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Review

The Role of Beneficial Microorganisms in Soil Quality and Plant Health

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Abstract: The practice of agriculture has always been a source of food production. The increase in the global population leads to improvements in agriculture, increasing crop quality and yield. Plant growth results from the interaction between roots and their environment, which is the soil or planting medium that provides structural support as well as water and nutrients to the plant. Therefore, good soil management is necessary to prevent problems that will directly affect plant health. Integrated crop management is a pragmatic approach to crop production, which includes integrated pest management focusing on crop protection. Currently, there is an extended idea that many microorganisms, such as fungi or bacteria, are useful in agriculture since they are attractive eco-friendly alternatives to mineral fertilizers and chemical pesticides. The microbes that interact with the plants supply nutrients to crops, control phytopathogens and stimulate plant growth. These actions have beneficial implications in agriculture. Despite the great benefits of microorganisms in agriculture, their use has been quite limited; however, there has been great growth in recent years. This may be because more progress is needed in field applications. One of the most employed genera in agriculture is *Bacillus* since it has several mechanisms to act as biofertilizers and biopesticides. In this review, the role of beneficial microorganisms, with special emphasis on the *Bacillus* genus, in soil and plant health will be discussed, highlighting the recent advances in this topic.

Keywords: agricultural sustainability; biofertilizers; crop protection; *Bacillus* sp.; plant growth promotion

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1. Introduction

Agriculture has always been a powerful method to meet the world's population demand for food. Currently, the population is growing very fast; therefore, it is very important that agriculture can meet this increase in demand. For this reason, it is important to increase crops' yield and quality [1]. However, the plants suffer from several diseases constantly due to pests and pathogens that provoke crops and economic losses. In addition, the soil loses a large amount of nutrients due to constant cultivation, leading to a decrease the yield and quality of the crops. In this sense, to lessen these negative effects, chemical fertilizers and pesticides have been used. However, their long-extended use has brought serious health and environmental problems, causing damage to ecology and pest resistance. To try to reduce the use of chemicals, biofertilizers and biopesticides are a greener way to increase the harvest of crops. Biofertilizers can be attractive biotechnological alternatives to increase crop yield, improve and restore soil fertility, stimulate plant growth, and above all, reduce production costs and environmental impacts associated with chemical fertilization [2].

The soil, where the interactions between the plant and the environment occur, needs to have enough quality to ensure good development and growth of the plant. There are many beneficial microorganisms, such as bacteria and fungi, inhabiting the soil and providing suitable conditions for the development of plants [3]. The beneficial interactions of these microbes with the plants include the nutrients supply to crops, plant growth stimulation, producing phytohormones, biocontrol of phytopathogens, improving soil structure, bioaccumulation of inorganic compounds, and bioremediation of metal-contaminated soils [4]. There are several works highlighting the role of beneficial microorganisms in plant grow promotion [5–8].

The use of biofertilizers or biopesticides has opened a new way to improve the yield of the crops [9]. Biofertilizers are considered feasible and sustainable attractive biotechnological alternatives to increase crop yield, improve and restore soil fertility, stimulate plant growth, and reduce production costs and the environmental impact associated with chemical fertilization. Biofertilizers have been evaluated in a wide variety of crops, including rice, cucumber, wheat, sugarcane, oats, sunflower, corn, flax, beet, tobacco, tea, coffee, coconut, potato, fan cypress, grass sudan, eggplant, pepper, peanut, alfalfa, tomato, alder, sorghum, pine, black pepper, strawberries, green soybeans, cotton, beans, lettuce, carrots, and neem, among others [2]. On the other hand, biopesticides have an important role in crop protection, although most commonly in combination with other tools, including chemical pesticides, as part of bio-intensive integrated pest management [10]. There are many pests or phytopathogens that attack the crops causing great economic losses. Among the microorganisms that are employed as biofertilizers and biopesticides, one of the most used is *Bacillus* genus. *Bacillus* can act using different direct and indirect mechanisms, which can act simultaneously during plant growth. The direct mechanisms include their ability to obtain nutrient supply, such as nitrogen, phosphorus, potassium, and minerals, or modulate plant hormone levels. The indirect mechanisms include the secretion of antagonistic substances to inhibit plant pathogens or the induction of resistance to pathogens [4]. One of the most used biopesticide worldwide is *Bacillus thuringiensis*.

With this point of view, it is important to visualize the contributions of microorganisms in agriculture by emphasizing the genus *Bacillus*, which is one of the most used microorganisms for this purpose. There have been recent developments to ensure the success and commercialization of these green products. For this reason, in this review, the role of beneficial microorganisms as biofertilizers, with special emphasis on the *Bacillus* genus, in soil and plant health will be discussed.

2. Relation between Soil and Plant Health

To develop and apply biofertilizers, before understanding their mechanism of action, it is necessary to first understand the interaction of plants roots with the surrounding environment, which is the soil or planting medium. The soil is formed by solid mineral particles such as sand, silt and clay size, water, air, and organic matter. The soil water, with carbon dioxide's help, dissolves the mineral particles very slowly and releases nutrients, making them available for the plants. The plants and soil organisms facilitate the cycling of organic matter and nutrients, which allows soil to continue supporting life. Therefore, the soil's health is key to agricultural sustainability [11]. Soil health supports the growth of high-yielding, high-quality, and healthy crops. Scientists use the term soil quality to refer to soil health and define it as the fitness of a specific soil to sustain plant and animal productivity [12].

When the soil is healthy the yield of the crops is high, mainly because the roots are able to proliferate easily, there is enough water entering and stored in the soil, there is a sufficient nutrient supply, there are no harmful chemicals in the soil, and beneficial organisms are very active and able to keep potentially harmful ones under control and stimulate plant growth. Healthy soil should have enough nutrients and a good soil structure for the development of plant roots. The soil needs to be well drained and have good aeration. Moreover, the soil should not have pests that can be aggressive to the plants provoking plant diseases and crop losses [13].

However, there are several problems associated with soil health such as soil erosion, soil organic matter loss, nutrient imbalance, soil acidification, soil contamination, waterlogging, soil compaction, soil sealing, salinization, and loss of soil biodiversity. There is a relationship between some soil properties (Figure 1). Therefore, when a problem is detected, some properties can be affected. For example, in compacted soils, the pores or spaces are lost, making it difficult or impossible for some of the larger soil organisms to move or even survive. Moreover, waterlogged soil can cause severe soil denitrifying [13,14].

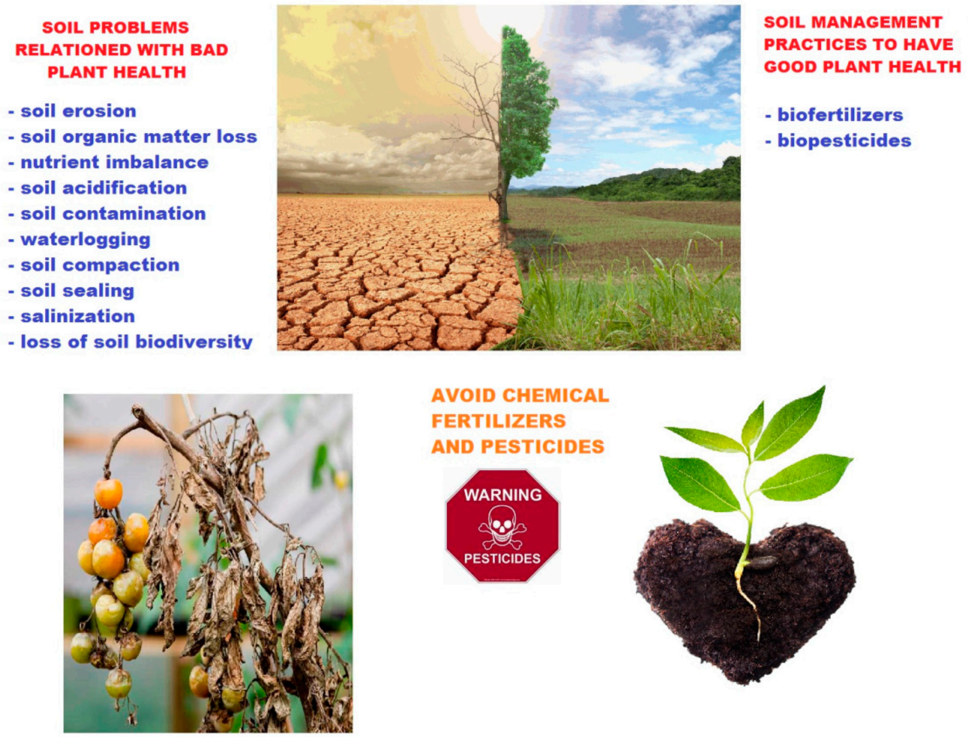

Figure 1. Relation between soil problems and soil management practices with plant health.

The soil's health can be degraded by several agricultural practices, such as tillage [14]. This practice breaks down soil aggregates, losing soil organic matter and accelerating erosion. Moreover, when the soil is compacted, it is harder for water to infiltrate, and the roots do not develop properly, causing accelerated erosion and poor crop production. The salinity of soils under irrigation in arid regions is another cause of reduced soil health [15]. Irrigation water contains mineral salts, which can reduce water infiltration in soils [16].

To achieve good crop yields, several soil-management practices have been applied to grow healthy plants with strong defense capabilities, to suppress pests, and to enhance beneficial organisms. For years, fertilizers and pesticides have been used for agricultural development. Fertilizers are used to supplement the nutrients of the soil and pesticides to diminish the pests and damage caused to plants. Therefore, both are considered crucial elements in agriculture since they increase the fertility of soil and crop productivity [17]. However, contradictorily, they also impact the health and environment because they change the soil's physical properties, disrupt the ecological balance of soil microflora and environment, and disturb many activities of soil. Therefore, these practices have led to poor-quality soil impacting the food security and livelihood supporting systems. Due to chemical fertilizers and pesticides, there are severe signs in and rainfed and irrigated farming areas [18,19] such as soil erosion, soil organic matter loss, nutrient imbalance. The excessive use of chemical fertilizers and pesticides has led to adverse effects on soil health, crop productivity, and environment and human health.

3. Microorganisms as Biofertilizers

Due to the above-mentioned issues related to chemical fertilizers and pesticides, there has been an important development toward sustainable agriculture using more ecological and clean methods, such as the employment of biopesticides and biofertilizers.

Biofertilizers can be inoculated on seeds as well as in the roots of different crop plants under ideal conditions, and they can also be applied directly to the soil [20]. Biofertilizer is a substance that contains living microorganisms, which, when applied to seed, plant surfaces, or soil, mobilizes the availability of nutrients particularly by their biological activity, and promotes plant growth [3]. Biofertilizers add nutrients through the natural processes of fixing atmospheric nitrogen, solubilizing phosphorus, and stimulating plant growth through the synthesis of growth-promoting substances [21,22]. They can be grouped in different ways based on their nature and function.

In this sense, the microorganisms, when applied to the soil or to the plant, that help increase the availability of nutrients to crop plants are known as biofertilizers, which are eco-friendly and cheap alternatives to chemical fertilizers [23]. There are different microorganisms that utilize several strategies such as fixing/solubilizing/mobilizing/recycling nutrients in the agricultural ecosystem to be beneficial for the crops, improving plant growth and productivity [24].

The plant rhizosphere, the narrow zone of soil surrounding the root system of growing plants, is colonized by a wide range of microbial taxa, out of which bacteria and fungi comprise the most abundant groups [25]. Free-living soil bacteria that thrive in the rhizosphere, colonize plant roots, and facilitate plant growth are designated as plant-growth-promoting rhizobacteria that produce and secrete various regulatory chemicals in the plant roots' vicinity helping in plant growth promotion [26,27].

Bacteria and fungi that inhabit the rhizosphere can function as biofertilizers that promote plants' growth and development by facilitating biotic and abiotic stress tolerance and supporting host plants' nutrition. They can function as biopesticides too since many of the microorganisms kill insects and other pests that threaten crops. Moreover, microorganisms have the ability to degrade and detoxify harmful organic as well as inorganic compounds that accumulate in the soil as contaminating substances, which are the result of many activities, including agriculture practices. They exert the bioremediation action benefiting soil and plant health [28].

Bacterial biofertilizers are a group of bacteria that help in fixing different nutrients needed for plant growth in the soil [29]. They can fix nitrogen, solubilize phosphorus and potassium or other micronutrients, and secrete organic compounds to suppress plant pathogens or growth-enhancing substances to support plant growth. Examples of the most popular bacterial biofertilizers that have been applied are *Azotobacter*, *Azospirillum*, *Rhizobium*, and *Bacillus*, among others, as shown in Figure 2 [30,31]. *Rhizobium* is used for legume crops and *Azotobacter* and *Azospirillum* for non-legume crops. *Acetobacter* is more specific for sugarcane [2]. Using these bacteria as biofertilizers for promoting plant growth and crop yield, improving soil fertility, and biocontrolling phytopathogens promotes sustainable agriculture by offering eco-friendly alternatives to synthetic agrochemicals, such as chemical fertilizers and pesticides.

The fungal biofertilizers form a symbiotic relationship within the plant roots. Such a relationship is called mycorrhiza, which allows the release and absorption of nutrients, especially phosphorus. Some nutrients cannot diffuse easily into the soil, and the roots deplete these nutrients from the surrounding zone. Arbuscular mycorrhiza are soil beneficial fungi that form a symbiotic relationship with plants and many agricultural crops through the roots of vascular plants [32]. The hyphae of these fungi extend into the depletion zone, which increases the absorption surface of plants and improves access to the nutrients [33]. The symbiosis of arbuscular mycorrhiza fungi improves the plant rhizosphere microenvironment, increases the absorption of mineral elements by the plant, improves stress and disease resistance, and promotes plant growth [34].

The application of microbial biofertilizers has several advantages, as mentioned above, such as their easy use and low cost and their beneficial effects on soil and plants. However, they have some challenges that have hindered their extensive and successful use. Firstly, an initial good laboratory screening is needed for the search of a good and specific biofertilizer strain. In addition, manufacturing and quality control of biofertilizers involve sophisticated technology and qualified and trained human resources, together with lack of enough financial resources to distribute and the unavailability of proper transportation services along with storage facilities, make it a complicated process from the beginning to the end. It should be highlighted among the main issues that can be found, including the poor quality of products, the use of unsuitable strains, the short shelf life, the lack of technical qualified personnel, the lack of awareness among farmers, environmental limitations, etc. [35]. Microbial strains should be able to survive in soil, be compatible with the crop on which they are inoculated, and interact with indigenous microflora in soil and abiotic factors to be efficient and successful bioinoculants. The advantages and disadvantages of microbial biofertilizers and biopesticides are enlisted in Table 1.

Figure 2. Different types of biofertilizers.

Table 1. Microbial biofertilizers and biopesticides advantages and disadvantages.

Microbial Biofertilizers and Biopesticides	
Advantages	**Disadvantages**
- easy to use - low cost - secrete compounds - promote plant growth - increase crop yield - improve soil fertility - eco-friendly products	- search for a good strain is tedious - poor quality of products - sophisticated technology - trained human resources - lack of financial resources - unavailability of proper transportation services - short shelf life

4. *Bacillus* spp. Beneficial for Plants

The genus *Bacillus* has several species and strains that have been used as biofertilizers, biopesticides, and important biotechnological tools. These bacteria can suppress pathogens and at the same time promote plant growth using different direct and indirect mechanisms, which can cat simultaneously during plant growth. The direct mechanisms include their ability to obtain nutrient supply such as nitrogen, phosphorus, potassium, and minerals and modulate plant hormone levels. The indirect mechanisms include the secretion of antagonistic substances to inhibit plant pathogens or the induction of resistance to pathogens [36]. Therefore, *Bacillus* strains are effective as biocontrol agents on plant tissues to prevent pathogen colonization by antibiosis towards pathogens and by the induction of systemic resistance in the host plant.

There are several *Bacillus* species that can fix atmospheric nitrogen, which has been probed by the presence of the *nif*H gene or through the experiment on nitrogenase activity [37]. Phosphorus is an important nutrient for soil health and plant growth, but it is scarce in soil in its inorganic form, which is the form absorbed by the plants. However, *Bacillus* can solubilize in its unavailable form of phosphorus to available phosphorus probably associated with the release of low-molecular-weight organic acids, such as succinic acid, that help to solubilize the fixed phosphorus into an exchangeable form [38]. Different species of *Bacillus* can also produce siderophores, which bind iron and zinc, increasing the availability of soluble metals in the soil and helping plants in the acquisition of iron and zinc [39].

Moreover, several species of *Bacillus* are able to secrete phytohormones, such as auxins, gibberellins, cytokinins, and abscisic acid, which play different roles in affecting plant cell enlargement and division and enlargement of roots [40]. Several genes have been identified participating in IAA biosynthetic pathways in *Bacillus*, observing an increase in root growth of several crops, such as potato [41,42]. Cytokinins and gibberellins are also produced by several strains of *Bacillus* and are involved in plant growth promotion [40]. Abscisic acid is involved in plant responses of tolerance to abiotic stresses (drought, chilling, heat, salinity, etc.) and in the dormancy process, which is present in several *Bacillus* species [40]. Three phytohormones, which are involved directly in defense responses to biotic stresses, such as salicylic acid, mainly against biotrophic pathogens, and jasmonic acid and ethylene, mainly against necrotrophic pathogens and pests, have been reported in different *Bacillus* species [43]. These three phytohormones interact with root tissues and can induce defensive responses in plants against future attacks by pests through a mechanism called induced systemic resistance [43]. Through the production of all these beneficial phytohormones, *Bacillus* can help the plant growth of several important crops being beneficial for agriculture, as shown in Figure 3.

The importance of soil health for plant development and the role of the microorganisms, such as *Bacillus*, as biofertilizers has been mentioned before. However, there is another problem related to the crops. Several fungi and insects act as parasites for different types of plants, destroying important crops. The genus of *Bacillus* sp. has extraordinary machinery to secrete several secondary metabolites, lytic enzymes, and toxins against the phytopathogens, which cause plant diseases, promoting plant growth [3]. The control of fungal diseases by *Bacillus*-based biopesticides represents an interesting opportunity for agricultural biotechnology since these microorganisms improve soil quality, soil health, and the growth, yield, as well as quality of crops. There are several *Bacillus*-based biopesticides that have been commercialized, as shown in Table 2.

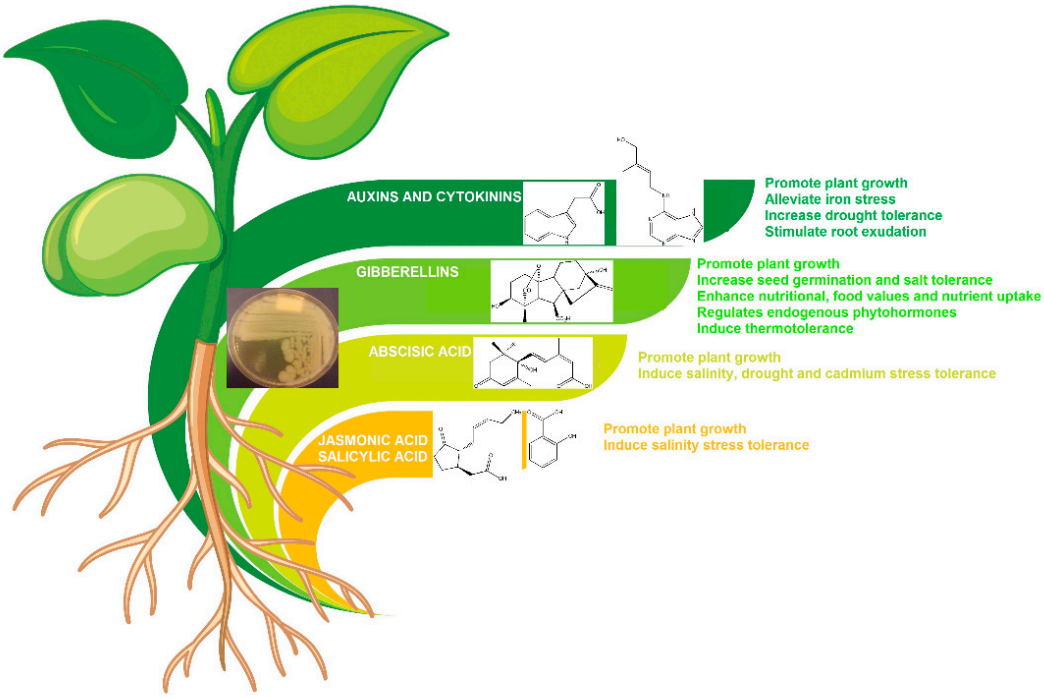

Figure 3. Phytohormones effect on the plants.

Table 2. Commercial *Bacillus*-based biopesticides currently in use.

Microorganism	Action	Brand Name	Producer
B. amyloliquefaciens	Fungicide	Serifel Integral Taegro Companion Maxxx Serenade Amylo-X Aveo	BASF Ag products Syngenta Group pH Douglass Plant Health Bayer CropScience LP Certis Valent BioSciences
B. pumilus	Fungicide	Ballad plus Sonata AS YieldShield	Bayer CropScience LP
B. sphaericus	Insecticide	VectoLex	Valent BioSciences
B. subtilis	Fungicide	Kodiak Cillus Biotilis	Bayer CropScience LP Green Biotech, Korea Agri Life
B. thuringiensis var. *aizawai*	Insecticide	XenTari Agree Turex Solbit	Valent BioSciences Certis Green Biotech, Korea
B. thuringiensis var. *israelensis*	Insecticide	Bactimos Teknar VectoBac VectoMax Aquabac Bacticide BTI granules	Valent BioSciences Becker Microbial Biotech Int'l Clarke Mos. Cont.

Table 2. *Cont.*

Microorganism	Action	Brand Name	Producer
B. thuringiensis var. *kurstaki*	Insecticide	Dipel Foray Cordalene Lipel Sp Lipel Biolep BMP 123 Baturad Belthirul Deliver Delfin Condor Crymax Javelin WG Lepinox WG Turex Turicide Safer BTK Rapax Lepinox plus	Valent BioSciences Agrichem Som Phytopharma Agri Life Biotech international Becker microbial Agrindustrial S.A. Probelte S.A. Certis Woodstream Canada Ecogen/Intrachem
B. thuringiensis var. *tenebrionis*	Insecticide	Novodor	Valent BioSciences

Antagonistic metabolites that *Bacillus* secrete include lipopeptide surfactants, such as surfactin, fengycin, and iturin families, which are potent biofungicides and have been applied in several crops against fungal plant pathogens, such as *Botrytis cinerea*, *Magnaporthe oryzae*, *Fusarium graminearum*, *Fusarium oxysporum*, among others [44]. *Bacillus* spp. also secrete several lytic enzymes, such as chitinases, β-1,3-glucanases, β-glucosidase, lipases, and proteases, which have the ability to degrade the components of the fungal cell wall, such as chitin, β-glucans, and proteins. However, the antagonistic activity of enzymes can rely on quorum quenching, which interferes with quorum-sensing molecules used by several pathogens. This is the case of lactonase enzymes, which have been found in several *Bacillus* and which interfere with *N*-acyl-L-homoserine lactones, well-known quorum-sensing molecules. Moreover, *Bacillus* strains have a wide arsenal of chemical compounds with antifungal and antibacterial activity against different phytopathogens, such as macrolactins or bacteriocins. A recent study suggested that *B. amyloliquefaciens* L-1 was a good biocontrol agent against pear ring rot [45]. *Bacillus* species can produce some metabolites, molecules, or chemical compounds inducing systemic resistance, which is an immune response expressed in all plant organs [46]. *B. subtilis* strain (UMAF6614) induced SA secretion and JA defense-related responses in melons, making the plants more resistant to powdery mildew [47].

As mentioned before, the *Bacillus* genus is a great factory that produces several chemical compounds with different activities that benefit the health of the crops. However, there are some factors affecting the production of these secondary metabolites, which can be important to better understand the real impact of these compounds on crops and agriculture. Abiotic factors, such as temperature, pH, and oxygen availability, have been the most studied, which influence the production of several metabolites in plant-associated microbes [44]. Biotic factors are also very important. For rhizosphere establishment, root exudates are essential, which provide nutrients for the plant-associated bacteria. Additionally, in this complex ecosystem of the rhizosphere, *Bacillus* has to compete with other microorganisms secreting several metabolites to fight against fungal and bacterial competitors [44]. It is important to highlight that sometimes *Bacillus* can interact with other beneficial microorganisms that have synergistic effects in protecting plants against pathogens and promoting plant health and growth.

It is mandatory to highlight the extended use of *B. thuringiensis* as a biopesticide worldwide. This bacterium secretes, along with spores, specific insecticidal proteins called Cry proteins, which are toxic against different insect orders, including some pests that attack important crops causing economic losses. These insecticidal delta-endotoxins are applied on the plant leaves or mixed with the soil and are specifically toxic against lepidopteran, coleopteran, or dipteran insects, as well as nematodes, depending on the type of Cry toxin secreted by each subspecies. Upon ingesting, the toxins are solubilized by the alkaline conditions in the insect midgut and are subsequently proteolytically converted into a toxic core fragment, which binds to the receptors of the apical microvillus membranes of epithelial midgut cells [48]. Then, the toxins' conformation changes and gets inserted into the cell membrane and forms pores, which leads to an osmotic imbalance until the cell rupture. This leads to the loss of midgut epithelium integrity, resulting in insect death caused by bacteremia and tissue colonization [48]. For this reason, many commercial products of *B. thuringiensis* bioinsecticides have been available in the market [49].

Despite being one of the most widely used biopesticides, it has had to overcome several obstacles. One of the major problems of *B. thuringiensis* bioinsecticides is that they are applied by spraying the leaves of crops. This is a limitation since it does not cover the whole plant [50]. For this reason, *B. thuringiensis*-based transgenic crops have been used. This has been the cause of an arduous debate about the possible risks to human health by consuming this type of food [51].

However, the extended use of these biopesticides generated some resistance in the insect population to the toxins. For this reason, the search for new *B. thuringiensis* strains secreting new insecticidal proteins was the objective for many years. With genetic molecular tools in hand, it has been possible to develop protein engineering and genetically modified crops, which constitutively express toxins. This has generated a great debate around the safety of genetically modified foods without so far having scientific proof of their risk to humans. There have been many reports ensuring the safety of *B. thuringiensis*-based crops for human consumption and health [52].

5. Practical Implications of This Study

Beneficial organisms in the rhizosphere zone provide the first line of defense against soil-borne diseases by competition or antagonism. There are two major types of induced resistance that are induced in response to signals from microorganisms: systemic acquired resistance and induced systemic resistance. The second is the result when plant roots are exposed to promoting rhizobacteria in the soil. Several growth-promoting microorganisms, such as bacteria or fungi, have been explored, which can be especially helpful in situations in which plants might be under stress, such as in soils with low organic matter content or soils that tend to be dry, since environmental stresses, such as salt and drought, play another important role in reducing biological activity.

One of the major problems with the use and commercialization of biofertilizers is that, in almost all cases, biofertilizers have been applied in laboratory conditions and greenhouse conditions; however, they do not perform the same way in the field. This may be because the crops are grown under different environmental conditions, such as temperatures, rainfall, soil type and crop diversity, leading to different results of applying biofertilizers in field conditions. This can be the reason why farmers would not be able to adopt biofertilizers so easily [26].

There is a need to understand the factors affecting the production of secondary metabolites to understand their exact role in inhibiting some pathogens and their role in stimulating immunity in crops. Another point to consider is the shelf life of the biofertilizer since the biofertilizer contains live microbial cells with a short shelf life (approx. 6 months, under 20–25 °C), and their storage and transportation require extra care and precaution, increasing the product cost. Moreover, regulatory issues in product registration due to the lack of a regulatory definition for plant biofertilizer or plant biostimulant make the process of product registration quite complex, time-consuming, and complicated [53].

The potential of the *Bacillus* species to be a biofertilizer or to control plant diseases has been widely reported, leading to the successful commercialization of *Bacillus* products. *Bacillus* species have the capacity to produce a wide range of secondary metabolites that play multiple roles in protecting crops and improving plant growth. It is important to remember that these metabolites can be isolated from microorganisms at very low yield, making their structural characterization and studying their biological activities, both in vitro and in vivo, difficult. It is necessary to develop new technologies to solve this problem [54].

Genome-based computational tools have advantages over traditional strategies for investigating *Bacillus thuringiensis*, including identifying the bacterial strain (16S rRNA-based approach), genome sequencing (PacBio or Illumina MiSeq), genome annotation and assembly (HGAP), and bioinformatics analysis viz. GeneMarkS, SwissProt [55]. This could be a way to develop new compounds by controlled applications of holographic microscopy, genetic engineering, bioinformatics, and deepCNN [56]. With the search for new strains, new compounds can be isolated from them with many possibilities of using the new compounds in agriculture, especially considering that many compounds can be used as antifungals or hormones or have some role in plant growth. Microbial-product-based technology needs to be researched profoundly and improved to elicit desired results and gain the trust of the farmers, the real stakeholders of agriculture.

6. Conclusions

Soil quality is an essential factor affecting a crop's health. Therefore, for years, farmers have paid attention to improving the quality of soils using chemical fertilizers and pesticides. However, there have been several problems with chemicals, such as environmental pollution and health problems. The issues related to food safety and the need to consume more healthy products have changed the consumer demand for organic food, leading farmers to adopt sustainable agricultural practices. This has been the main reason for using more green and friendly methods, such as using biofertilizers and biopesticides. The ultimate purpose of ecological soil management is to create a healthy habitat belowground, with a good soil structure, thriving and diverse soil organisms, and nutrients in sufficient supply for high crop yields without causing pollution. As such, plants are provided with the optimal conditions for their growth and protection against pests. These ecological practices can be grouped into these strategies: grow healthy plants with defense capabilities, suppress pests, and enhance beneficial organisms. In this sense, there are many beneficial microorganisms that can be used to improve the quality and yield of crops.

Beneficial microorganisms play an important role in sustainable agriculture since they can support plant growth and act against pathogens in an environmentally friendly way. *Bacillus* genus has been demonstrated as very successful in this sense since it plays both the biofertilizer and biopesticide role. In this review, the main roles of beneficial microorganisms in agriculture have been highlighted, focusing on the *Bacillus* genus, which has been the most commercially used. There are many studies about the advantages and benefits of microbial products in agriculture; however, it is necessary to pay attention to the challenges that face microbial biofertilizers and biopesticides so that we can increase their use.

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