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Economic Analysis of Bio-Fertilizer as an Alternative Innovation to Farmers

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Abstract

Several microorganisms have functional relationships which constitute holistic and beneficial effects on plant growth. Bio-fertilizer is a component that carries living microorganisms which applied into the soil as inoculants to help provide certain nutrients for plants. This review x-rays the role of bio-fertilizers in sustainable agriculture thereby meeting the needs of farmers and plant biologists whose work base on creating clean and efficient means of improving soil quality by nourishing and maintaining the useful and natural flora of microorganisms. It presents the alternative use live fertilizer in the field of agricultural management which reveals the potentials of the application in terms of increased nutrient profiles, plant growth and productivity as well as an improved tolerance to environmental stress. In view of these, this paper used available literature to analyze the term "bio-fertilizer," the origin of bio-fertilizer, economic importance of bio-fertilizer to crops, benefits of bio-fertilizer over chemical fertilizers, factors affecting bio-digestion and limitations to bio-fertilizer.

Keywords: Bio-Fertilizer; Agriculture; Environment; Crops; Farmers

Abbreviations: PGPR: Plant Growth Promoting Rhizobacteria; VAM: Vesicular Arbuscular Mycorrhiza; MRB: Malaysian Rubber Board.

Introduction

Agriculture has undergone series of stages since the 12th century and now being practiced extensively throughout the world today. In 2007, it was accounted that one- third of the world's workers were employed in the area of agriculture. However, not less than 55% of people in Africa can earn a living through agriculture. In Nigeria, agriculture is the basic means of livelihood for people in most areas especially the rural areas [1]. Soil management strategies today are mainly relied on inorganic chemical-based fertilizers, which cause a serious problem to human health and the environment. Plants nutrients are essential for the production of crops and healthy food for the world's ever increasing population. 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 been important in agricultural sector due to their potential role in food safety and sustainable crop production [1]. The continuous cultivation on the same piece of land year by year due to increased population has resulted to reduction in soil fertility to the extent that even with the application of chemical inorganic fertilizer, little is obtained in return.

Agriculture plays an important role in meeting the food security of a growing human population, which has led to an increasing dependence on the use of chemical fertilizers and pesticides for increased productivity [2]. Chemical fertilizers are industrially made substances which are composed of known 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 [3]. According to Chun-Li, Shiuan-Yuh and Chiu-Chung [4], though the practice of using chemical fertilizers and pesticides boosts 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 the above, attempts have recently been made towards the production of nutrient rich high quality fertilizer (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 [5]. Organic farming is one of such strategies that not only ensures food safety but also adds to biodiversity of soil [6]. 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) 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. However, technically, there is a big difference between them. Vishal and Abhishek [7] 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 increased 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. According to Khosro and Yousef [5], the term bio-fertilizer may be used to include all organic resources for plant growth which are provided in available form for plant absorption through microorganisms or plant associations or interactions. 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 [8]. It is a modernized form of organic fertilizer into which beneficial microorganisms have been incorporated [9]. Hari and Perumal [10], 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 bio-fertilizers 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 explained as formulations containing either living or latent cells of efficient strains of microorganisms that facilitate the uptake of nutrients from crop plants. They carry out this pivotal role through interactions in the plant rhizosphere when applied through seed or soil. Microorganisms that commonly used as bio-fertilizer components are; nitrogen fixers (N-fixer), potassium and phosphorus solubilizers, growth promoting rhizobacteria (PGPRs), endo and ecto mycorrhizal fungi, cyanobacteria and other useful microscopic organisms. 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 [1]. In view of these, this study used available literature to review the economic analysis of bio-fertilizer as an alternative use by the rural farmers.

The origin of bio-fertilizer

Application of beneficial microorganisms in agricultural practices started about 60 years ago before it became clear that these beneficial microbes could also increase plant resistance to adverse environmental stresses. The idea of application of microbial inoculum is a long history which moves from generation to generation of farmers. It began with culture of small scale compost production that has clearly proved the ability of bio-fertilizer to increase crop productivity [5]. This was known when the culture accelerated the decomposition of organic residues and agricultural by-products through various processes and gave healthy harvest of crops [1]. Therefore, bio-fertilizers such as Rhizobium, Azotobacter, Azospirillum and Blue green algae (BGA) have been in use since a long time ago. Industrial scale production of microbial inoculants began in late 1940s and was popularized in 1970s in Malaysia, through Bradyrhizobium inoculation on legumes. In 1895, Nobbe and Hilther propagated the commercial history of bio-fertilizer with the launch of "Nitrogen". This was followed by the discovery of Azotobacter and then Blue-green algae and a host of other microorganisms which are being used till date as bio-fertilizer [11]. As the matter of the importance, government research institute of Malaysian Rubber Board (MRB) started conducting research on Rhizobium inoculums for leguminous crops in the inter rows of young rubber trees in large plantation. However, University Putra Malaysia (UPM) also conducted many researches since 1980s on Mycorrhiza and initiated the research to assess the contribution of nitrogen from Azospirillum to oil palm seedling [12]. Bio-fertilizers are usually prepared as carrier

based inoculants containing effective microorganisms [8]. Microorganisms used as bio-fertilizer include: Nitrogen fixers (N. fixers) e.g, Rhizobium Spp., Cyanobacteria, and Azotobacter chroococcum, potassium solubilizers (K – solubilizers) e.g, Bacillus mucilaginous, phosphorus solubilizers (P – solubilizers) e.g, Bacillus megaterium, Aspergillus fumigatus, Plant Growth Promoting Rhizobacteria (PGPR), Vesicular Arbuscular Mycorrhiza (VAM) e.g, Glomus mosseae and sulfur oxidizers (S – oxidizers) [1].

Economic importance of bio-fertilizer to crops

Several microorganisms possess functional relationships which bring about total and beneficial effects on plant growth [8]. Bio-fertilizer is a component that contains living microorganisms which are given into the soil as inoculants to help provide certain nutrients for plants [13]. Bio-fertilizers keep the soil environment rich in all kinds of macro and micro nutrients via nitrogen fixation, phosphate and potassium solubilization or mineralization, release of plant growth regulating substances, production of antibiotics and biodegradation of organic matter in the soil [14]. Bio-fertilizers multiply and participate in nutrient cycling and lead to crop productivity when applied as seed or soil inoculants. Generally, 60% to 90% of the total applied fertilizer is lost and the remaining 10% - 40% is taken up by plants. Bio-fertilizers can be important components of integrated nutrient management systems for sustaining agricultural productivity and a healthy environment [15].

They ignite certain microbial processes in the soil which supplement nutrients in a form easily assimilated by plants. Bio-fertilizers supply nutrients through the natural processes of nitrogen fixation, solubilizing phosphorus and stimulating plant growth through the synthesis of growth-promoting substances. 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. Biological fertilization (bio-fertilization) as a process of application of natural inputs including fertilizers, offers significant advantages in the efforts of contemporary agriculture to reduce the use of chemical fertilizers and pesticides. Bio-fertilizers keep the soil environment rich in all kinds of macro and micro nutrients through 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 [14].

In terms of bio-digestion \bio-degradation of wastes, bio fertilizer has the following advantages: It leads to an increase in available nutrients, it leads to a decrease in weight thereby reducing handling and transportation problems arising due to bulkiness of the wastes, it reduces the volume of the wastes, it improves handling and transportation, High degradation temperatures kill pathogens and weed seeds, to enable graded wastes come into equilibrium with the soil, it reduces odor [16]. Application of bio-fertilizers with organic manure is expected to increase soil fertility, fertilizers efficiency and crop productivity. The interaction between manure and soil microorganisms can improve the aggregate and the soil structure becomes loose. The results of decomposition by soil microorganisms such as extra polysaccharides can function as glue or adhesives between soil particles so as to increase the amount of soil pores and eventually become a suitable medium for plant growth because of the wider range of roots so that nutrient absorption is easier. With the expansion of root reach and increasing nutrient uptake, fertilization efficiency is expected to increase so that plants can grow well [17]. Biological treatments for these wastes by means of bio-organic treatments have been adapted in order to maximize agricultural production to limit the pollution of environment, through seed and soil inoculation by different types of microorganisms [18]. Study has confirmed that Azotobacter chroococcum inoculation is essential for increasing agricultural production through its ability of fixing nitrogen, producing phytohormons, bio control activity and stimulating other soil microbial strains [1]. Application of organic compost manure and including bio fertilizers in the farming systems can help maintain consistently high yields through improvements in water and nutrient use efficiencies, soil biotic activity and soil organic matter levels. An increase of 1 ton of soil organic carbon pool of degraded soils may increase crop yield by 20-40 kg/ha for wheat and similar increases for other crops, besides enhancing food security.

In the same respect, the bio-organic fertilizer promote the stems and leaves of cassava growth, increase the chlorophyll content and the photosynthesis of leaves, and improve the physiological metabolism of cassava but also promote the photosynthetic organism to transfer to the tuber root and increase the yield and starch content in the root of cassava [18]. For vegetables, the addition of bio-fertilizer alone increased growth 4 times. More so, an enhancement of growth by 7 times was observed due to the addition of natural mineral fertilizers, in combination with the bio-fertilizer x [19]. Based on these, the most important advantages can be summarized as the improvement of plant nutrients, water uptake, plant growth, plant tolerance to abiotic and biotic factors and quality yields of plant for sustainable food security in totality.

Benefits of bio-fertilizer over chemical fertilizers

The people's demand for fertilizer has greatly increased in the past few decades. According to Fertilizer Suppliers Association of Nigeria (FESPAN) (2007), Nigeria's fertilizer demand is estimated to be 12 million metric tons per annum.

The use of inorganic fertilizers has been popularized in Nigeria and throughout the world because they are easily affordable and have the advantage of fast action due to their prompt release of nutrients. Despite this, there have been many findings on the demerits of inorganic fertilizers and these have indicated that they have disadvantages which cannot be overlooked. Most of the problems associated with harvested crops and some of the pollution of our natural environment occurred as a result of inorganic fertilizer use [20]. All the fertilizers used in Nigeria are imported and due to the high cost of importation, the price of the fertilizers becomes very high, thereby preventing resource poor farmers from accessing it. On the other hand, inorganic fertilizers when applied incorrectly, excessively and inadequately have negative effects. Many of the fertilizers imported into the country were wasted as farmers refused to purchase them due high cost and constraints associated with it [1]. Ifokwe, 1988 [21] in Itelima, et al. [1] was of the view that different types of fertilizers are suitable for different soil types. To get fertilizers which will suit a particular soil, the soil needs to be analyzed. According to him, most of the fertilizers imported into the country are not suitable for our soil thereby giving negative rather than positive results; besides one requires a good knowledge before applying it but today, every illiterate farmer applies fertilizers without understanding how it works and its side effects. All these problems can however be avoided by the use of indigenous fertilizers which is environment friendly. These findings have led to the need for the provision of an environment friendly fertilizer known as bio-fertilizer. According to Itelima et al [1], yam farmers complained that the fertilizers were responsible for the early decay of harvested yam tubers. It is of no doubt that crops cultivated with inorganic fertilizers have fewer flavors, taste, and aroma than those cultivated without inorganic fertilizers. Excessive fertilizer application leads to salt burn and in most cases leads to the death of young plants [22]. Due to they are non-biodegradable, long term use of inorganic fertilizers result in accumulation of harmful substances and acidification of the soil thereby causing a decrease in the fertility of the soil [23,1].

Because of their high solubility in water, inorganic fertilizers applied to the soil could be leached deep into the soil (where plant roots cannot reach) and into underground water causing pollution. These fertilizers known as bio-fertilizers can achieve all that is achievable with inorganic fertilizers and even more without any side effects [1]. Bio-fertilizers are environment friendly and do not cause pollution unlike inorganic fertilizers which often 'run off' into water bodies causing eutrophication and 'blue baby syndrome' (acquired methemoglobinemia) when the nitrate level is above 10 mg/L [24,1]. The issue of excessive application does not arise in the use of bio-fertilizer and special skills are not required for its application [1]. Bio-fertilizers have long lasting effects due to their slow nutrient release. The nutrients from bio-fertilizers are released to plants slowly and steadily for more than one season.

As a result, long term use of bio-fertilizer leads to the buildup of nutrients in the soil thereby increasing the overall soil fertility. Moreover, bio-fertilizers have been found to help control of plant diseases such as pythium root rot, rhizoctonia root rot, chill wilt and parasitic nematode [16]. Research has shown that some bio-fertilizers particularly those made with degraded tree barks and roots release chemicals that inhibit some plant pathogens. Disease control with bio-fertilizer has been attributed to four possible mechanisms: Successful competition for nutrients by beneficial microorganisms present in the fertilizer, production of antibiotics by the beneficial microorganisms, successful predation against pathogens by beneficial microorganisms, activation of disease resistant genes in plants by the microorganisms.

Bio-fertilizer acts as a soil conditioner adding organic matter to the soil which helps to bind the soil particles together preventing soil eructing, desertification, and erosion while increasing the water retention capacity of the soil [19]. It enriches the soil with beneficial microorganisms while boosting the already existing ones unlike chemical inorganic fertilizers which acidify the soil making it hard for microorganisms to survive [19]. Bio-fertilizers contain a wide range of nutrients which are often absent in inorganic fertilizers (these include trace elements). Studies have shown that application of nitrogen fertilizer in some weather conditions cause emission of nitrous oxide which has a global warming effect potential 296 higher times than that of an equal mass of carbon dioxide [25,26,1]. Methane emissions from crop fields (notably rice paddy fields) are increased by the application of ammonium based fertilizers whereas the composting of animal waste in a confined place or in an anaerobic condition (an important process in the production of bio-fertilizer), reduces the addition of methane to the atmosphere as these add methane to the atmosphere when left to decay on their own. Bio-fertilizer when compared to raw (undegraded) organic manure has the advantage of easier assimilation by plants and also the odor reduces after degradation [9]. The risk with raw organic manure is that it may contain pathogens such as Salmonella Spp. which may contaminate crops such as leafy vegetables and lead to the ingestion of the pathogen when the product is consumed. Bio-fertilizer also contains useful microorganisms which may not be present in organic (degraded) fertilizer [5]. These bio-fertilizers can be produced from cheap waste materials which are abundant in Nigeria and the cost of production is low compared to inorganic fertilizers which required high energy.

Factors affecting bio-digestion

According Ezigbo [27] in Itelima et al. [1], the rate of bio-degradation is affected by the following factors: Moisture content-Bio-digestion occurs faster in the presence of moisture while lack of water makes the survival of degrading organisms difficult. Surface area-This plays an important role in bio-degradation. The finer the particles are, the faster the digestion rate. PH- Bio-digestion occurs best at a medium to slightly acidic pH. Temperature-High temperature favors bio-digestion while low temperatures slow it down. Sophisticated bio-digesters have been built in countries such as Sweden and Japan which combine all these parameters. The bio-digesters consist of a chamber where the substrates are screened thoroughly to avoid bringing plastic and metallic substances into the digester.

It makes use of magnetic separation to separate the metals. Also, there is a chamber where pre-treatment and homogenization of the substance occur. The digesters make use of two temperatures; 37 °C for the growth mesophiles growth and 55°C for thermophiles. The gas given off during bio-digestion is known as "biogas". The bio-digesters have a chamber for collection of the biogas which has many uses. These bio-digesters use 24hrs to complete their digestion [9].

Limitations

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 [28] some of the major limitations are as follows:

Lack of regulatory acts and facilities for testing the samples: Technical tests must be carried out to verify their safety at global scale. Current research of the use of bio-fertilizers in different regions of the world is necessary to obtain a framework that facilitates the development of future investigations in the agricultural sector and, consequently, 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 a variety of factors affecting the adoption of bio-fertilizers by farmers. They 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 limitation 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. In this context, 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 microflora 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 microflorain 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

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. Therefore, 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

Over use of chemical fertilizers and pesticides has created dangerous and hazardous to human health. As a matter of this, attention is now moving from consuming food grown with chemical fertilizers to food grown with organic fertilizers because of the hazardous and harmful effects that these foods have in the body when consumed. Bio-fertilizers can help solve the problem of food need of the ever increasing global population. It is important to realize the importance of bio-fertilizers so as to apply it in modern agricultural practice to bring about poverty reduction and food security as well. Applications of bio-fertilizers contain beneficial microbes that promote to a large extent, crop productivity. These potential biological fertilizers play a key role in productivity and sustainability of soil and protect the environment as eco-friendly and cost effective inputs for the benefits of farmers. Using the biological and organic fertilizers, a low input system can help to achieve sustainability of farming.

The new technology when developed using the tool of molecular biotechnology can enhance the biological pathways of production of phytohormones if identified and transferred to the useful plant growth to promote rhizobacteria. This technology will help provide relief from environmental stresses. However, Lack of knowledge and skills for correct application of bio-fertilizers, Lack of regulatory acts and facilities for testing the samples, inadequate popularization of bio-fertilizers and low level of farmer acceptance and reduction in the population of bacteria under certain climate conditions and influence of surrounding microflora and fauna are some of the limiting factors to bio-fertilizers among the users.

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