotobacter some of which are motile by means of peritrichous flagella, others are not. These bacteria utilize atmospheric nitrogen gas for their cell protein synthesis. This cell protein is then mineralized in soil after the death of *Azotobacter* cells thereby contributing towards the nitrogen availability of the crop plants. Azotobacter spp. is sensitive to acidic pH, high salts, and temperature (Tchan and New, 1989). *Azotobacter* has beneficial effects on crop growth and yield through, biosynthesis of biologically active substances, stimulation of rhizospheric microbes, producing phyopathogenic inhibitors (Chen, 2006; Lenart, 2012). Modification of nutrient uptake and ultimately boosting biological nitrogen fixation (Somers et al., 2004). Inoculation of plants with these PGPR is accompanied by a significant increase in productivity that results from two main beneficial mechanisms: stimulation of plant growth and protection of plants against soil borne diseases (Saida A et al., 2015) and could allow growers to reduce the use of synthetic fertilizers and increase the sustainability of crop production. Similarly, microbial products are considered safer, self–replicating, target specific, which is regarded as major component of integrated nutrient management from soil sustainability perspective. To achieve maximum benefits in terms of fertilizer savings and better growth, the P-solubilization based inoculation technology should be utilized along with appropriate levels of fertilization. However current trends in phosphate

rock scarcity scenario, there has to be a shift towards low reliance on inorganic phosphate and search for locally available agricultural inputs which minimize dependence on inorganic phosphate inputs sustaining agricultural production to feed the world's exponentially growing population (Hungria et al., 2013). Most of these bacteria belong to the genus *Pseudomonas* and *Azotobacter* (Valle et al., 2007), which can producing plant growth promoters, nitrogen-fixing bacteria, and phosphate solubilizers (Loreno et al., 2004). In soil, an extensive range of bacteria, fungi and actinomycetes are able to release soluble P from various forms of insoluble phosphate compounds.

These microorganisms are termed as Phosphate Solubilizing Microorganisms (PSMs) (Chen *et al*., 2006). Most soils in Ethiopian especially Vertisols (heavy black clay soils) are deficient in P when assayed by chemical methods (Tekalign Mamo and Haque, 1987). It is also established that more than 70% of Ethiopian agricultural soils are characterized by P deficiency (Desta Beyene, 1982), which is very severe in acidic soils of southern, southwestern and western regions. In these areas Al3+ and Fe3+ are totally incriminated with P fixation (Tekalign Mamo *et al*., 1988). Given the downside and limited access of most farmers to phosphate fertilizers in Ethiopia it is necessary to screen and incorporate into cropping systems some efficient strains of PSMs that can supply P to plants in a more environmentally-friendly and sustainable manner. In Ethiopia, there are some 12.7 million hectares of Vertisols of which 7.6 million are distributed in the central highlands. They are potentially among the most productive soils, where N and P are the two most important elements which are relatively low in Vertisols (Tekalign Mamo *et al*., 1988).

Phosphorus is one of the major growth-limiting macronutrients required for proper plant growth, particularly in tropical areas, due to its low availability in the soil (Santana et al., 2016). P is essential in every aspect of plant growth and development, from the molecular level to many physiological and biochemical plant activities including photosynthesis (Sharma et al., 2013). ,development of roots, strengthening the stalks and stems, formation of flowers and seeds, crop maturity and quality of crop, energy production, storage and transfer reactions, root growth, cell division and enlargement, N fixation in legumes, resistance to plant diseases (Sharma et al., 2013; Kumar et al., 2018; Khan et al., 2009; Satyaprakash et al., 2017; Walpola and Yoon, 2012). , transformation of sugar to starch, and transporting of the genetic traits (Satyaprakash et al., 2017; Mehrvarz et al., 2008). Adequate P availability is also required for laying down the primordia of plant reproductive parts during the early phases of plant development (Satyaprakash et al., 2017). About 75–90% of the added chemical P fertilizer is precipitated by metalcation complexes and rapidly becomes fixed in soils and has long-term impacts on the environment in terms of eutrophication, soil fertility depletion, and carbon footprint (Sharma et al., 2013). Microorganisms are integral in the natural phosphorus cycle.

The use of phosphate solubilizing microorganisms (PSMs) as bio-fertilizers for agriculture enhancement has been a subject of study for years. 'is review is intended to provide a brief on availability of soil P and diversity of PSM, mechanisms of P solubilization, how PSM induce plant growth, and their possible role as bio-fertilizer in crop production. Modern agriculture lost its sustainability owing to excess use of chemical fertilizers and harmful pesticides further leading to higher cost of cultivation, declined food security and safety, and finally the reduction in soil fertility (Saritha and Prasad Tollamadugu, 2019). Biological nitrogen fixation is a central life supporting process that provides most of the fixed nitrogen needed to sustain life. Animals, including humans, rely on plants to supply a great deal of the energy and nitrogenous compounds required for survival. Plants are likewise dependent upon the availability of nitrogenous compounds produced from atmospheric N2 either commercially or biologically by microbes. In this way, nitrogen fixation assumes significant importance in agriculture because good crop yields depend on an adequate supply of fixed nitrogen by which the biological process contributes about 65% of the total annual yield of fixed nitrogen (Fisher and Newton, 2002). Worldwide, 5.7 billion hectares contain too little available P for sustaining optimal crop production. Suboptimal levels of P can lead to a 5-15% loss in the yield of plants (Hinsinger, 2001).

2. Effect of Azotobacter in Agriculture

The presence of *Azotobacter sp*. in soils has beneficial effects on plants, but the abundance of these bacteria is related to many factors, soil physico–chemical (e.g. organic matter, pH, temperature, soil moisture) and microbiological properties (Kazilkzya, 2009). Its abundance varies as per the depth of the soil profile (Vojinoviv, 1961; Sariv, 1969; Malek et al., 1979; Kalaigandhi et al., 2010). *Azotobacteria* are much more abundant in the rhizosphere of plants than in the surrounding soil and that this abundance depends on the crop species (Sariv and Ragoviv, 1963). These bacteria are already being successfully used in few countries in the developing world and are expected to grow with time (Weekley et al., 2012).

2.1. Seed inoculation with Azotobacter on biomass increments

Seed Inoculated with Azotobacter helps in uptake of N, P along with micronutrients like Fe and Zn, in wheat, these strains can potentially be used to improve wheat nutrition (Rajaee et al., 2007). Seed inoculations of Azotobacter profoundly contribute to increase yield by supplying nitrogen to the crops. Inoculation of seeds with

Azotobacter chroococcum increased carbohydrate and protein content of two corn varieties (Inra210 and Inra260) in greenhouse experiment (Kizilog et al., 2001). There is increment in Maize biomass with the application of manure and Azotobacter (Meshram and Shende, 1982). In nitrogen–deficient sand, seed inoculation increased plant length, dry weight, and nitrogen content in addition to a significant increase in soil nitrogen (Monib et al., 1979). It was found that A.chroococcumat concentration of 108cfu ml–1 increased seed germination of Cucumber (Salhia, 2013). Seeds of wheat (*Triticum aestivum*) were inoculated with 11 bacterial strains of A.chroococcum, Research result showed that all A. chroococcums trains had positive effect on the yield and N concentrations of wheat (Kizilkaya, 2008).

2.2. Impact of Azotobacter in growth substances

Due to nitrogen fixation, Azotobacter produces, Thiomin, Riboflavin, Nicotin, Indol Acetic Acid and Giberalin. When Azotobacter is applied to seeds, seed germination is improved to a considerable extent (Brakel and Hilger, 1965) showed that Azotobacter produced Indol–3–Acetic Acid (IAA) when tryptophan was added to the medium (Hennequin and Blachere, 1966). found only small amounts of IAA in old cultures of Azotobacter to which no tryptophan was added. Bacteria of the genus Azotobacter synthesize auxins, cytokinins, and GA–like substances, and these growth materials are the primary substance controlling the enhanced growth of tomato (Azcom and Barea, 1975). These hormonal substances, which originate from the rhizosphere or root surface, affect the growth of the closely associated higher plants (Eklund, 1970). demonstrated that the presence of Azotobacter chroococcum in the rhizosphere of tomato and cucumber is correlated with increased germination and growth of seedlings (Puertas and Gonzales, 1999). report that dry weight of tomato plants inoculated with Azotobacter chroococcum and grown in phosphate–deficient soil was significantly greater than that of non-inoculated plants. Phytohormones (*auxin, cytokinin, and gibberellin*) can stimulate root development.

3. Impact of chemical fertilizer in Azotobacter for plant growth

Combined application of bio–fertilizer with 50% of chemical fertilizers (N and P) has significant effect in plant growth, plant height, number of branches, fresh and dry weight of safflower in comparison with chemical fertilizers alone. Similarly, application of Azotobacter bio-phosphate and organic fertilizers, with half dose of chemical fertilizers increases the economic yield of safflower (Ojaghloo et al., 2007). Efficiency of Azotobacter found decreased with increased N level (Soleimanzadeh and Gooshchi, 2013). The best combination was recorded with NH4Cl at 0.1g/L whereas, action of copper in Azotobacter found toxic even in very low concentration (Gül, 2003). The population of Azotobacter may suffer due to high amount of nitrates and the acidic environment created because of chemical fertilizer.

3.1. Biochemical effects of Azotobacter

Several strains of Azotobacter are capable of producing amino acids when grown in culture media amended with different carbon and nitrogen sources (Lopez et al., 2005). Substances like amino acid produced by these rhizobacteria are involved in many processes that explain plant– grown promotion. Biochemical analysis of chlorophyll, nitrogen, phosphorous, potassium and protein content was higher in Azotobacter inoculated plants as compared to non–inoculated control plants (Naseri et al., 2013).

3.2. Accessibility of phosphorus in the soil

Phosphorus is a reactive element and does not exist as elemental form in the soil. Phosphorus in the soil solution exists as insoluble inorganic phosphorus and insoluble organic phosphorus (Walpola and Yoon, 2012). Its cycle in the biosphere can be described as “sedimentary,” because there is no interchanging with the atmosphere, and unlike the case for nitrogen, no large atmospheric source can be made biologically available (Walpola and Yoon, 2012; Rodr and Fraga, 1999). Consequently, deficiency of phosphorus severely restricts the growth and yield of crops (Walpola and Yoon, 2012). The phosphorus level in the soil is about 0.05% (Sharma et al., 2013; Walpola and Yoon, 2012). Soil test values are generally much higher, but the greater part of it, about 95 to 99%, is present in the form of insoluble phosphates (Pradhan and Sukla, 2005). The concentration of soluble P in soil solution is usually very low, normally at levels varying from ppb in very poor soils to 1 mg/L in heavily fertilized soils (Sharma et al., 2013; Khan et al., 2009; Walpola and Yoon, 2012; Rodr and Fraga, 1999). Plant cell might take up several P forms, but the greatest part is absorbed in the forms of phosphate anions mainly $HPO4^{2-}$ or $H2PO4^{-}$ depending upon soil pH (Kumar et al., 2018; Satyaprakash et al., 2017; Walpola and Yoon, 2012; Rodr and Fraga, 1999; Mahidi et al., 2011).

P gets immobilized by cations such as $Ca2+$ in calcareous or normal soils to form a complex calcium phosphate ($Ca3(PO4)2$) and with $Al3+$ and $Fe3+$ in acidic soils to form aluminum phosphate (AlPO) and ferrous phosphate (FePO) (Kumar et al., 2018; Satyaprakash et al., 2017). These are insoluble forms and consequently unavailable. These accumulated phosphates in agricultural soils are adequate to maintain maximum crop yields worldwide for about 100 years (Walpola and Yoon, 2012). If it could be mobilized, converted into soluble P

forms using of PSM. A greater concern has, therefore, been made to get an alternative system yet low-priced technology that could supply adequate P to plants.

3.3. Range of phosphate solubilizing microorganisms

Phosphate solubilizing microorganisms (PSMs) are group of beneficial microorganisms capable of hydrolyzing organic and inorganic phosphorus compounds from insoluble compounds. Among these PSMs, strains from bacterial genera (Bacillus, Pseudomonas, and Rhizobium), fungal genera (*Penicillium* and *Aspergillus*), *actinomycetes*, and *arbuscular mycorrhizal* (AM) are notable **(Table 1)**. Soil is a natural basal media for microbial growth. Mostly, one gram of fertile soil contains 101 to 1010 bacteria, and their live weight may exceed 2,000 kg ha−1 (Khan et al., 2009). Among the whole microbial population in soil P, solubilizing bacteria comprise 1–50% and P solubilizing fungi 0.1 to 0.5% of the total respective population (Khan et al., 2009; Walpola and Yoon, 2012; Chen et al., 2006). PSMs are ubiquitous, and their figures differ from soil to soil. Most PSMs were isolated from the rhizosphere of various plants, where they are known to be metabolically more active (Khan et al., 2009; Walpola and Yoon, 2012; Selvi et al., 2017). Apart from those species, symbiotic nitrogenous rhizobia (Khan et al., 2009; Walpola and Yoon, 2012; Rodr and Fraga, 1999). and *nematofungus Arthrobotrys oligospora* (Khan et al., 2009; Walpola and Yoon, 2012; Takur et al., 2014); Duponnis et al., 2006). have also shown phosphate solubilizing activity.

Table 1: Potential P solubilizing microorganisms

Types	PSMs
Bacteria	*Bacillus circulans*
	Bacillus megaterium
	Bacillus polymyxa; B. subtilis
	Bacillus pulvifaciens]
	Bacillus coagulans; B. fusiformis; B. pumilus;
	B. chitinolyticus
	Bacillus sircalmous
	Tiobacillus ferrooxidans
	Pseudomonas canescens
	Pseudomonas putida
	Pseudomonas calcis
	Pseudomonas fluorescens
	Pseudomonas striata
	Pantoea agglomerans
	Rhizobium meliloti
	Rhizobium leguminosarum
	Mesorhizobium mediterraneum
	Aspergillus nNiger
	Aspergillus clavatus
	Aspergillus awamori
	Aspergillus candidus; A. parasiticus; Aspergillus
	fumigatues; A. rugulosus
	Aspergillus flavus
	Aspergillus foetidus; A. nidulans; A. wentii
	Aspergillus terreus
	Aspergillus tubingensis
Fungi	*Aspergillus sydawi; A. ochraceus; A. versicolor*
	Penicillium bilaii
	Penicillium citrinum
	Penicillium digitatum; P. lilacinium; P. balaji;
	P. funicolosum
	Penicillium oxalicum
	Penicillium simplicissimum; P. rubrum
	Arthrobotrys oligospora
	Trichoderma viride
	Aspergillus sydawi; A. ochraceus; A. versicolor
	Penicillium bilaii
	Penicillium citrinum
	Penicillium digitatum; P. lilacinium; P. balaji;
	Acinetobacter rhizosphaerae
Actinomycetes	*Acinetobacter rhizosphaerae*
	Streptomyces albus; S. cyaneus; Streptoverticillium album
	Acinetobacter rhizosphaerae
Cyanobacteria	*Calothrix braunii*

Sources: (Kalayu, 2019)

4. Mechanism of p solubilization

PSMs mineralize soil organic P by the production of phosphatases like phytase (Santana et al., 2016; Kumar et al., 2018; Khan et al., 2009; Asri et al ., 2009; Selvi et al., 2017; Tarafdar et al., 2003; that hydrolyze organic forms of phosphate compounds, thereby releasing inorganic phosphorus that will be immobilized by plants. Alkaline and acid phosphatases use organic phosphate as a substrate to convert it into inorganic form. PSMs apply various approaches to make phosphorus accessible for plants to absorb. These include lowering soil PH, chelation, and mineralization. 5.1. Lowering Soil pH. The principal mechanism for solubilization of soil P is lowering of soil pH by microbial production of organic acids or the release of protons (Kumar et al., 2018; Satyaprakash et al., 2017; Walpola and Yoon, 2012; Rodr and Fraga, 1999; Pradhan and Sukla, 2005; Son et al., 2006; Selvi et al., 2017; Yosefi et al., 2011).

In alkaline soils, phosphate can precipitate to form calcium phosphates, including rock phosphate (fluorapatite and francolite), which are insoluble in soil. Their solubility increases with decreases in soil pH. PSMs increase P availability by producing organic acids that lowers the soil pH (Satyaprakash et al., 2017). Strong positive correlation has been reported between solubilization index and organic acids produced (Alam et al., 2002). PSMs are also known to create acidity by evolution of CO2 (Yousefi et al., 2011). as observed in solubilization of calcium phosphates (Walpola and Yoon, 2012). Production of organic acid coupled with the decrease of the pH by the action of microorganisms resulted in P solubilization (Selvi et al., 2017). The PSMs may release several organic acids **(Table 2**). These organic acids are the products of the microbial metabolism, mostly by oxidative respiration or by fermentation when glucose is used as carbon source (Satyaprakash et al., 2017; Alam et al., 2002). The type and amount of organic acid produced differ with different organisms. Efficiency of solubilization is dependent upon the strength and nature of acids. Moreover, tri- and dicarboxylic acids are more effective as compared to monobasic and aromatic acids, and aliphatic acids are also found to be more effective in phosphate solubilization compared to phenolic, citric, and fumaric acids (Walpola and Yoon, 2012; Mahidi et al.,2011). The common isolates identified so fare are Bacillus *sp., Pseudomonas, Proteus sp., Aspergillus, Azospirillum sp., Penicillium sp., Erwinia herbicola* and Thermotolerant acetic acid (Kumar et al., 2018; Selvi et al., 2017; Sane and Mehta, 2015).

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Table 2: Diversity of organic acid produced by PSMEs.

PSM isolates	Organic acids	References
Bacillus sp.	Citric acid, malic acid, succinic acid, fumaric acid, tartaric acid, gluconic acid	(Selvi et al.,2017)
Pseudomonas	Citric acid, succinic acid, fumaric acid, gluconic acid, 2-ketogluconic acids	(Kumar et al.,2018) (Selvi et al.,2017)
Proteus sp.	Citric acid, succinic acid, fumaric acid, gluconic acid	(Selvi et al.,2017)
Aspergillus	Citric acid, gluconic acid, oxalic acid, succinic acid, malic acid, glycolic acid	(Sane and Mehta,2015)
Azospirillum sp.	Citric acid, succinic acid, fumaric acid, gluconic acid	(Selvi et al.,2017)
Penicillium sp.	Gluconic acid, glycolic acid, succinic acid, malic acid, oxalic acid, citric acid	(Sane andMehta,2015)
Erwinia herbicola	Gluconic acid, 2-ketogluconic acids	(Kumar et al.,2018)
Thermotolerant acetic acid	Acetobacter, Gluconobacter	(Kumar et al.,2018

4.1. Way of plant growth promotion by PSMs

PSMs promote plant growth via generating phytohormones, such as auxins, gibberellins, cytokinins, or polyamides (Santana et al.,2016; Mittal et al., 2008; Yosefi et al., 2011; Vikram and Hamzehzaghani, 2008). Organic acids such as carboxylic, glycolic, malonic, succinic, fumaric, and alpha-ketoglutaric acid that hasten the maturity and thereby enhance the ratio of straw as well as the total yield have also been recognized among phosphate solubilizers. PSMs also promote plant growth indirectly by increasing the accessibility of other trace elements such as siderophore (Santana et al., 2016; Walpola and Yoon, 2012; Rodr and Fraga, 1999; Wani et al., 2007). Besides, the PSMs also facilitate plant growth by promoting the efficiency of nitrogen fixation through bio-inoculation trials (Hajjam and Cherkaoui, 2017). This, production of IAA and GA coupled with phosphate solubilization by *Rhizobium leguminosarum* and *Pseudomonas sp*. (54RB) has been reported (Afzal and Bano, 2008). PSMs also protect plants by avoiding phyto-pathogens, typically owing to the production of antibiotics, hydrogen cyanate (HCN), and antifungal metabolites.

4.2. PSMs use as bio-fertilizer and feature prospect

Phosphorus use efficiency in agricultural lands can be improved through inoculation of PSM. Indications of their contribution in solubilization of inorganic phosphates and mineral phosphates were reported (Asri et al ., 2009; Tarafdar et al., 2003; Khan et al., 2007; Yadav and Verma, 2012). Ghaderi et al., 2008; demonstrated that the rate of P released by Pseudomonas putida, Pseudomonas fluorescens CHAO, and Tabriz Pseudomonas fluorescens was 51, 29, and 62%, respectively. Similarly, the inoculation of Glomus fasciculatum and Azotobacter resulted in significant improvement in uptake of P, K, and N through mulberry leaf as compared to the uninoculated plants (Baquall and Das, 2006). Likewise, improved phosphorus uptake and increased grain yield of wheat were reported following inoculation of phosphate solubilizing Pseudomonas and Bacillus species (Walpola and Yoon, 2012). PSM increases the availability of P without disturbing the biochemical composition of the soil.

This is essentially applicable, where access to chemical fertilizers is limited. PSM can be used for various crops and not host specific. Several studies reported that the use of PSM enhanced growth, yield, and quality in many crops including walnut, apple, maize, rice, mustard, oil palm, aubergine and chili, soybean, wheat, sugar beet, sugarcane, chickpea, peanut and legumes, and potatoes). PSMs have shown to enhance P uptake, the growth, and the yield when applied to crop plants (Pandey et al., 2006; Vikram and Hamzehzaghani, 2008). Adequate supply of P helps in seed formation and early maturation of crops like cereals and legumes (Sharma et al., 2013). It causes early ripening and stimulates young plants to produce deeper and abundant roots (Mehrvarz et al., 2008).

Table 3: Effect of PSM on growth and yield performance of different crops.

P Solublizer Microorganisms (PSMs)	Host plants	References
Azotobacter	Wheat	(Rodr´ıguez and Fraga, 1999)
Azotobacter chroococcum	Wheat	(Tofazzal Islam et al., 2007)
Azospirillum spp.	Maize, sorghum, and wheat	(Rodr´ıguez and Fraga, 1999)
Bacillus	Wheat (*Triticum aestivum L*.)	(Walpola and Yoon, 2012; Rodr´ıguez and Fraga, 1999)
Bacillus	Peanut, potato, sorghum, and wheat	(Rodr´ıguez and Fraga, 1999)
Bacillus circulans and *Cladosporium herbarum*	Wheat	(Tofazzal Islam et al., 2007; Singh and Kapoor, 1999)
Bacillus megaterium and *Azotobacter chroococcum*	Wheat	(Rodr´ıguez and Fraga, 1999)
Pseudomonas	*Zea mays* L.	(Walpola and Yoon, 2012; Bano and Fatima, 2009)
Pseudomonas	Soybean	(Walpola and Yoon, 2012; Son et al., 2006)
Pseudomonas chlororaphis and *putida*	Soybean	(Tofazzal Islam et al., 2007)
Pseudomonas fluorescent	Peanut	(Dey et al., 2004)
Pseudomonas putida and *Pseudomonas fluorescens*	Canola, lettuce, and tomato Potato, radishes, rice, sugar beet, tomato, lettuce,	(Rodr´ıguez and Fraga, 1999)
Pseudomonas putida and *Pseudomonas fluorescens*	apple, citrus, beans, ornamental plants, and wheat	(Rodr´ıguez and Fraga, 1999)
Mesorhizobium mediterraneum	Chickpea and barley	(Peix et al., 2001)

5. Azotobacter and p solublizer isolated in Ethiopia

Isolation and characterization of Azotobacter and p-solublizer microganizems are done by some authors in different crops and soil sources (**Table 4**). Those important microorganisms were isolated from soil and crops (tef, tomato, coffee, fava bean, haricot bean, cabbage).In the other study conducted in Arsi zone , *Azotobacter Sp*. and *Pseudomonas Sp*. were used on yield and yield components of malt barley (*Hordeum Vulgare L*.) (Amare et al 2021).

Table 4: Azotobacter and P Solublizer explorations in Ethiopia

List of Isolates	Source	Location	reference
Pseudomonas spp.	Cofee	Bonga and Yayu	(Muleta et al ., 2013)
Burkholderia spp.			
Bacillus spp.			
Chryseomonas sp.			
Aeromonas spp.			
Acinetobacter sp.			
Vibrio spp.			
Pasteurella sp.			
Alcaligenes sp.			
Chromobacterium sp.			
Agrobacterium sp.			
Stenotrophomonas sp.			
Pseudomonas sp.	Lentil	Ethiopia	(Midekssaet al.,2015)
Burkholderia (B. cepacia)			
Bacillus sp.			
Enterobacter kobei			
Chryseomonas luteola			
Sphingomonas paucimobils			
Agrobacterium radiobacter			
Aeromonas sp.			

List of Isolates	Source	Location	reference
Bacillus sp.	Soil	Mekele, Tigray	(Kibrom et al.,2017)
Pseudomonas sp.	Tef (Eragrostis tef)	Oromiya region	(Zerihun et al.,2019)
Enterobacter cloacae ss disolvens,			
Virgibacillus sediminis,			
Citrobacter amlonaticus,			
Serretia marcescenss marcescens,			
Flavobacterium mizutai,			
Klebsiella oxytoca,			
Chryseobacterium gleum,			
Bacillus ereus (pseudomycoide)			
Aspergillus sp	Tomato, cabbage, sugarcane, f.bean, haricot bean Tomato, cabbage	Jimma Zone	(Eliaset al.,2016)
Penicillium spp	Tomato, cabbage, sugarcane, f.bean, haricot bean Tomato, cabbage		
Fusarium species	Tomato		
Pseudomonas SP.	soil		
Pseudomonas sp	soil	N.Shewa (Amhara)	Keneni et al.,2010

6. Conclusion

Application of efficient Azotobacter and p-Solubilizer microbial has been alternative advantage by enhancing soil fertility and crop productivity for sustainable Agriculture. Exploitation of those beneficial microbes as bio-fertilizers has become of highly importance using in agricultural sector due to their potential role in food safety and sustainable crop productivity. Several sorts of bio-fertilizers being one of the important components of organic farming which plays role in sustaining long term soil fertility and sustainability by fixing atmospheric di-nitrogen (N=N), mobilizing fixed both micro and macro nutrients or conversion of insoluble P into plant available form, there by increases their efficiency and availability. The integration of bio-fertilizers (N-fixers) plays vital role in enhancing soil fertility, yield attributing characters and thereby maximum and higher yield has been reported by many studies. The application of bio-fertilizer in soil enhances soil biota and lower the sole use of chemical fertilizers and also it help in maintaining the quality of produce as well as the environment. These bacteria are already being successfully used in few countries in the developing world and are expected to grow with time.

In Ethiopia soil fertility is diminishing gradually due to soil erosions, loss of nutrition, accumulation of toxic elements, water logging and unbalanced nutrient compensation. Bio-fertilizers are the alternate source to meet the nutrient requirement of crops. Bio-fertilizers, benefiting the crops are *Azotobacter*, *Azosprillium*, *Phosphobacter* and *Rhizobacter* which are very important. The proper application and use of bio-fertilizer will not only have an impact on sustainable agriculture, economic development, which contributes to a sustainable ecosystem and the holistic well-being. *Psdomonas sp, Bacilus sp*, *Aspergillus sp*. *Penicillium spp. Fusarium species* were the common important microorganisms which were isolated from soil and different crops such as tef (*Eragrostistef*) ,tomato, coffee, fava bean, haricot bean, cabbage in Ethiopia.

Finally, Current paper review clearly showed that beneficial Azotobacter and P-Solubilizer Microorganisms are vast impacts for the development of sustainable agricultural product and productivity. Thus, the introduction of beneficial bacteria and fungi in the soil tends to be less aggressive and cause less impact to the environment than chemical fertilizer, which makes it an affordable agronomic imputes and a mechanism to minimize cost of production to farming system. In the future, biological fertilizers are become practicable inputs along with chemical fertilizers, pesticides and artificial growth regulators showed numerous side-effects to sustainable agriculture. Overall, future research should give more emphasis to apply this *Azotobacter* and *p solublizer* using as agricultural imputes.

Conflicts of interest

The author declares no conflict of interest.

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