e-ISSN 1983-4063 - *www.agro.ufg.br/pat* - Pesq. Agropec. Trop., Goiânia, v. 53, e76326, 2023

Review Article/Special Supplement: Bioinputs in Agriculture

Bioinputs and organic production in Brazil: a study based on the Embrapa's Bioinsumos application[1]

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ABSTRACT

The use of bioinputs has been intensified in conventional and organic systems. In Brazil, the National Bioinputs Program was instituted to enhance their production and use in crops, and the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) launched the Bioinsumos (bioinputs) application, containing the bioproducts registered by the Brazilian Ministry of Agriculture, Livestock and Supply. This study aimed to identify the classes and number of bioinputs for phytosanitary control included in the Embrapa's Bioinsumos application with authorized use for the organic agriculture in the country. There are 526 bioinputs for the phytosanitary control of several pests and diseases in various agricultural crops, which are divided into eleven classes, of which only two do not have bioproducts for organic agriculture: microbiological bactericide and pheromone. Despite the number of bioinputs for organic agriculture, in practice, their use is still reduced, what may be related to limited financial resources, lack of knowledge of their existence and the ways of using them. Thus, it is necessary a greater incentive and public guidance for the development of bioinputs with greater accessibility for rural producers, especially for those who work with organic agriculture.

KEYWORDS: Agroecology, sustainable agriculture, pesticides, organic products, conservation of natural resources.

RESUMO

Bioinsumos e produção orgânica no Brasil:
um estudo a partir do aplicativo Bioinsumos da Embrapa

O uso de bioinsumos tem sido intensificado em sistemas convencionais e orgânicos. No Brasil, foi instituído o Programa Nacional de Bioinsumos para potencializar a produção e uso destes nos cultivos, e a Empresa Brasileira de Pesquisa Agropecuária (Embrapa) lançou o aplicativo Bioinsumos, no qual constam os bioprodutos cadastrados no Ministério da Agricultura, Pecuária e Abastecimento. Objetivou-se identificar as classes e o número de bioinsumos para o controle fitossanitário inseridos no aplicativo Bioinsumos da Embrapa, com uso autorizado na agricultura orgânica do país. Existem 526 bioinsumos destinados ao controle fitossanitário de diversas pragas e doenças em várias culturas agrícolas, os quais estão divididos em onze classes, das quais apenas duas não possuem bioprodutos para a agricultura orgânica: bactericida microbiológico e feromônio. Apesar do número de bioinsumos para a agricultura orgânica, na prática, o uso destes ainda é reduzido, o que pode estar relacionado aos recursos financeiros limitados, não conhecimento da existência e das formas de uso destes produtos. Faz-se necessário maior incentivo e orientação pública para o desenvolvimento de bioinsumos com maior acessibilidade para os produtores rurais, especialmente para aqueles que trabalham com agricultura orgânica.

PALAVRAS-CHAVE: Agroecologia, agricultura sustentável, defensivos agrícolas, produtos orgânicos, conservação de recursos naturais.

INTRODUCTION

Agriculture is one of the most representative and important human activities. It represents different aspects of humanity, which include the economic, social, cultural and environmental spheres. Agriculture can be considered the dawn of humanity. Thus, it is worth noting the great challenges that this sector faces to maintain production and profitability, while seeking sustainable alternatives to fight pests and diseases that usually affect crops.

Therefore, it is necessary to emphasize the lack of techniques and technologies organized for supplying inputs that do not compromise human health and natural resources, such as soil and water (Vidal et al. 2021). This theme represents a historical approach among scholars and practitioners of sustainable agriculture, such as organic agriculture. Using alternative products to synthetic inputs is a way to ensure the conservation and increase biodiversity in cultivation areas and, consequently, guarantee the sustainability of the practiced agriculture.

[1] Received: May 31, 2023. Accepted: Sep. 04, 2023. Published: Sep. 29, 2023. DOI: 10.1590/1983-40632023v5376326.
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Modern agriculture is characterized as a simplification of the environmental structure in large areas, where natural diversity is reduced through the implementation of monocultures (Marchese & Filippone 2018). Thus, it results in greater problems regarding pest control in simplified production systems (Letourneau et al. 2011). The severity of the attack of pests and diseases and the increased use of synthetic chemicals for phytosanitary control in these agroecosystems evidence it.

Thus, offering products that control pests and diseases has been seen as an alternative to synthetic chemical pesticides that directly contribute to reducing agroecosystem biodiversity. Some researchers have already reported that this need for sustainable food production is a key factor in maintaining the life quality of rural and urban populations. Furthermore, they emphasize that research, extension, teaching and industry institutions have an important role in the success of this agriculture with a sustainable focus (Marchese & Filippone 2018, Vidal et al. 2021).

In this perspective, several research institutions, including universities, have sought to develop sustainable products: bioinputs. Thus, disseminating these products and the knowledge of the purpose of each one is widely realized. The Empresa Brasileira de Pesquisa Agropecuária (Embrapa) and other research agencies developed the Bioinsumos (bioinputs) application, which offers the options of bioinputs registered by the Brazilian Ministry of Agriculture, Livestock and Supply in the Bioinputs National Catalog, as well as relevant information on their use in agriculture (Embrapa 2020a).

In addition to these guidelines, it is possible to detect which bioinputs can be used in organic production systems. Moreover, this global agribusiness sector (organic agriculture) has grown significantly in recent years due to the increased demand from the consumer market, which has sought food free of pesticide residues and sustainably produced. From 2000 to 2017, there was an increase of 365 % in the area cultivated with organics on the planet (IPEA 2019), as well as an increase from 15 to 69.8 million hectares cultivated. In this period, the largest producers included Oceania (with 51 % of the world's organic agricultural area) and Europe (21 %), followed by Latin America (11 %), Asia (9 %), North America (5 %) and Africa (3 %).

This scenario shows the need to develop alternatives for the phytosanitary management of crops in Brazil and worldwide. Therefore, this study aimed to identify the classes and quantity of bioinputs for phytosanitary control (pests and diseases) included in the Embrapa's Bioinsumos application authorized for use in organic production systems in Brazil.

MATERIAL AND METHODS

This study was conducted from January to May 2023, based on the Bioinsumos application made by the Empresa Brasileira de Pesquisa Agropecuária (Embrapa) in partnership with several research institutions, which catalogs all the bioinputs currently existing in Brazil and proposes to guide rural producers to use those that cause less damage to the environment and to the human organism itself (Embrapa 2020a).

The products registered in the Ministry of Agriculture, Livestock and Supply are inserted in the application and divided into two categories: pesticides (control of pests, diseases and nematodes) and inoculants (plant growth promoters). Furthermore, by using this application, it is possible to detect which bioproducts can be used in organic production systems. Since not all bioinputs are considered organic, not all have their use released in organic production systems.

All bioinputs were studied, and classifications regarding their use (defensive or inoculant) were observed. Thus, as a selection criterion, we chose to work with those used for controlling pests, diseases and nematodes (defensives) that the Ministry of Agriculture, Livestock and Supply authorizes in organic agricultural production systems.

In addition to the study in the Bioinsumos application, this research is the result of bibliographic surveys based on the studies already carried out with bioinputs, bibliographic review articles with this theme, and official websites of the Federal Government, Embrapa and Instituto de Pesquisa Econômica Aplicada (IPEA), among others.

For the scientific basis, articles published in scientific journals were selected, carefully seeking to relate the research results with the current organic production scenario in Brazil, especially observing the relationship between bioinputs and the organic production increase in the country.

RESULTS AND DISCUSSION

The Embrapa's Bioinsumos application includes 1,081 products, of which 526 are intended to control pests, nematodes and diseases (phytosanitary control) and 555 for inoculation (plant growth promoters). Plant protection products are ordered into eleven classes (Table 1).

Of the 597 bioinputs included in the National Catalog of Bioinputs and found in the application, 332 have been released for use in organic production systems (information found in the application, whose bioinputs that can be used in organic agriculture present, in particular, the following expression: "phytosanitary product with approved use for organic agriculture"), which represent 55.6 % of the total. Among the bioinput classes, the one that represents the highest percentage is the microbiological insecticide, with 267 products constituting 44 % of the total bioinputs inserted in the application.

Among the 267 microbiological insecticides for organic agriculture, 169 have their use released by the Ministry of Agriculture, Livestock and Supply, representing 63.3 % of the total. This percentage is of great relevance, since the Excellence Mig-66 used in the control of whitefly (*Bemisia tabaci* race B) and corn leafhopper (*Dalbulus maidis*) is among these products, which affect plant species of extreme importance for the Brazilian and world economy, such as tomato, soybean, bean, cotton and corn crops (Embrapa 2020a). Therefore, this product deserves to be highlighted, because it contributes to reducing phytosanitary problems in several agricultural species that directly impact the country's gross domestic product.

In addition to causing direct damage to plants, these pest insects (whitefly and corn leafhopper) can be vectors of viruses and favor the high proliferation of fungi belonging to the Capnodium genus (Marín 1987). The current crop conditions have contributed to the increase in the application of pesticides, because they are viruses vectors and can cause direct and indirect damage. Thus, there is a need for preventive measures to control whiteflies in the cultivation of plant species (Queiroz et al. 2016). That is because the level of economic damage is not always related to the amount of insect pests present in crops (Oliveira et al. 2007).

In organic agriculture, preventive control measures are the most used, whether for problems related to pests or diseases (Stoleru & Sellitto 2016). The commonly adopted measures include: using species resistant to insect pests, cultural practices (crop rotation, intercropping, fallow areas, plant pruning), organic fertilization, syrup and plant extracts application, and adequate irrigation management (Altieri 2002), in addition to the use of biological control, as observed by Visconti et al. (2017) for the tomboy banana (*Cosmopolites sordidus*) attack, using the *Beauveria bassiana* fungus, one of the constituents of the Excellence Mig-66.

The aforementioned practices have shown success in organic crops, what may justify the fact that many organic producers, especially family-based ones, do not use bioinputs produced in specialized laboratories, but opt for alternative or preventive control

Table 1. Classification, total number, quantity and percentage of bioinputs registered by the Brazilian Ministry of Agriculture, Livestock and Supply for phytosanitary control in organic agriculture.

Classification	Total number	Number of bioinputs used in organic agriculture	Percentage of bioinputs used in organic agriculture
Acaricide	1	1	100.0
Microbiological acaricide	53	52	98.1
Biological control agent	68	62	91.2
Microbiological bactericide	5	0	0.0
Pheromone	46	0	0.0
Formicide	2	2	100.0
Fungicide	7	6	85.7
Microbiological fungicide	81	22	27.2
Inseticide	11	10	90.9
Microbiological insecticide	267	169	63.3
Microbiological nematicide	56	8	14.3
Total	597*	332	55.6

* The same pesticide can be classified as insecticide, fungicide or acaricide, among others, being cited more than once in the application, what justifies the value higher (597) than indicated on the home page of the application (526).

practices (Souza 2015). Furthermore, the preventive measures adopted by these producers have been efficient and have not compromised their crops when they adopt joint practices such as organic fertilization and foliar application of plant extracts (Marinho-Prado et al. 2018). Corroborating that, Neri et al. (2020) observed a lower incidence of insects in plants sprayed with aqueous neem extract (at 5 %) to control whiteflies in watermelon. The authors found that the extract had a repellent effect on adult insects, which resulted in less attacks on plants and a lower oviposition index. This fact demonstrates that, together with other practices such as crop rotation, the application of plant extracts is a strong ally of organic producers.

On the other hand, microbiological fungicides represent the second class with the largest number of products inserted in the application. However, the percentage of these bioinputs for organic agriculture is only 27.2 %, with products of extreme importance for acting against organisms that cause significant economic damage to crops. Examples include the TrikoSoil used in the control of the wilted diseases of fusarium (*Fusarium oxysporum*) and damping-off (*Rhizoctonia solani*), which affect many crops, from vegetable crops such as tomato to fruits such as passion fruit (Embrapa 2020a).

Several phytosanitary problems affect crops daily, sometimes with a greater severity, such as for nematode attacks. These are parasites that populate the soil, so their control is complex (Araujo et al. 2023). There are 56 bioproducts (microbiological nematicide) for controlling these living beings, and, among them, eight can be used in organic agriculture, such as Nemabac. It is a biological pesticide, whose target is the gall nematode (*Meloidogyne incognita*), which attacks several crops of great national and international economic importance, such as soybean, cotton, bean, sugarcane and coffee, among others (Dias et al. 2010).

No inputs with authorized use in organic production systems were found for the microbiological bactericide and pheromone classes. On the other hand, there are two formicides with the possibility of use in this conservation agriculture. They include Bio Karamujo and Biobait, which are used to control the ants glass-headed sauva (*Atta laevigata*), lemon sauva and red sauva (*Atta sexdens* rubropilosa), which attack several species of economic and environmental interest, such as forest species. Moreover, within the organic production system, the problem with ants has been aggravating and has worried the most diverse professionals in the agricultural and forestry areas.

In order to guide organic and agroecological producers, the Ministry of Agriculture, Livestock and Supply has prepared a booklet with many control methods for pests (including ants), diseases, nutritional management of plants, conservation and soil fertility improvement (Brasil 2016), that seeks to inform about practical, low-cost and accessible technologies for rural producers.

Of the microbiological acaricides class (53 in total), 52 can be used in organic agriculture, representing 98.51 % of the total of bioinputs registered in the Ministry of Agriculture, Livestock and Supply. Examples include the Excellence Mig-66, that acts to fight the *Tetranychus urticae* mite, which usually causes serious economic damage to crops of more than 150 agricultural species in the most diverse botanical families (Zhang 2003). This bioinput is also considered a microbiological insecticide, contributing to the control of insect pests in crop areas (Embrapa 2020a).

The biological control agents class comprises 68 bioinputs, of which 62 can be used in organic agriculture, representing 91.2 % of the total. *Trichograma pretiosum* AMIPA and Trichobio-P are used to control tomato moth (*Tuta absoluta*), soybean caterpillar (*Anticarsia gemmatalis*), fall armyworm (*Spodoptera frugiperda*) and big fruit borer (*Helicoverpa zea*) (Embrapa 2020a).

The use of bioinputs in agriculture has been of great importance, because the search for sustainable technologies by rural producers has been increasingly common. They aim to promote a more efficient agricultural system, both in the economic and socio-environmental aspects (Embrapa 2021). In addition to this information, bioproducts within agriculture may promote a gradual replacement of currently used pesticides and pesticides that have generated several socio-economic-environmental disorders. Furthermore, in recent years, Brazil has been singled out as the largest and leading consumer of pesticides in the world (Oliboni et al. 2023, Pineda et al. 2023).

In this sense, the National Bioinputs Program (Brasil 2020) seeks to meet the increase in demand from the productive agricultural sector and representatives of civil society for alternative products to synthetic inputs especially related to the control of pests and diseases in crops (Embrapa 2020b).

In this perspective, Vidal et al. (2021) highlight that the Program is not focused only on producing new inputs, but directly related to the registration of products for commercialization. The researchers also complement that there are three major thematic axes in the Program: animal, vegetable and post-harvest production, including, at this stage, the processing of products of plant and animal origin.

The current phytosanitary control methods have not been sustainable. Therefore, the proposal of the Program goes against the current environmental damage caused by the excessive use of synthetic chemicals, whose objective is to fight pests and diseases in crops, but also eliminate other living beings (natural enemies) that could contribute to biological control in crops (Embrapa 2020b).

The current way of working with agriculture has contributed significantly to changes in agroecosystems, increasing their vulnerability and dependence on non-renewable synthetic inputs, what reinforces the idea of rethinking current production models and seeking the encouragement of alternative systems for agriculture (Souza et al. 2022).

Due to the excessive application of chemicals in agricultural systems, a reduction in biodiversity has been perceived in simplified agroecosystems (such as monocultures), what does not benefit the environment. However, the need for an increase in the number of biological control agents has been increasingly notorious, and this fact is pointed out as a great challenge to overcome in the current Brazilian agricultural production systems (Almeida 2020). The use of bioinputs is a very viable alternative.

The National Bioinputs Program (decree 10.375/2020; article 2) conceptualizes bioinput as a product, process or technology of different origins (vegetable, animal or microbial) used in the different stages of the production chain of planted agricultural, aquatic or forest systems, and that positively affects the response of living beings and derived substances (Brasil 2020).

Thus, considering the definition of bioinputs within the Brazilian organic production, the used bioinputs differ from those inserted in the Embrapa's Bioinsumos application. That is because producers adopt different techniques, from cultural practices and use of plant extracts to the biological control itself, through the manual collection of caterpillars and beetles, when the crops are carried out in small areas (Göldel et al. 2020).

Even though they were not mentioned in the application, biofertilizers are another important bioinput. Their use has been quite common in organic crops, especially because they favor the soil microbiota, and these organisms present antagonism to edaphic phytopathogens (Visconti et al. 2017).

Organic agriculture is defined as one that adopts practices that do not compromise the quality and biological diversity in a given agroecosystem (Duarte et al. 2017). Souza (2015) states that organic food production is based on technical standards established by the Law 10.831/2003 (Brasil 2003), which seeks to fully conserve the product quality.

Food or organic products are "obtained in an organic system of agricultural production or from a sustainable extractive process and not harmful to the local ecosystem" (Brasil 2003). Therefore, there is an increase in this agriculture area worldwide, and, in Brazil, until 2023, 23,926 organic producers were included in the National Register of Organic Producers of the Ministry of Agriculture, Livestock and Supply (Brasil 2017). Most of these were concentrated in the South (38 %) and Northeast (27 %) regions of the country.

It is worth mentioning that these producers are distributed in three forms of organic conformity assessment existing in the country: audit (certifier), participatory conformity assessment body and social control organization (Brasil 2007). In recent years, the number of organic producers in Brazil has increased considerably, what is encouraging information, as it means more products free of pesticides and other chemical substances available to the consumer market (IPEA 2019).

Furthermore, it is worth noting that, within an agroecosystem, it is essential to have an ecological balance perceptible by the interaction between macroorganisms and microorganisms. This balance enables the maintenance of populations of insect pests and phytopathogens below the economic damage level (Souza 2015). Therefore, organic agriculture adopts several techniques beyond applying organic inputs or bioinputs. Moreover, Gindri et al. (2020) highlight that using bioinputs to maintain plant health is an efficient solution that causes little environmental and human health damage, and may even promote Brazil as the largest bioinput producer and consumer worldwide.

In the case of industrialized bioinputs or belonging to companies that create the bioproduct, no scientific information regarding their use in organic properties in large proportions was found. However, it is believed that their use is more commonly carried out by producers who have an easier access to the Internet, since such bioproducts, in most cases, are acquired only through online sales, what makes it difficult for groups of farmers who are members of social control organizations, for example, to buy them. According to Brasil (2017), they represent 19.7 % of the organic producers in Brazil.

Within Brazil's organic agriculture, specifically in family-based organic agriculture, phytosanitary management uses biofertilizers and plant extracts. These products are not among the bioinputs of the Embrapa's Bioinsumos application; however, they have been essential for advancing the organic agriculture in the country. Biofertilizers, for example, are more streamlined to produce, store and use, when compared to bioinputs produced in the laboratory. Most of the materials making up this bioinput (biofertilizer) can be acquired or found in the production unit itself (farm property), significantly reducing financial costs.

In order to control pests and diseases in organic crops, farmers have adopted preventive or remedial techniques through syrups or plant extracts, and, in some occasions, biological control (Riveros et al. 2021). These authors highlight that, in Brazil, the public sector still makes a low investment in science, technology and innovation focused on agroecological practices, especially the preparation and use of inputs aimed at organic food production. It increases the values of products manufactured in laboratories, such as the bioinputs that appear in the Ministry of Agriculture, Livestock and Supply records.

Moreover, Souza et al. (2022) highlight that, even though there are many advantages regarding the production and use of bioinputs, there are risks of contamination in their production, especially through inadequate handling. Thus, there are risks with residues and contamination by pathogens that enable unforeseen reactions through the interaction among organisms in crops.

The establishment of the National Bioinputs Program by the Federal Government in 2020 has been regarded as an advance to reduce the use of synthetic pesticides that damage the environment and human health, because other options for the phytosanitary management of crops arise. However, the need for investments in many sectors is still paramount, so that these bioproducts can be elaborated and reach organic producers.

In summary, in recent years, organic agriculture in Brazil and in the world has increased significantly, requiring professional scientists to advance research to develop feasible alternatives combined with organic production growth. The use of bioinputs is a very important ally of this agriculture, because it proposes to initially decrease the use of synthetic inputs and, later, gradually replace them. Thus, it will soon result in ecological benefits in agroecosystems, especially regarding the increase in biodiversity in these cultivation areas.

CONCLUSIONS

1. The bioinputs registered in the Embrapa's Bioinsumos application are categorized into 11 classes, of which only nine (acaricide, microbiological acaricide, biological control agent, formicide, fungicide, microbiological fungicide, insecticide, microbiological insecticide and microbiological nematicide) have products with use authorized in organic production systems in Brazil;
2. Among the 526 bioinputs registered in the application, only 332 can be used in phytosanitary management (pest and disease control) in organic agricultural crops in Brazil, as they comply with the current legislation, and the class of microbiological insecticides is the one with the largest number of registrations: 169 bioinputs, representing 17 % of the total registered phytosanitary control products.

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