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Biological inputs, more economy and greater sustainability

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Resumo

Os problemas gerados pelo uso inadequado de agrotóxicos e produtos químicos importados e custosos para garantir a sanidade das plantas têm sido um grande desafio para os agricultores brasileiros. O crescente desenvolvimento e oferta de novos produtos de origem biológica no mercado vêm fortalecendo o portfólio de bioinsumos disponíveis para o sistema de produção. Entre os benefícios da utilização de bioinsumos está a maior sustentabilidade do sistema produtivo, com surtos de pragas menos frequentes, redução dos custos de aplicação, maior eficiência da fixação biológica de nitrogênio e promoção de crescimento de plantas. Esses benefícios irão propiciar maior lucratividade e contribuir para uma agricultura mais sustentável. Dessa forma, esta revisão tem o intuito de descrever algumas das técnicas que podem ser utilizadas na agricultura dentro dos preceitos da agricultura sustentável.
Palavras-chave: bioinsumos; agricultura biológica; rentabilidade; produtividade; sanidade.

Insumos biológicos, mais economia e maior sustentabilidade

Abstract

The problems generated by the inappropriate use of agrotoxins and imported and costly chemical products to guarantee the health of the plants have been a great challenge for Brazilian farmers. The growing development and supply of new products of biological origin on the market is strengthening the portfolio of available bio-inputs for the production system. Among the benefits of the use of bioinputs is the greater sustainability of the productive system, with less frequent outbreaks of pests, reduction in application costs, greater efficiency of biological nitrogen fixation and promotion of plant growth. These benefits will promote greater profitability and contribute to a more sustainable agriculture. In this way, this review intends to discover some of the techniques that can be used in agriculture within two preceitos of sustainable agriculture.
Keywords: bio-inputs; organic farming; profitability; productivity; heal.

Introduction

Agricultural sustainability has been a topic of great global concern, which is gaining more and more importance as the discussions on this issue gain attention in the most different forums around the world. It is indisputable that among the agricultural management strategies available, the use of bio-inputs (inputs of biological origin) is among the most sustainable. Before being considered a definitive and immediate solution to all agricultural problems, biological inputs are now important components in the evolution of a systemic, integrated and sustainable agriculture (BUENO *et al.*, 2022). These are products based on bacterial or fungal micro-organisms or are inspired by plant extracts, enabling farmers to improve their yields through integrated disease management and resistance combat. To exemplify, only the biological fungicides, insecticides and nematicides that are now part of crop protection practices around the world. And they can be used in various cultures, from fruits, vegetables and legumes, to grains, sugarcane, among others (SINUELO AGRICULTURAL, 2022). They are divided into two types: macrobiological, which consist of the use of insects, mites and other natural enemies of pests; and microbiological, which are based on bacteria, fungi and viruses (SANTOS *et al.*, 2022).

The agricultural activity is very dynamic and several factors can impact your results. Every year, between 20% to 40% of yields are lost in the field due to the presence of pathogens, insects and diseases. Therefore, having an integrated control allows better production results for farmers. The biological products can generate a symbiosis with the root system of the plant, providing a better absorption of nutrients and nitrogen (SINUELO AGRICULTURAL, 2022).

In 2020, the Ministry of Agriculture, Livestock and Supply (MAPA) launched the National Bioinputs Program, whose purpose is to encourage the use of bioinputs in the country. Currently, there are more than 580 products, including entomological inoculants and defensives, registered in the MAPA as bioinputs, intended to enhance the production of crops of economic interest and to control the main pests that affect numerous species throughout the national territory (BRAZIL, 2020).

Worldwide, the biologics market moves around US$ 3.8 billion and the expectation is that by 2025 it will reach US$ 11 billion, according to data from the Annual Meeting of the Biocontrol Industry (ABIM, 2018).

The sector is led by the United States (37%), Spain (14%) and Italy (10%). In Argentina, farmers already use biological products, mainly in the cultivation of legumes such as soy. In the case of rice, the tendency is to incorporate these fungus-based products to improve rhizosphere generation, root growth and absorption of nutrients such as phosphorus. In Ecuador, a country whose most important agricultural activity is the production of bananas with around 190000 hectares, the use of biological products is already bringing positive results (GOULET *et al.*, 2020).

In addition to increasing productivity, the result of the work is already reflected in the environment with a reduction of up to 30% in chemical load thanks to the integrated management of disease control. Brazil is the fourth country with the best performance in the production of biological products, accounting for 7% of world sales. Brazilian producers have already been using biological agents exponentially in tomato, potato, leafy vegetable crops and we are introducing this year the solution in citrus (CAMPOS *et al.*, 2021).

Bioinputs:

In regenerative agriculture, the use of bioinputs is one of the foundations that has been helping to obtain high productivity, and in recent years Brazil has become the largest producer of soy and leader in the bioinput market. The leadership in bioinputs is due to the high investments of the industry, the growing record of new products and more efficient and innovative formulations, the discovery of new microorganisms, the combination of microorganisms in the same formulation, the synthesis of metabolites and the use of plant extracts (EMBRAPA SOJA, 2022).

The bioinput industry brings in its essence, innovation as a rule, and the technical teams are composed of masters and doctors, and that together with public research, has been advancing in more assertive positions, understanding the modalities of action, the compatibilities, the best environmental conditions for successful application, aiming to reach the target of interest (EMBRAPA SOJA, 2022).

***Azospirillum* Syrup:**

A common practice for supplying nitrogen (N) to agricultural crops is fertilization with industrialized fertilizers. Despite having high solubility, and consequently slight availability for absorption, it is a nutrient with great potential for loss in the environment (TEIXEIRA FILHO *et al.*, 2010) and, consequently, large amounts of the nutrient are needed by crops, especially grasses, which which raises production costs. As an alternative to N in synthetic form, there is the possibility of using inoculants based on N-fixing bacteria, mainly from the genus *Azospirillum* (MILLÉO; CRISTÓFOLI, 2016).

In nature, there are some microorganisms capable of colonizing the surface of roots, rhizosphere, phyllosphere and internal tissues of plants, among which diazotrophic or atmospheric nitrogen-fixing bacteria, which have the ability to associate with plants in different degrees, and may be classified as associative, endophytic and/or symbiotic bacteria (ALMEIDA *et al.*, 2021; SILVA *et al.*, 2022).

Among these microorganisms, there are those capable of producing growth regulators, such as auxins and gibberellins, which are also known as Plant Growth Promoting Bacteria (BPCPs) because they influence plant development and productive performance, as well as help in the absorption of water and nutrients (SILVA *et al.*, 2022). Some examples of BPCP's are those belonging to the genera *Azospirillum, Rhizobium*, *Bradyrhizobium, Agrobactetirium* and *Gluconacetobacter* (SILVA *et al.*, 2022).

The genus *Azospirillum* has the ability, when associated with grasses, to fix atmospheric nitrogen and help with the solubilization of inorganic phosphate, in addition to being widely present in tropical and subtropical soils (ELMERICH; NEWTON, 2017; ALMEIDA *et al.*, 2021). According to Cantarella (2007), these organisms assimilate atmospheric nitrogen and transform it into NH_3, being responsible for biological fixation through the enzymatic complex nitrogenase.

The process of biological nitrogen fixation is the second most important biological process in plants, after photosynthesis. Nitrogen operates in plant metabolism, as it participates directly in the biosynthesis of proteins and chlorophyll, as well as in the initial development of the plant (ANDRADE *et al.*, 2013).

Therefore, the use of ammonium and urea-based fertilizers ends up causing soil acidification, especially with the increase in doses in the production system (CAIRES *et al.*, 2015), burdening production and enhancing environmental impacts (FERNANDES *et al.*, 2017).

Sales *et al.* (2021) observed, in the inoculation of rice seeds with A. *brasilense* added to 50% of the recommended dose of N, there was an increase in plant height, number of panicles and grain yield. Rampim (2021), found no differences between treatments in the first corn crop, even with doses higher than the recommended inoculant. The greatest root development of the seedlings was obtained only from the reinoculation for two consecutive seasons, however the development of the aerial part of the corn plants was restricted.

For Dartora *et al.* (2016), when evaluating the inoculation response of A. *brasilense* and H. *seropedicae* in relation to nitrogen fertilization in corn, verified that nitrogen fertilization favored the development of the crop. The inoculation of microorganisms provided a 12% increase in shoot dry matter and a 7% increase in productivity. According to Araújo *et al.* (2014), inoculation with A. *brasilense* in maize increased the number and mass of commercial husked ears. Furthermore, the combination of inoculation and nitrogen fertilization increased ear production by approximately 30%. In the experiment conducted by Dias *et al.* (2018), inoculation with A. *brasilense* promoted an increase in grain productivity and oil content.

This interaction has enabled a reduction in the application of fertilizers to crops and a reduction in production costs, as well as providing less environmental contamination (HUNGRIA *et al.*, 2018). A viable alternative for pest and disease control is biological control. It is defined as the use of living organisms to suppress the population of a specific pest or disease, making it less abundant or less harmful. This is a natural phenomenon, as almost all species have natural enemies that regulate their populations (MONNERAT *et al.*, 2017).

Thus, it is important for producers to be guided about the risks that the multiplication of these microorganisms inside the farms, called ON FARM, may cause and to show the use of bioreactors to carry out this multiplication, which are sterilizing equipment, which control the pH, aeration and temperature of the medium, aiming to multiply only growth-promoting microorganisms and those that will be used in the biological control of pests, without contamination of crop handlers and products (HARDOIM *et al.*, 2022).

Therefore, based on the above and the need for research, the present work aimed to evaluate the efficiency of the mixtures produced through the "on Farm" method of multiplication of microorganisms from inoculants based on *Azospirillum* with different culture media (HARDOIM *et al.*, 2022).

Importance of nitrogen fertilization:

Nitrogen (N) is the nutrient required in greater quantity by plants and, with greater frequency, its low availability is a limiting factor for agricultural production. This stems from its role since the basis of life, in the composition of nucleic acids (DNA and RNA), amino acids and proteins, in addition to several molecules essential to life, such as chlorophyll. However, N availability is limited in many soils, particularly in the tropics, and although the Earth's atmosphere consists of 78% nitrogen gas (N_2), no plant or animal is able to utilize this form (HUNGRIA *et al.*, 2022).

As a consequence, modern agriculture has been highly dependent on N-based industrial fertilizers, which has been intensified since the 1960s with the "Green Revolution" (HUNGRIA *et al.*, 2022). Gaseous nitrogen incorporates into the pore space of the soil and some microorganisms (some archaebacteria, but mainly bacteria) that live there, and manage to use N_2. This is due to the action of the enzyme called nitrogenase, which makes it possible to break the triple bond of N_2, reducing it to ammonia (HUNGRIA *et al.*, 2017).

Fertilization increasing the amount of nitrogen in the soil is one of the ways to increase productivity in pastures, especially when the forage responds to the use of nitrogen fertilization (PEARSE; WILMAN, 1984). About 50% of nitrogen fertilizers are lost in the soil-plant system. Losses occur due to ammonia volatilization, denitrification, surface runoff, leaching and microbial immobilization (SAIKA; JAIN, 2007). In a study carried out in three different regions of Brazil, using degraded areas, authors testified that inoculation with *Azospirillum brasilense* was equivalent to an additional fertilization of 40 kg of N per ha^{-1} (HUNGRIA *et al.*, 2017). However, in a review with compiled data, the process of biological nitrogen fixation can contribute to a plant around 25 to 50 kg ha^{-1} $year^{-1}$ of N (LANA *et al.*, 2017).

With the use of liming, nitrification and mineralization increase, making more nitrogen available to plants and causing greater leaching of nitrate in the soil profile. Nitrification is limited to soil layers with pH around 4.0. Even the incorporation of limestone increasing the distribution of nitrate in the profile, at deeper levels, 40-60 cm, there is no difference if the limestone is applied on the surface or incorporated. A large part of the applied nitrogen is immobilized, no matter how the corrector is applied. The absorption of nitrogen by plants, plus the addition to the mass of microorganisms in the soil, neutralizes the effects of ammoniacal nitrogen fertilizer on soil pH (HUNGRIA *et al.*, 2017).

The benefits of *Azospirillum brasilense* on plant growth are attributed to several single or combined mechanisms, which operate cumulatively or in cascade. And the production of phytohormone secretion directly contributes to the growth and development of the root system (FUKAMI *et al.*, 2018), providing an increase in the absorption of nutrients and water (ARDAKANI *et al.*, 2020).

Azospirillum provides improvement in plant characteristics, such as higher root biomass, root branching and higher density of root hairs, helping to tolerate water deficit and promoting better exploitation of water in the soil (MARKS *et al.*, 2015). The improvement of plant root activity has been explained due to the action of phytohormones synthesized by the bacteria (FILHO, 2020). In maize, the inoculation of *Azospirillum brasilense* resulted in an increase in grain yield, which reached 27%, compared to the control treatment without inoculation (HUNGRIA *et al.*, 2017).

Use of diazotrophic bacteria:

Diazotrophic bacteria are those capable of fixing atmospheric nitrogen. These bacteria can live free in the soil, associated with plant species, both in the rhizosphere and endophytes, as well as forming symbioses, as occurs in many legumes. Associative diazotrophic bacteria are found in different plant species, including different representatives of the Poacea family, such as rice, corn and sugarcane (BHATTACHARJEE *et al.*, 2008; MOREIRA *et al.*, 2010).

Examples of endophytic bacteria that convert atmospheric N_2 into ammonia are: *Gluconacetobacter diazotrophicus, Herbaspirillum seropedicae, Klebsiella* spp., *Azoarcus* spp., *Azospirillum* spp. and *Azotobacter* spp. However, unlike symbiotic bacteria (Rhizobium), associative bacteria excrete part of the fixed nitrogen for the plant. Then, the mineralization of the bacteria can collaborate as a complementary supply of nitrogen to the plants. It is extremely important to point out that the process of biological fixation by these bacteria can partially supply the nutritional requirements of the plants (HUNGRIA, 2018).

Bacteria of the genus *Azospirillum* gained great prominence worldwide from the 1970s onwards with the discovery of their ability to carry out biological N_2 fixation when associated with grasses. However, it is now known that bacteria of the genus *Azospirillum* do not have host specificity and can associate with both grass and non-grass plants, with the species *Azospirillum lipoferum* and *Azospirillum brasilense* being the most common, currently studied for use in inoculants (PEREG *et al.*, 2016).

Trichoderma and its benefits:

The *Trichoderma* spp., known as *Trichoderma*, are free-living fungi with asexual reproduction, more frequently found in soils in temperate and tropical regions. Many strains have no known sexual cycle (HARMAN *et al.*, 2014) classified in the Deuteromycotina subdivision. Fungi, mainly those of the genus *Trichoderma* spp., play a consolidated role in agricultural production due to their ability to colonize the rhizosphere and other locations in the aerial part of plants, promoting beneficial effects on plant development (MAYO-PRIETRO *et al.*, 2020).

Rezende *et al.* (2021) and Guimarães *et al.* (2018) mention that fungi of the genus *Trichoderma* have the ability to act in various biological control mechanisms, such as: (a) parasitism - nutritional relationship between two living beings in which one of the components of the relationship, the parasite obtains all or part of its food at the expense of the other component, the host; (b) hyperparasitism - higher level of parasitism, in which the host is also a parasite; (c) antibiosis - interaction in which one or more metabolites produced by an organism have a harmful effect on the other; (d) competition - process referring to the interaction between two or more organisms engaged in the same action and (e) induction of plant resistance to diseases - increase of the plant's defense capacity against a wide spectrum of phytopathogenic organisms.

Furthermore, it improves nitrogen use efficiency when combined with other species such as *Bacillus* spp. or *Rhizobium* spp., and induces defense against biotic and abiotic stresses, mainly salt stress (RUBIO *et al.*, 2017).

Pietro-Souza *et al.* (2020) highlighted the induction of plant resistance to biotic and abiotic stresses such as heavy metals, water deficit and salinity. França *et al.* (2017), evidenced the positive action of *Trichoderma* in promoting development França *et al.* (2017), evidenced the positive action of *Trichoderma* in promoting plant development, considering that it is also capable of producing phytohormones, solubilizing phosphates and other minerals.

Final consideration

Bioinputs are efficient in terms of use and effect on agricultural crops of economic interest, which are of great importance on a national and international scale. In fact, biological control has proven to be increasingly effective in managing pests and diseases, justifying its ever-increasing adoption in Brazilian agriculture.

Another point observed was the issue of these bioinputs being able to expand the productive potential of the agricultural sector, as their ability to promote the most diverse plants features that involve from root growth, shoot growth, promotion of nodulation, to a better absorption and use of nutrients available in the soil, converting these results into reduced costs and productivity in the field.

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