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BIOFERTILIZATION AND ITS ROLE IN SUSTAINABLE AGRICULTURE: A REVIEW

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Abstract

The continuous use of chemical fertilizers has many adverse effects on the environment, such as soil degradation, groundwater pollution, shrinking biodiversity, and higher gas emissions. Although fertilizers increase the productivity of most crops, high concentrations of some elements in them may be injurious to health. Biofertilizers are one of the modern technologies for reducing excessive use of mineral fertilizers as they contribute significantly to improving the chemical, physical, and biological properties of soil, maintaining nutritional balance in agricultural soils, and converting them into forms ready to feed the plant. They are also less costly as they speed plant growth, in addition to secreting antibiotics that strengthen plant resistance to diseases and pests endemic to the soil and contribute to the secretion of various enzymes that stimulate plant growth. Therefore, biofertilizers are essential components of sustainable agriculture with positive long-term effects on soil fertility.

Keywords: Biofertilizers, Soil microbes, Sustainable agriculture.

التسميد الحيوي ودوره في الزراعة المستدامة: مراجعة مقال

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الخلاصة

يؤدي الاستخدام المستمر للأسمدة الكيميائية إلى تدهور التربة وتلوّث المياه الجوفية وانخفاض في التنوع الحيوي وزيادة في كمية الغازات المنبعثة وعلى الرغم من أن استخدام الأسمدة يزيد من الإنتاجية لأغلب المحاصيل ولكنها قد تنتج ضرراً صحياً بزيادة تركيز بعض العناصر فيها، تعد الأسمدة الحيوية احدى التقانات الحديثة للحد من الاستعمال المفرط للأسمدة المعدنية لما لها من أهمية كبيرة في تحسين بعض الصفات الكيميائية والفيزيائية والحيوية للتربة ويحافظ على اتزان العناصر الغذائية في الترب الزراعية وتحويلها للصور الجاهزة لتغذية النبات، كما إنها تكون اقل كلفة اقتصادية من الاسمدة المعدنية لكونها اقل ثمناً وتزيد سرعة نمو النبات بالمقارنة مع النباتات المعاملة بالأسمدة المعدنية فقط، فضلاً عن افرازها لمضادات حيوية تزيد من مقاومة النبات للأمراض والآفات المستوطنة في التربة وتسهم بفرز الكثير من الإنزيمات المحفزة لنمو النبات، لذلك تعد الأسمدة الحيوية مكونات أساسية للزراعة المستدامة مع تأثيرات طويلة الأمد في خصوبة التربة.

كلمات مفتاحية: الأسمدة الحيوية، ميكروبات التربة، الزراعة المستدامة.

Introduction

Most agricultural lands in arid and semi-arid regions are characterized by low levels of many essential nutrients and organic matter content, resulting in a significant decrease in soil biomass. Nitrogen and phosphorus are major nutrients necessary for the growth and production of various crops, and their use as mineral fertilizers is accompanied by several problems, especially in Iraqi soils. These soils are high in calcium carbonate content, thus readily precipitating phosphorus in the form of calcium phosphate, resulting in most of the added mineral phosphorus together with that already present in the soil, turning into unavailable phosphorus. Nitrogen is also lost through washing or in the form of gases through reverse nitrification and ammonia evaporation, which causes serious environmental issues (4). The excessive use of chemical fertilizers creates various health and environmental problems, and scientists have focused on seeking new sources and modern technologies to increase production and improve its quality. Organic biofertilizers are among the most important of these technologies (5).

Modern agricultural methods to increase agricultural production rely primarily on the use of chemical fertilizers, but their excessive and uncontrolled use lead to adverse effects on the environment over the long term (51). The continuous use of chemical

fertilizers leads to soil degradation, groundwater pollution, decreased biodiversity, and increased gas emissions. Although fertilizer use increases crop productivity, it may be harmful to health from the increased concentration of some elements in them. Hence, it is critical to explore new strategies that incorporate elements of preserving the health of society and environmental sustainability. Therefore, in recent years, organic and biological fertilizers have begun to be used in agriculture as a suitable complement to chemical fertilizers (15).

Biofertilizers are natural preparations containing one or more types of beneficial microorganisms that are not genetically modified and do not contain any pesticides or active chemicals, making them safe preparations from a health perspective. They are essential for improving soil fertility due to their ability to release nutrients continuously, which makes them safe if the ideal conditions for their growth are available to cover some of the needs of plants. Thus, they contribute to providing plants with some of their nutritional needs in a sustainable and environmentally safe manner, thereby reducing the quantities of added mineral fertilizers and reducing production costs (7). Biofertilizers are among the modern technologies used in the agricultural field. They are preparations that contain one or two types or a group of microorganisms that are used as a soil additive via scattering or by inoculating seeds or seedlings or a combination to improve the soil's chemical, physical, and biological properties. Also, maintaining the balance of nutrients in the soil and converting them into ready-made forms to feed the plant during its life cycle reduces the use of chemical fertilizers, increases production, and reduces agricultural production costs (2 and 52)

Biofertilizers offer a sustainable and environmentally friendly approach to enhancing nutrient availability, promoting plant growth, and improving soil health. They are critical in ensuring food security and environmental sustainability (34 and 36) and reduce the need for chemical fertilizers while promoting sustainable agricultural systems, even if they are not full substitutes for chemical fertilizers (49). Sustainable agriculture aims to balance meeting human food needs with preserving the environment and ensuring the sustainability of natural resources for future generations. It also relies on practices that conserve soil, reduce the use of non-renewable resources, and enhance biodiversity (17).

This study emphasizes the importance of biofertilizers and their function in sustainable agriculture, highlights the potential and importance of microbial fertilizers in promoting sustainable agricultural development. It presents new strategies and perspectives for future agricultural production based on their composition and roles, such as nitrogen fixation, phosphorus solubilization, phosphorus assimilation, rhizobacteria that promote plant growth and micronutrient-based biofertilizers.

Biofertilizers:

Biofertilizers are microscopic organisms or a group of microscopic organisms that can facilitate the nutrients necessary for plant growth and convert them from unavailable into available forms ready for absorption by the plant, especially nitrogen, phosphorus, and potassium. The various sources of biofertilizers include bacteria, fungi, and algae, mainly blue-green algae. These organisms play an effective role in serving plants by preparing nutrients, resisting diseases, or facing unfavorable

conditions, such as climate changes or environmental stress in the soil. Many microorganisms work in a mutually beneficial relationship with plants (27).

Biofertilizers are essential for dissolving deposited compounds, releasing phosphorus into the soil solution, and reducing the degree of soil reaction (42). Their proper use is a cost-effective and environmentally friendly means to provide plants with nutrients and thus increase crop production, making it possible to create sustainable agricultural systems (33 and 43)

The use of plant growth promoting rhizobacteria (PGPR) in agriculture is essential in increasing crop production, as they secrete various organic acids and plant hormones (18). Biofertilizers have also proven their ability to restore environmental balance and obtain a healthy environment, in addition to contributing to producing crops with good and healthy specifications free of chemical pollutants. They provide many fertilizers in agricultural fields and achieved an improvement in the physical, chemical, fertility, and biological properties of the soil. This is achieved by fixing elements such as nitrogen, dissolving compounds containing phosphorus and potassium, and facilitating nutrients for plants, in addition to secreting enzymes, organic acids, growth regulators, chelating materials, and biological inhibitors for some microscopic diseases (26).

Reasons for switching to biofertilizers:

Chemical fertilizers constitute a major input in agricultural production and have been widely used by farmers for their important role in increasing crop productivity. Plants require the essential elements found in chemical fertilizers, such as nitrogen, phosphorus, and potassium, in a readily absorbed form thus achieving high productivity (30). However, such fertilizers have been proven to be harmful to human health and the environment. The excessive and unscientific application of mineral nitrogen fertilizers leads to increased accumulation of nitrates in surface water, soil, and plants, leading to serious health problems (38). Nitrogen and phosphorus are among the most essential nutrients related to pollution, especially when optimal administrative methods are not followed in fertilization (21).

The random use of chemical fertilizers poses much risk to agricultural production, soil, and human and animal health. Their large-scale use to obtain huge returns from agricultural lands creates intractable risks that affect the ecosystem (41). It is clear that environmental safety is one of the essential priorities that must be considered, and the most important means of protection from pollution is organic bio-agriculture (37). Therefore, biofertilizers have been resorted to because of their significant and effective role in reducing environmental pollution, especially those resulting from adding these fertilizers (32). Biofertilizers play an effective role in providing large quantities of mineral fertilizers, reaching 50% of the amount recommended for a specific crop, which leads to obtaining a product of high quality and health safety. They also help raise production, as the increase in the resulting crop can reach more than 30% and help improve the crop's nutritional content compared to mineral fertilizers alone (33).

A study conducted in Korea on the deleterious effects of nitrogen fertilizers in rice fields (12) found that they increased the rate of leakage of nitrogen derivatives such as ammonia, ammonium, nitrates, and nitrites. In contrast, excessive use of phosphate fertilizers in the long term increases the risk of contamination with residues of some

toxic metal elements such as cadmium, arsenic, and lead (29). It also contributes to altering many physical and chemical properties of the soil, such as the degree of soil reaction, which in turn affects the abundance of microbial communities in the soil. It also reduces enzymatic activity, deteriorates soil fertility, and pollutes water, air, and soil, as elements are transferred from fertilizers to water bodies as a result of surface runoff and soil erosion, especially in soils that have received large amounts of chemical fertilizers (31).

The Importance of Biofertilizers in Agriculture:

1. The beneficial effects of microscopic rhizosphere organisms on plant growth:

In a study, (45) indicated that PGPR are the safest and most environmentally friendly microorganisms present in the plant root zone and play an essential role in soil health, fertility, and plant growth. The most important are bacteria, fungi, and mycorrhizal fungi which work to improve plant growth and productivity or act as antibiotics for plant or insect diseases. Compared to non-inoculation, treating the soil with biofertilizers increases the seedling emergence rate in clay or sandy soil due to increased water absorption rates for the inoculated treatments (44). The first doses of mineral fertilizers may be effective in the early stages of plant growth, followed by the microbial vaccines in supplying the plant with the required nutrients, meaning that biofertilizers have a complementary role to adding mineral fertilizers (50).

Rhizosphere microorganisms benefit the plant's nutritional status and impact related to the production of growth-regulating substances and their ability to halt or limit the spread of pathogens in the soil. Biofertilizers are an essential part of the nutritional supplement system, and the level of fertility must be given importance. Therefore, supporting and backing the soil to increase its productive capacity must be done using microorganisms that can either fix atmospheric nitrogen or dissolve insoluble phosphorus in the soil (36).

2. Increased nutrient availability:

As mentioned by (46), biofertilizers fix nitrogen, reducing its loss to 54% when using 50% urea of the specified amount. Also, (14) showed that biofertilizers, whether phosphate or nitrogenous, reduce fertilizer recommendation by 25% thus reducing pollution from chemical fertilizers. In addition, it increases the availability of nutrients in the soil and increases plant growth in terms of quality and quantity. Biofertilizers are one of the environmentally friendly alternatives. They are microbial bioproducts containing millions of effective microorganisms that can be added to the soil or seeds or both, stimulating plant growth by enhancing nutrient availability in the root zone, especially nitrogen and phosphorus from their unavailable sources (48).

Biofertilizers contain a variety of beneficial microorganisms that can encourage plants to absorb nutrients by colonizing the rhizosphere and plant roots. They are characterized by their effectiveness in terms of low cost and environmentally friendly nature. They effectively complement chemical fertilizers that pose an environmental risk (13). A study by (47) indicated that adding phosphate-dissolving bacteria with a mono superphosphate fertilizer or phosphate rock to sugarcane (Saccharum filifolium) reduced the need to add phosphorus by 25% and 50%, respectively, as the process of

dissolving phosphate is the result of the combined effect of low soil reaction temperatures and the production of organic acids (1).

A study found that adding phosphate rock and potassium alone or together to soil planted with pepper and cucumber plants did not significantly increase phosphorus and potassium availability (20). However, adding phosphorus-solubilizing bacteria (PSB) Bacillus megaterium var. phosphaticum and potassium-solubilizing bacteria (KSB) Bacillus mucilaginosus to phosphate rock led to a significant superiority in the availability of phosphorus and potassium in the soil. This was directly reflected in the root and vegetative groups and the growth of pepper and cucumber compared to not inoculating with bacteria. A study by (28) noted that inoculating wheat grains (Triticum aestivum L.) with the genus Azotobacter and organic fertilization using 60 kg N ha-1 from a source (FYM) can provide 50% of the NPK mineral fertilizer. (6) showed the accumulation of nutrients in wheat plants, especially nitrogen, and phosphorus, which reached 0.47%P and 5.01%N when using biofertilizer consisting of A. chroococcum, A. brasilense, and P. fluorescens isolates, with 100% of the recommended phosphorus and nitrogen added to fertilize the wheat crop.

(53) concluded that inoculating the soil with Azotobacter and Pseudomonas bacteria with mineral fertilization at a 50% rate produced results that did not differ significantly from adding the full fertilizer recommendation. This confirms that farmers can fertilize wheat with half the recommended amounts if the seeds are inoculated with the two biofertilizers mentioned in the study.

A study (23) on the effect of inoculating wheat seeds with bacteria (Bc. subtilis + Ps. putida) on the yield and its components of wheat showed that adding the full mineral fertilizer recommendation did not differ significantly from the half-treatment dosage with inoculation for all the studied traits except for the increase in microorganisms. Thus, 50% mineral fertilizer dosages can be replaced with biological fertilizers to reduce the risks of pollution and the cost of mineral fertilizers.

3. Secretion of growth-stimulating substances:

Many studies confirm that microorganisms contribute to improving growth and increasing yield by forming growth regulators such as auxins, gibberellins, and indole acetic acid (IAA), as well as vitamins that directly or indirectly affect increasing crop productivity. They produce some plant growth-stimulating substances, and these stimulating effects were first clearly observed by rhizosphere organisms in wheat plants. Their effect was attributed to the production by these microorganisms of the stimulating auxin (IAA) (4). As noted by (11), the improved wheat plant growth when inoculated with types of accompanying bacteria A. brasilense, A. chroococcum, and B. megaterium is attributed to their production of growth regulators such as auxins, gibberellins and cytokinins and not because they prepare nutrients in mineralization and nitrogen fixation processes.

Several studies indicate the important role of mycorrhizal fungi and their ability to increase the absorption and storage capacity of roots through the secretion of auxins, gibberellins, and related compounds. This is because these substances have an essential role in terms of their effect on the rate of seed germination, development of the root system, and increasing the rate of nutrient absorption (24). A study by (25) indicated that some bacteria species inhabiting the rhizosphere can encourage plant growth when

added to seeds, roots, and leaves through the secretion of many growth-stimulating substances. These probiotic bacteria (PGPR) include Bacillus, Pseudomonas, Azospirillum, Azotobacter, Acetobacter Enterobacter and Herbaspirillum.

4. Improving some soil properties:

Biofertilizers are among the modern technologies for curtailing the use of chemical fertilizers, thus contributing to reducing sources of pollution, lowering production costs, and increasing soil fertility, as they increase nutrient availability in soil by fixing atmospheric nitrogen and converting it into ammonia using Azotobacter and Azospirillum bacteria. In addition, they secrete hormones, growth regulators, and enzymes (8). Local and international research on crops such as yellow corn, wheat, potatoes, and tomatoes confirmed that biofertilization compensated for a significant portion of chemical and organic fertilization. In addition, it improved fertility and productivity and increased organic matter and total nitrogen content in soil (22).

A study (16) showed that microbial vaccines can mitigate the degree of soil reaction by producing organic acids, and they also work to chelate the positive ions responsible for fixing phosphorus in calcareous and basic soils. A study (9) noted that inoculating sandy soil with the genus Azospirillum led to increased soil aggregates and stability due to its secretion of binding materials and polysaccharides. At the same time, (10) indicated that inoculating wheat plants with B. polymyxa bacteria increased the average diameter of soil particle aggregates due to the secretion of polysaccharides that lead to binding the particles together and improving the structure of sandy soil.

(19) concluded that there is a gradual decrease in the values of the degree of soil reaction inoculated with phosphorus-dissolving bacteria, which encouraged an increase in the amount of phosphorus released and its availability in basic soils. Also, biofertilizers have a positive effect on soil properties through the analysis of organic matter and the production of negatively charged carbon compounds that play a role in increasing the stability of soil aggregates. A study (39) confirmed that inoculating basic soil with the genus Bacillus increased the rate of phosphorus released from superphosphate fertilizer, decreased the degree of soil reaction, and improved its properties. In contrast, (40) showed that the use of biofertilizers affected the components of the chickpea plant's yield under different levels of irrigation, as they reduced the stressful effect of low water levels

Conclusions

Organisms working in soil and plants play a significant role in the functioning of the ecosystem by effecting many chemical processes and decomposing organic matter. For this reason, biofertilizers are considered a sustainable complement to agricultural practices based on mineral fertilizers, which reduce environmental risks due to reducing chemical inputs and increasing the efficiency of nutrient use. This affords a long-term sustainable agricultural system that improves soil vitality and reduces the amounts of mineral fertilizers used and production costs.

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The authors declare no conflict of interest.

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