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Bio-Fertilizer and Constraints to Adoption of Biofertilizer among the Users

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Abstract

The basic goal of agricultural development organizations is to influence farmers to adopt agricultural innovations. The transfer of innovation and knowledge from research unit to farmers will trigger substantial development if farmers agree to adopt it. Organic farming is one of such strategies that not only ensures food safety but also adds to biodiversity of soil. Application of bio-fertilizer to the soil increases the biodiversity which comprises all kinds of useful bacteria and fungi including the arbuscular mycorrhiza fungi called plant growth promoting rhizobacteria and nitrogen fixers. Bio-fertilize means 'live fertilizer' and it was used to include organic fertilizer. Despite the fact that bio-fertilizer technology is a low-cost and ecofriendly technology, many constraints limit its application and implementation among the users; these constraints are technological, infrastructural, financial, environmental, human resources, unawareness and quality. In view of these, this study used available literature to review bio-fertilizer, biochemistry of bio-fertilizer production, types of bio-fertilizes, microorganisms used in bio-fertilizer, the role of bio-fertilizers in promoting plant adaptation to environmental change and the constraints to adoption of bio-fertilizer among the farmers.

Keywords: Bio-Fertilizer; Ecofriendly Technology; Farmers

Abbreviations: AMF: Arbuscular Mycorrhiza Fungi; PGPR: Plant Growth Promoting Rhizobacteria; PSB: Phosphorus Solubilizing Bacteria; VAM: Vesicular Arbuscular Mycorrhiza.

Introduction

Agriculture plays essential roles in meeting the food needs of a growing human population, which has led to an increasing dependence on the use of chemical fertilizers and pesticides for increased productivity [1]. Chemical fertilizers are industrially made substances which are composed of estimated quantities of nitrogen, phosphorus and potassium. The use of chemical fertilizers causes air and ground water pollution as a result of eutrophication of water bodies (Youssef and Eissa, 2014). According to Chun-Li, Shiuan-Yuh and Chiu-Chung [2], though the practice of using chemical fertilizers and pesticides accelerates soil acidification, it also poses the risk of contaminating ground water and the atmosphere. It also weakens the roots of plants thereby making them to be susceptible to unwanted diseases. As a matter of this, attempts have recently been made towards the production of nutrient rich high quality fertilizer such as bio fertilizer to ensure bio-safety. Therefore, bio fertilizer has been identified as an alternative to chemical fertilizer to increase soil fertility and crop production in sustainable farming. These potential biological fertilizers would play the key role in productivity and sustainability of soil and also protect the environment as eco-friendly and cost effective inputs for the farmers [3].

Organic farming is one of such strategies that not only ensures food safety but also adds to biodiversity of soil [4]. The application of bio fertilizer to the soil increases the biodiversity which constitutes all kinds of useful bacteria and fungi including the arbuscular mycorrhiza fungi (AMF) called plant growth promoting rhizobacteria (PGPR) [5] and nitrogen fixers. There are so many microorganisms thriving in the soil, especially in the rhizosphere of plant. The term 'bio fertilizer' means 'live fertilizer' and it was used to include organic fertilizer. According to Khosro and Yousef [3], bio fertilizer may be used to include all organic resources for plant growth which are rendered in available form for plant absorption through microorganisms or plant associations or interactions. A bio-fertilizer is simply a substance which contains living microorganisms which when applied to the soil; a seed or plant surface colonizes the rhizosphere and promotes growth by increasing the supply or availability of nutrients to the host plant [6]. It is a modernized form of organic fertilizer into which beneficial microorganisms have been incorporated [7].

Hari and Perumal [8], are of the view that bio-fertilizer is most commonly referred to as selected strains of beneficial soil microorganisms cultured in the laboratory and packed in suitable carriers. Therefore biofertlizers are those substances that contain micro-organisms' living or cells that increase the nutrients of the host plant when applied to their seeds, plant surfaces or soil by colonizing the rhizospher of the plant. They can be defined as formulations containing either living or latent cells of efficient strains of microorganisms that facilitate the uptake of nutrients from crop plants. They execute this pivotal role through interactions in the plant rhizosphere when applied through seed or soil. Vishal and Abhishek [9] in an attempt to distinguish between bio-fertilizer and organic fertilizer said "bio-fertilizers are microbial inoculants consisting of living cells of microorganisms like bacteria, algae, fungi, alone or a combination which may help in increasing crop productivity. Biological activities are markedly enhanced by microbial interactions in the rhizosphere of plants. Organic fertilizers on the other hand are obtained from animal sources such as animal manure or plant sources like green manure. Microorganisms that are commonly used as bio-fertilizer components are; nitrogen fixers (N-fixer), potassium and phosphorus solubilizes, growth promoting rhizobacteria (PGPRs), endo and ecto mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. These potential biological fertilizers played 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 [10]. Several microorganisms possess functional relationships which constitute holistic and beneficial effects on plant growth [6]. Bio fertilizer is a component that contains living microorganisms that are given into the soil as inoculants to help provide certain nutrients for plants [11]. Bio fertilizers keep the soil environment rich in all kinds of macro and micro nutrients via nitrogen fixation, phosphate and potassium solubilisation or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil [12]. The basic goal of agricultural development organizations is to influence farmers to adopt agricultural innovations. The transfer of innovation and knowledge from research unit to farmers will trigger development if farmers agree to adopt it.

Therefore, the basic role of agricultural extension agent in the transfer of technology is to assist farmers in putting the blue prints or readymade technologies into practice, despite the fact that they may not be appropriate. Therefore, adoption is regarded as a decision to make full use of an innovation or technology as the best course of action available. Adoption of an innovation is the decision made by an individual or group to use an innovation [13]. Despite the fact that bio fertilizer technology is a low-cost and ecofriendly technology, several constraints limit its application and implementation among the users. According to Bio-Fit web: version 1.1.1 / 12.12.2017, [14] these constraints is technological, infrastructural, financial, environmental, human resources, unawareness and quality. In view of these, this study used available literature to review the bio-fertilizer and constraints to adoption of bio fertilizer among users.

Biochemistry of Bio-Fertilizer Production

There are a lot of things that need to be considered for bio-fertilizers production, these include microbe's growth profile, types and optimum conditions of organism and formulation of inoculum. The formulation of inocula, method of application and storage of the products are all critical to the success of the biological product. In general, six steps are used for making bio fertilizer. These are: choosing of active microorganisms, isolation and selection of target microbes, selection of method of propagation and carrier material, phenotype testing, and large scale tests [3]. In the first place, decision must be taken on the active microorganisms to be used. For instance, it must be decided whether to use organic acid bacteria or nitrogen fixer or a combination of some organisms, after which target microbes are isolated. Usually organisms are isolated from plant roots by luring it using a decoy such as placing cool rice underground beneath bamboo plants [3]. The isolated organism will be grown on Petri dishes before it is mass produces on flask. It is also important to choose the right carrier material. If the desire is to produce bio-fertilizer in powder form, then apioca flour or peat are the right carrier materials to use. Selection of propagation method is mainly to find out the optimum growth condition of organism. This can be done by determining growth profile under different parameter and conditions after which the phenotype is tested and selection is made. Finally, the bio-fertilizer is tested on large scale at different environment to analyze its effectiveness and limitations [3]. The production of bio-fertilizer involves three biochemical steps which include the breaking down of complex materials into simpler substances in a process known as anaerobic digestion. (Anaerobic bio-digestion is a process whereby microorganisms breakdown biodegradable materials in the absence of oxygen [15]. In the first stage, complex organic matter is broken down by cellulolytic microorganisms to produce simple molecules such as long chain fatty acids and other substances. In the second stage, the products from stage one are fermented leading to the production of simpler intermediates such as acetic acids, pyruvic acids, carbon dioxide and so on. In the third stage, methanogens act on the products, giving off a mixture of gases known as biogas.

Types of Bio-Fertilizes

Bio-fertilizers are classified into different types based on the type or group of microorganisms they contain. Table1 shows the classification of bio-fertilizers on the bases of the different types of microorganisms used. The different types of bio-fertilizers include: Nitrogen fixing bio-fertilizers, Phosphate solubilizing bio-fertilizer, Phosphate mobilizing bio-fertilizers, Bio-fertilizers for micronutrients and Plant growth promoting Rhizobacteria.

Groups	Examples
	Nitrogen fixing bio-fertilizers
Free-living	Azotobacter, Bejerinkia, Clostridium, Klebsiella, Anabaena, Nostoc
Symbiotic	Rhizobium, Frankia, Anabaena, Azollae
Associative symbiotic	Azospirillum
	Phosphate solubilizing bio-fertilizer
Bacteria	Bacillus megaterium var, Phosphaticum, Bacillus subtilis, Bacillus circulans
Fungi	Penicillum Spp. Aspergillus awamori
	Phosphate mobilizing bio-fertilizers
Arbuscular Mycorrhiza	Glomus Spp., Gigaspora Spp., Acaulospora Spp. Scutellospora Spp. and Sclerocystis Spp.
Ectomycorrhiza	Laccaria Spp. Pisolithus Spp, Boletus Spp. and Amanita Spp.
Ericoid Mycorrhiza	Pezizella ericae
Orchid Mycorrhiza	Rhizoctonia solani
	Bio-fertilizers for micronutrients
Bacillus Spp	Silicate and zinc solubilizers
	Plant growth promoting Rhizobacteria
Pseudomonas	Pseudomonas fluorescens

Source: Ritika and Uptal [16]

Table 1: Different Microorganisms used in Bio-fertilizer Production.

Mechanisms

Nitrogen fixing bio-fertilizers (NFB): Examples include Rhizobium Spp., Azospirillum Spp. and blue-green algae; these work by fixing atmospheric nitrogen and converting them to organic (plant usable) forms in the soil and root nodules of legumes, thereby making them available to plants. Nitrogen fixing bio-fertilizers are crop specific bio-fertilizers [17].

Phosphate solubilizing bio-fertilizer (PSB): Examples include Bacillus Spp., Pseudomona Spp. and Aspergillus Spp. These work by solubilizing the insoluble forms of phosphate in the soil, so that plants can use them. Phosphorus in the soil occurs mostly as insoluble phosphate which cannot be absorbed by plants [18]. However, several soil bacteria and fungi possess the ability to convert these insoluble phosphates to their soluble forms. These organisms accomplish this by secreting organic acids which lower the pH of the soil and cause the dissolution of bound forms of phosphate making them available to plants [18].

Phosphate mobilizing bio-fertilizers (PMB): Examples are Mycorrhiza. They work by scavenging phosphates from soil layers and mobilizing the insoluble phosphorus in the soil to which they are applied. Chang and Yang [19], stated that phosphorus solubilizing bio fertilizer (PSB) sometimes act as phosphate mobilizers. Phosphate mobilizing bio-fertilizers are broad spectrum bio-fertilizers.

Microorganisms used in Bio-Fertilizer

Organisms that are commonly used as bio-fertilizers components include nitrogen fixers (N – fixers), potassium solubilizers (K – solubilizer) phosphorus solubilizer (P – solubilizer) and phosphorus mobilizers (P – mobilizers). They used solely or in combination with of fungi. According to Khosro and Yousef [3], most of the bacteria used in bio-fertilizers have close relationship with plant roots. Rhizobacterium has symbiotic interaction with legume roots, and Rhizobacteria inhabit root surfaces or rhizosphere soil. The phospho-microorganisms mainly bacteria and fungi make insoluble phosphorus available to the plants [18]. Many soil bacteria and few species of fungi have the capacity to covert insoluble phosphate in soil into soluble forms by releasing organic acids. These acids lower the soil pH and bring about the dissolution of bound forms of phosphate [18]. While Rhizobium, blue-green algae, and Azolla are crop specific, bio-inoculants such as Azotobacter, Azospirillum, phosphorus solubilizing bacteria (PSB), and Vesicular *Arbuscular Mycorrhiza* (VAM) were regarded as broad spectrum bio-fertilizers [18]. VAM are fungi that are found associated with majority of agricultural crops and enhanced accumulation of plant nutrients [3, 20].It has been suggested that VAM stimulate plant by physiological effects or by reducing the severity of diseases caused by soil pathogens. Examples of free living nitrogen fixing bacteria are obligate anaerobes Clostridium pasteurinnum obligate aerobes, facultative anaerobes, photosynthetic bacteria Rhodobacter, cyanobacteria (Azotobacter), and some Methanogens. The most commonly used K – solubilizer is Bacillus mucilaginous while P– solubilizers are *Bacillus megaterium, Bacillus circulans, Bacillus subtilis* and *Pseudomonas straita* [18].

The Role of Bio-Fertilizers in Promoting Plant adaptation to Environmental Change

Abiotic and biotic factors are the major constraints that affect the productivity of crops. Many tools of modern science have been widely applied for crop improvement under stress, of which Plant Growth Promoting Rhizobacterias (PGPR) **s**' [5] role as bio-protectant has become of paramount importance in this regard [21]. PGPRs as biological agents proved to be one of the alternatives to chemical agents for providing resistance against various pathogens' attacks. According to Hussain, Mujeeb and Tahir [22], *Rhizobium trifoli* inoculated with *Trifolium alexandrium* showed higher biomass and increased number of nodulation under salinity stress condition. *Pseudomonas aeruginosa* has been shown to withstand biotic and abiotic stress. *Pseudomonas putida* RS-198 enhanced germination rate and several growth parameters including plant height, fresh weight and dry weight of cotton under conditions of alkaline and high salt via increasing the rate of uptake of k^+, Mg^{2+} and Ca^{2+} and by decreasing the absorption of Na^+.

Few strains of Pseudomonas conferred plant tolerance via 2, 4-diacetylphloroglucinol. Mycobacterium phlei provides tolerance to high temperatures and salinity stress. It has been demonstrated by Ansari, Trivedi and Sahoo, [23] that inoculation of plants with *Arbuscular mycorrhiza* fungi also improves plant growth under salt stress. Ansari, Trivedi and Sahoo, [23] also observe that a root endophytic fungus *Piriformospora indica* was found to defend host plant against salt stress. Combination of AM fungi and Nitrogen fixing bacteria help the legume plants in overcoming drought stress. Application of Pseudomonas Spp. to basal plants under water stress improves their anti-oxidant and photosynthetic pigment content. Pseudomonas Spp. was found to have positive effect on the seedling growth and seed germination under water stress [24]. Ruiz-Sanchez, Aroca and Monoz [25] reported that the photosynthetic efficiency and the anti-oxidative response of rice plant subjected to drought stress were found to increase after inoculation of *Arbuscular mycorrhiza*. The beneficial effect of mycorrhizae has also been reported under both the drought and saline conditions.

Apart from acting as growth promoting agents, they can provide resistance against pathogens by producing metabolites [26]. Bacillus subtilis GBO can induce defence related path ways. *Bacillus subtillis* N11 along with mature compost was found to control Fusarium infestation on banana root. However, the exploitation of PGPRs was found to be very significant in managing spotted wilt viruses in tomato, cucumber mosaic, virus of tomato and pepper, and banana bunchy top virus. In some cases, it was observed that along with bacteria, mycorrhizae can also confer resistance against fungi pathogens and inhibit the growth of many root pathogens such as *R. solani* and Pythium Spp.

Constraints to Adoption of Bio-Fertilizer

The quality of bio-fertilizers demands not only intensive study of the microbial characteristics, but also explanation of the precautions and limitations of their use at laboratory, at levels of production as and field level as well. Bio-fertilizers offer a wide range of opportunities for the development of better agro-practices due to the advantages and benefits provided for the soil, crops and farmers. Despite these, there are limitations of these practices that are clearly recognized. These limitations demand feasibility studies to be carried out to find better solutions for each particular case in agricultural activities. According to **Bio-Fit web**: version 1.1.1 / 12.12.2017 [14] some of the major constraints are as follows:

Lack of regulatory acts and facilities for testing the samples: Further research on bio-fertilization should be based on identifying the options available to tackle the issues and offer valid frameworks for development of environmentally friendly practices around the world that allows improvements on the efficiency and consequent supply of product for the industry in the global economies. However, technical tests should be carried out to verify their safety at global scale. Current research of the use of bio-fertilizers in various regions of the world is necessary to obtain a framework that facilitates the development of future investigations in the agricultural sector to promote the reduction of environmental impacts associated with the continuous use of chemical fertilization.

Inadequate popularization of bio-fertilizers and low level of farmer acceptance: In spite of having various potential activities, bio-fertilizers have not yet gained popularity among farmers for proper adoption. There are various factors affecting the adoption of bio-fertilizers by farmers. Farmers are not aware of bio-fertilizers' usefulness in increasing crop yields sustainably. Their lack of awareness about the concentration, time and method of bio-fertilizer application; about the efficacy of bio-fertilizers compared to their familiarity with the use of conventional and tested inorganic fertilizers is a serious constraint of their wide-scale application. Knowing the different constraints faced by farmers in the use of bio-fertilizers, the extent of adoption of bio-fertilizers can be increased by tackling these issues and problems.

Lack of knowledge and skills for correct application of bio-fertilizers: Entrepreneurs lack knowledge and skills for correct application of bio-fertilizers and have limited capacity to support considerable marketing strategies about this. In order to promote sustainable agriculture, both central and local government authorities have to support extensive extension education on skills and application of bio-fertilizers among farmers. Based on this, emphasis in attaining higher yield and better quality crops is being given in several directions: the production of inoculants; extension programmers for the farmers to know how to apply inoculants; and demonstration and awareness programmers to show farmers the benefits of inoculated crops.

Possible risks for the safety of consumers and the physicochemical and biological stability of soils: High contents of ammonia can burn the foliage and roots of plants; the presence of manure could increase the amount of weed flora. The presence of heavy metals such as mercury, chromium and lead brings a threat due to their carcinogenic potential and their capability of bio-accumulation and bio-magnification in the food chain. Owing to this reason, the use of manure to fertilize soils should be well assessed.

Reduction in the population of bacteria under certain climate conditions and influence of surrounding micro flora and fauna: on application of bio-fertilizers to seeds, roots or soil, mobilizes the availability of nutrients through their biological activity and building up the micro flora in particular and in turn the soil health in general. Their bio-efficacy is dependent on many biotic and abiotic factors of which unfavorable climate conditions such as changes in temperature and humidity can cause a decline in the bacterial populations. Similar negative effects on bacterial quantity can be imposed by the surrounding micro flora and fauna, which compete with the introduced beneficial microorganisms for nutrients and other vital factors in the micro-ecological niches. Antagonistic microorganisms already present in the soil compete with microbial inoculants and often do not allow their effective establishment by out competing the inoculated population.

Requirements for application: Extensive and long-term application may result in accumulation of salts, nutrients and heavy metals that could cause adverse effects on plant growth, development of soil organisms, water quality and human health. Excessive application can generate extreme levels of nitrogen, ammonia and salts that could lead to significant reduction of plant growth and problems for farmers and the soil. Large volumes are required for land application due to low contents of nutrients, in comparison with chemical fertilizers, because main macronutrients may not be available in sufficient quantities for growth and development of plants. Also, there could be some nutritional deficiencies caused by the low transfer of micro- and macro-nutrients. Thus, the implementation of bio fertilization techniques requires monitoring of environmental variables involved in metabolic processes, acquisition of biological inputs, capital investment, time and trained personnel.

Conclusion

Development of an innovation using the tool of molecular biotechnology can enhance the biological pathways of production of phyto-hormones if ascertained and transferred to the useful plant growth promoting rhizobacteria. This technology is bound to provide relief from environmental stresses. However, lack of good knowledge as regards to improved protocols of bio-fertilizers application to the field is one of the few constraints to bio-fertilizers usage. In the light of this, this study used analytical approach to review bio-fertilizer, biochemistry of bio-fertilizer production, types of bio-fertilizes, microorganisms used in bio-fertilizer, the role of bio-fertilizers in promoting plant adaptation to environmental change and the constraints to adoption of bio-fertilizer among the farmers.

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