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Literature Review

Evaluation of biological agents with cover crops for sustainable agriculture: Literature review

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Summary

Cover crops combined with biological agents constitute a promising alternative to improve soil health and contribute to the environmental sustainability of agricultural systems, for which a search has been carried out whose objective was to carry out a critical analysis of the existing literature on agents, bioremediation with cover crops for sustainable agriculture. In exploratory non-experimental research, a content analysis of scientific articles identified in the Web of Science databases and through Google Scholar was carried out. It was investigated starting in 2012 for a period of 10 years regarding the type of documents, field of thematic area, number of publications per year, and leading countries. Of the types of documents analyzed, 58 works corresponding to scientific articles were selected, of which, most of them located in the area of microbiology, whose set of results shows that the highest number of publications was reached in 2021, with 31 %. For the countries that publish the most on the subject, the People's Republic of China is leading with 57%. These numbers plot the publication outlook for the topic based on the selected keywords; and reflect a continuous increase in published works on the implementation of this production technique to provide solutions based on sustainability, safety, and food security. However, studies are required that make it possible to strengthen management systems in order to increase their reliability and performance in producers.

Introduction

The Dominican Republic faces its main challenges as it is affected by projections of impacts generated by the intensification of land use and human actions, the effects of which have led to its degradation, as well as the appearance of pests and diseases [1] resulting in one of the most common problems in the agricultural sector and violating the food security and independence of the Dominican population [2]. The production conditions with cover crops come to support the demands of the markets for more harmless products, in addition to contributing to the demands of quality standards by international markets [3].

This condition is lost if farmers do not keep crops in the field, contributing to there not being enough leaf biomass, and therefore the soils remain uncovered, favoring erosion, rapid mobilization of water, loss of nutrients through percolation, and above all, loss of the soil layer. Therefore, not maintaining a balance in carbon sequestration and nutrients, contributes negatively to the agricultural system and environmental pollution [4]. Cover crops represent a positive alternative to improve the carbon balance and protection of the soil, which has an enormous capacity to store this element in organic form with appropriate management measures. At times when there is no crop in production, it is necessary to identify alternatives that keep the soils covered, and cover crops, when kept in the field at those times, are the best option. Although these crops do not generate a direct economic benefit for farmers, there is a way to take advantage of them, in addition to providing benefits to the environment, is to try to make combinations between cover crops and potential beneficial microbes that can then help the producer in its subsequent cultivation [5].

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Studies of this nature project the need for research into the problem of the interaction of biocontrol agents in combination with cover crops in agricultural production systems, as this country has very few scientific documents referring to the subject, which assist government authorities and all actors in the agricultural sector to better decision-making regarding sustainable agriculture [6].

The benefits of this combined system could be the reduction of soil erosion, reduction of loss through deep percolation of nutrients, reduction of water loss, increase of carbon sequestration, maintenance of beneficial insects in agricultural systems, and therefore subsequent benefit in the productivity of the next crop [7]; Therefore, this work aims to address the large losses in productivity that have caused the reduction and deterioration of the soil due to erosion and poor management, proposing as an alternative the implementation of legume cover crops, necessary to establish to validate and transfer technologies to technicians and producers in the country.

The objective of this work is to present an analysis of the studies published during the last ten years on the interaction between beneficial organisms (*Bacillus subtilis*, *Beauveria bassiana,* and *Trichoderma harzianum*) and cover crops (*Canavalia ensiformis*, and *Vigna unguiculata*). This literature review responds to the interest in focusing on a sustainable agriculture management model that minimizes the environmental impacts generated by the misuse of soils and dysfunctional agricultural systems in the Dominican Republic.

Methodology

This methodology is based on an exploratory non-experimental design that searches different bibliographic sources on the topic: Evaluation of biological agents in combination with cover crops to promote sustainable agriculture in the Dominican Republic.

In this bibliographic review document, the Web of Science database was used, in the period 2012 - 2021, with some exceptions that we consider very important for each section, with the keywords in both English and Spanish: cover crops, interaction, biomass, biocontrol microorganisms, sustainable agriculture, interaction and biomass and microorganisms, through the EndNote Bibliographic Manager for the references that cover the research document in the different search strategies for each case, using the chain of keywords per section: I. Legumes, biomass, soil cover; II. Biomass, soil cover, beneficial organisms; III. Beneficial organisms, legumes, biomass, land cover, interaction, using the logical connector "or" in the search string for Spanish. The data obtained in the search were managed in the Microsoft Word 2010, word processor and Excel for the preparation of tables and figures [8]. The existing information was reviewed, the bibliographic material was selected according to the topic to be discussed and then the document was structured coherently, the review was limited to the type of document found in the highest percentage, excluding the types of documents with less relevance.

Results

A number of 117 documents were found among them were scientific articles (58), books (9), theses (10), and web documents (40) (Figure 1); The information was filtered to scientific articles with a total of 58 selected for this review because they presented the highest percentage compared to the other types of documents; filtered into the fields of thematic areas related to environmental sciences, microbiology, agronomy and mycology (Figure 2); filtered by number of publications per year (Figure 3) and by leading countries (Figure 4) for the last 10 years.

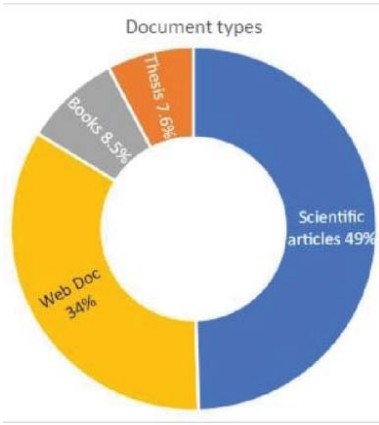

Figure 1: Distribution of publications by type of documents referring to the topic in the period 2012-2021.

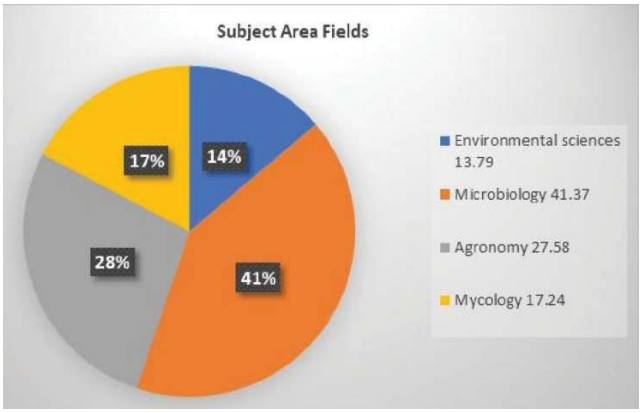

Figure 2: Distribution of publications by thematic area field in the period 2012-2021.

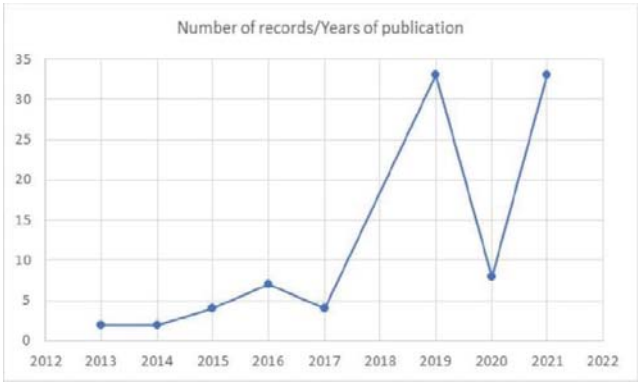

Figure 3: Distribution of publications by year in the period 2012-2021.

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Figure 1 shows the percentages of the types of documents found in the search on the topic, indicating that, of the 117 documents found, the type of document corresponding to scientific articles reached the highest percentage with 49%, representing almost half of the total. of publications, followed by web documents with 34%, followed by books with 10%, and finally theses with 9% with the lowest number of publications. These numbers show that scientific articles have supremacy over the other types of documents analyzed.

These data were similar to those obtained by Fula Sandoval, et al. (2018) in their review of books and theses, finding a slight difference in Web documents compared to scientific articles, exceeding it by 13%, moreover, in our work, scientific articles surpassed Web documents by 15%, this indicates that as the years go by, the publications of scientific articles on the subject have increased.

Figure 2 shows the fields of thematic areas with the greatest relevance to the topic for the 58 selected articles, headed by microbiology with 41% of publications, followed by agronomy with 28%, followed by mycology with 17% and finally the environmental sciences with 14% with the lowest number of publications. These numbers represent the number of publications per subject area on biological agents with cover crops, in accordance with Morales, et al. [9], where publications on the topic have been increasing, reaching more than 40% of publications in the microbiological area.

Figure 3 shows that, in the last 10 years, the highest number of publications was reached in the years 2019 and 2021, with a total of 33 documents published for both. In 2020, a significant decrease was noted in this sense with only 8 publications, taking the increasing trajectory again in 2021, followed by 2016 with 7, and 2015 and 2017 with 4. A lower number was found published in 2013 and 14 only getting 2 publications between each other; In 2012 and 2018 there was no publication on this topic with the selected keywords, so they are not presented in the graph.

According to Sandoval, et al. (2018), publications regarding the topic reached an uptick in 2016, however in our review, this enhancement was reached in 2021. These numbers trace the trend of publications per year of the proposed research topic, indicating that in recent years there has been an increase in interest in seeking solutions to scientific problems that concern the community in terms of plant protection.

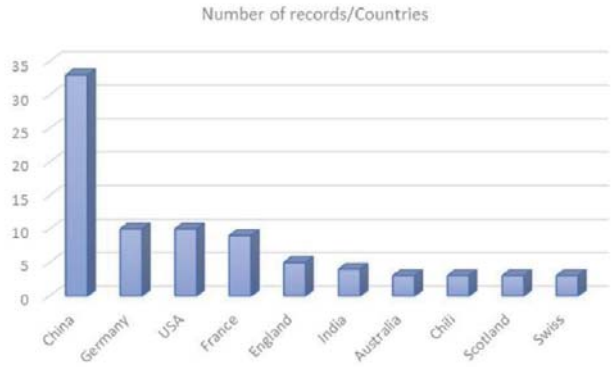

Figure 4: Distribution of articles among the ten leading countries on the topic of biocontrollers with cover crops in the period 2012-2021.

The countries that publish the most on the topic are shown in Figure 4, indicating that the highest number of publications was reached in the People's Republic of China, reaching 33 publications for 56.90% of the total, followed by the United States and Germany with 10 respectively. for 17.24%, followed by France, England, and India with 9, 5, and 4 for 15.52, 8.62, and 6.90%, the other countries, Australia, Chile, Scotland, and Switzerland had the same number of publications with 3 documents each for a 5.17%. These numbers plot the perspective of publications by country on the topic related to my thesis based on the selected keywords. According to data provided by Peña Borrego, et al. [10], the countries that contributed the most to research results are China and the United States regarding the topic. The Dominican Republic is not on the list of leading countries in publications on the subject because it has little information on the subject, which is why, currently, it makes its best efforts with research projects that support sustainable agricultural systems.

These results indicate that this research topic continues to be an active line of research that is increasing, given the publications of the last 10 years, reaching a greater number of reports for the year 2021, led by the People's Republic of China; moved by the facilities of a technology that is necessary on a daily basis to stimulate this field in the country. The issue of sustainability in its dimensions is emphasized, taking into account the need for countries to reduce soil pollution, and promote the use of beneficial organisms that contribute to this cause, food security, and other biological groups.

Effect of two legumes *Canavalia ensiformis* and *Vigna unguiculata* used on biomass production and soil cover.

Soil health is the ability of soil to function as a vital living system, within the boundaries of the ecosystem and land use, to support productivity, maintain or improve water and air quality, and promote health. vegetable and animal [11]. Methods have recently been described to understand the functioning of plant communities and improve crop production strategies that correspond to healthy soil [12]; There is a group of crops that have highly branched roots with a higher biomass than other groups of plants, which provides more habitat for root-associated bacteria such as legumes [13].

Legumes have a prominent role in maintaining agricultural productivity, they are grown due to their ability to interact with nitrogen-fixing bacteria and can also be used in rotation systems to control pests, diseases, and weeds [14]; Therefore, in this section I, based on a bibliographic review, the scientific information on legume cover cropping systems used on biomass production and soil cover is summarized to achieve cleaner productions, since it is an environmentally friendly production technique and has proven to be effective and sustainable. These crops are a key piece of sustainable agriculture systems [15]. However, diseases caused by soil pathogens limit their establishment when they are favored by

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environmental conditions such as low temperatures and high levels of humidity [16]. In agriculture, legumes are used to improve soil texture and add nitrogen fixed by bacteria of the genus Rhizobium [17].

Legume cover crops, especially *Canavalia ensiformis* and *Vigna unguiculata* (Figure 5, a and b), increase biodiversity in agroecological production systems [18], measuring their importance in the impact of the erosive process on the soils as a strategy to minimize the losses caused by rain, adding the contribution to soil fertility that the plant mass makes when decomposing (Figure 5c), the competition with herbicide-resistant weeds and the improvement in water intake to the soil profile, thus contributing to the conservation and improvement of soils, making them more productive (Figure 5d) through conservation agriculture as a response to the problems of soil degradation caused by agricultural intensification [19].

Cover crops provide practical alternatives to address other agricultural side effects as reported by Neelipally, et al. [20], indicating that consecutive monoculture can cause a constant decrease in yield and productivity, as well as an increase in susceptibility to diseases; Therefore, the soil microbiome, being a crucial component of soil health [9], it is necessary to evaluate the response to cover crops to support their viability as a conservation practice [21]. The cover crops most used in the Dominican Republic are *Canavalia ensiformis*, *Vigna unguiculata*, and *Pueraria phaseoloides*, being used sporadically in all national production areas [22], without reporting considerable data on these species. only having reports of harvestable species (*Phaseolus* sp.) (M. A., personal communication, Devares, 2022).

Effect of three biocontrollers *Trichoderma harzianum*, *Beauveria bassiana*, and *Bacillus subtilis* acting on biomass production and soil cover

Most farmers use chemical control agents to combat diseases, but the environmental, economic, and social risks are very high [23]; Therefore, in this section II, based on a bibliographic review, the scientific information on biocontrollers acting on biomass production and soil cover is summarized. According to Pedraza, et al. [24], the use of agrochemicals can generate harmful impacts on the environment; Bacmaga, et al. [25], indicated in their work that insecticides alter the composition of the soil microfauna, causing its impoverishment and therefore, reduction in production capacity. Likewise, Neuwirthová, et al. [26], corroborate with Bácmaga saying that fungicides negatively affected the populations of fungi and bacteria in the soil, and pesticide residues could remain in the soil for a long period after their application; Therefore, the replacement of these with microorganisms is presented as a valuable alternative to achieve sustainability in production systems; The use of bioremediation represents a new technology considered clean, therefore the incorporation of organisms (*Bacillus subtillis*, *Beauveria bassiana,* and *Trichoderma harzianum*) selected in this research for their functions in the development processes of healthy soil.

Figure 5: a: Cover crop *Vigna unguiculata*; b: Cover crop *Canavalia ensiformis*; c: Cultivation incorporated into the soil; e: Soil improved with cover crop.

In the 1980s, Japanese doctor Teuro Higa created a technology related to the use of efficient microorganisms that served as the basis for new reviews that provide information on the groups of beneficial microorganisms such as fungi and bacteria present in natural ecosystems [27]. Soils are important for providing ecosystem services and are a fundamental component of the ecosystem, which constitutes a non-renewable resource; Microorganisms are responsible for carrying out a large part of soil functions [28]. Although bacteria are the most used in the bioremediation process, other microorganisms such as fungi, algae, cyanobacteria, and actinomycetes have also been used for the degradation of toxic compounds in the soil [29]. The relationship that exists between the structure and function of microbial communities continues to require studies that link these aspects focused on processes of environmental relevance [30]. Fungi were the first microbial agents used to control insect pests [31]. Microorganisms can infect their prey through multiple mechanisms of action, which gives them a high capacity to prevent the host from developing resistance [32].

The Dominican Republic has enormous potential for the biological control of phytopathogens, however, there are few reports and publications on experiences carried out in this thematic area (Serra, et al. 2011), however, the importance of the soil microbial population has been highlighted, which serves as a genetic reservoir, with great diversity that houses great biotechnological potential. Microbial activity is capable of altering its environment and this regulates its activity; therefore, altering the edaphic environment has an impact on the various functions carried out in the soil microbiota [33]. According to Cedeño [34], mycorrhizal fungi colonize approximately 90% of vascular plants, and in agroforestry systems, there is a heterogeneous organization; therefore, knowing this reality, the country maintains active soil improvement programs with the use of agents biological through the Dominican Institute of Agricultural and Forestry Research (IDIAF), universities and other institutions committed to research (Araujo, 2020). At the same time, (Gregorutti, et al. 2021), studied the effect of cover crops and additions of organic amendments, applied to the soil surface without the presence of a living plant cover, on the abundance and activity of nitrifying microorganisms and cellulolytic, which allowed them to identify the effect of the

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addition of the residue of cover crops and organic amendments, on the dynamics of the microorganisms under study.

Núñez, et al. [6] carried out the characterization of native mycorrhizae in soil and roots from livestock farms in Montecristi, Dominican Republic, evaluating the variable responses of the number of spores and the percentage of mycorrhizal colonization, where the presence of spores of mycorrhizal fungi in soil was found and roots, identified 9 morphotypes of spores, of which they characterized three genera: *Glomus*, *Acaulospora* and *Gigaspora*, by PCR and identified the existence of the genus *Paraglomus*. (González, 2020) isolated spores of native mycorrhizas for selection and classification, from livestock farms in Montecristi, Dominican Republic. The greater presence of spores in certain farms and the presence of mycorrhizal-forming propagules and other similar structures such as vesicles and hyphae, as well as similar to the Glomus sp genera, were determined. and *Acaulospora* sp.

The data revealed in this research highlight the great importance of beneficial microorganisms as components of the soil remediation technique, finding the most recognized biocontrollers to antagonistic fungi such as *Trichoderma* spp., *Coniothyrium minitan*, *Beauveria* sp., competitors such as *Pythium oligandrum* or bacteria such as Bacillus sp. [35]. The list within which the organisms selected for our research work are found; their conditions represent having a great capacity to store nitrogen and phosphorus, representing a food source for soil fauna; their developed defense mechanisms to defend themselves against their enemies, such as chemical weapons and the formation of crystals in the mycelium [36].

The importance of the use of bioremediation microorganisms with phytoremediation plants is framed within the Sustainable Development Goals (SDG) concerning No. 12 and 15, consisting of promoting the sustainable use of terrestrial ecosystems (ECLAC, 2018). It also corresponds with the General Law of the Environment and Natural Resources (Law 64-00) (Of the Executive Branch, 2000) chapter I, in its articles 4, 5 and 16, and with the National Development Strategy (Law 1 -12) in its objective 3.5.3 to increase the productivity and environmental sustainability of agricultural production chains, in order to contribute to food security (Del Poder Executive, 2012), without the use of agrochemicals in agricultural systems, which ensures the food safety using environmentally friendly options that do not affect human health.

Interaction between the biocontrollers *Trichoderma harzianum*, *Beauveria bassiana*, and *Bacillus subtilis* and the cover crops *Canavalia ensiformis* and *Vigna unguiculata*

Conventional agricultural management practices, such as the extensive use of pesticides, have a significant impact on the environment [37], increasing the greenhouse effect [38], reducing biodiversity, and increasing toxicity in the chain food. Such practices could have serious impacts on the soil environment and more specifically on the microorganisms that comprise it; Therefore, in this section III, based on a bibliographic review, the scientific information on the interaction of biocontrollers and cover crops in agricultural systems is summarized.

In the agricultural sector, there is a group of microorganisms that has gained special attention due to their potential to protect plants against fungal pathogens [39] who stated that information on interactions between plants and microbes is mainly based on monocultures. of plants. Biocontrol fungi, despite being one of the most important fungal components in agriculture, in the Dominican Republic there are no studies that specifically examine the interactions between these agents and legume species, which is where the importance of our work lies. Some researchers have shown that fungal communities differ from each other and that they present interaction networks [40]. Plant-microbe interactions drive plant performance to a large extent, so in accordance with [39], soil biocontrol agents influence, in addition to the acquisition of nutrients, the protection of plants from Other damaging agents, likewise, enhance plant immune responses and stress tolerance and improve plant growth [41]. Work has been carried out that demonstrates the effects of plants on the effectiveness of biocontrol microorganisms and that these are influenced by changes induced by plants in these communities [42].

Eisenhauer [43] said that the effects of soil microorganisms on plant growth depend on plant diversity. Dormann, et al. [44] devised a matrix as a model to evaluate interactions between species. Penon [45] says that organic farming practices help fertilize the soil, increasing microbial activity and biomass, and elevating soil microbial diversity, thus affecting soil microbes in its structure. Lerna and Mauromicale [46] discussed the need for more environmentally friendly viable alternatives to increase productivity and improve soil quality, demonstrating that these are increasing. Bizos, et al. [47] described the use of bacteria and fungi as inoculants to improve crop production. Seguel, et al. [48] in their work on soil inoculation with plant growth-promoting rhizobacteria demonstrated beneficial effects on plant growth and identified the genera that are most frequently used in sustainable agriculture. Aviléz-Alvear [49] indicated that Pseudomonas species can suppress the growth of soil pathogens by inducing systemic plant resistance. Alori, et al. [50] determined that Bacillus-based inoculants have demonstrated important biocontrol properties by inhibiting the growth of plant pathogens due to the secretion of antifungal compounds or toxins. Pedraza, et al. [51] demonstrated that certain fungal species can increase the concentration of essential soil nutrients.

Trabelsi and Mhamdi [52] pointed out that, during recent years, many studies have been carried out to investigate the effect of microbial inoculants in various varieties, achieving a significant impact on a wide range of interactions with other microbes such as competition, synergy. or prey-predator interactions [53].

The potential of biocontrol agents in legume species has been widely studied to reduce contamination by soil pathogens [20]. Anna-Todd [54] describes the biological activity of 6-pentylapyrone, a secondary metabolite produced by *T. harzianum* that has been involved as a regulator of plant development. Burbano-Orjuela [55] stated that the survival and role of soil microorganisms are important for soil ecosystems

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because they participate in key processes, such as the cycle of minerals, and the decomposition of organic waste, among others. Li, et al. [56] noted that the continuous secretion of exudates by the roots of legume species affected the microbial diversity in the soil.

These data encourage us to carry out new field studies to evaluate the interaction of biocontrol agents with cover crops for sustainable agriculture in the Dominican Republic, based on the concept of improving the agroecosystem with minimal dependence on agrochemical and energy inputs, in which Synergistic microbial interactions provide the system with the mechanism to support soil fertility and protect crops. From this section it is expected that the biocontrollers will have suppressive effects on microbial pathogenic biomass in the foliar biomass of cover crops, resulting in a narrower range of interaction responses and microbial attributes compared to the relevant effects recorded in the organic management system.

Perspectives in research and development of sustainable systems

According to the results analyzed in this article, the proposal for Evaluation of biological agents in combination with cover crops to promote sustainable agriculture: Bibliographic review will have a positive environmental impact over time, which is expected to generate scientific data that provides useful information for the management of sustainable agriculture in the Dominican Republic, so the results obtained in our review will be used as a means of verification together with the presentation of both national and international scientific works. Talks and discussions will be held with producers at the national level in support of the training projects of the Ministry of Agriculture and will contribute to the application of policies for change and sustainable use of cultivated soils.

According to the authors of this review, research and applications of cover crops in interaction with beneficial organisms are aimed in the coming years at maximizing the efficiency of production systems by implementing technologies that are in accordance with the environment [57-66].

Conclusion

This review study highlights the importance of the evaluation of biological agents in combination with cover crops to promote sustainable agriculture in the Dominican Republic. The expression variables of the effects of cover crops (*Canavalia ensiformis*, and *Vigna unguiculata*), beneficial organisms (*Trichoderma harzianum*, *Beauveria bassiana*, and *Bacillus subtilis*), and the interaction between these on biomass and soil cover seen in their respective sections, consistently impacted a better production system. The results suggest that plants can manage specific microbial activities with important consequences for soil health. The legume species studied improve plant productivity through symbiosis between nitrogen-fixing bacteria and increased biomass production.

The use of biological agents in combination with cover crops is referenced in various bibliographies, especially in the areas of microbiology and agricultural sciences in the search to promote sustainable agriculture. The lack of studies on organism-crop interaction made the search for information not as effective. It was evident that microorganisms have been studied as much as cover crops, however, more studies are needed to evaluate the effectiveness of the interaction of this consortium to support sustainable agriculture, since in our country there is no information on the potential interaction of this association, we do not know if it is possible to establish them and if possible, the incident factors must be identified, which is why it is necessary to continue working on this aspect.

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