IMPACTO CIENTÍFICO EDITORA

TECHNOLOGICAL INNOVATIONS AND DEVELOPMENT OF NEW MARKETS IN SOYBEAN CULTIVATION

INOVAÇÕES TECNOLÓGICAS E DESENVOLVIMENTO DE NOVOS MERCADOS NA CULTURA DA SOJA

A INNOVACIONES TECNOLÓGICAS Y DESARROLLO DE NUEVOS MERCADOS EN EL CULTIVO DE LA SOJA

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Rosilene da Costa Porto de Carvalho[1], Cibelle Christine Brito Ferreira[2], Vitória Beatriz Silva[3], Eduarda Coelho Amaral[4], Marianna Aguiar Costa[5], Osmany Manuel Herrera Armijos[6], Manuel Antonio González Muñoz[7], Flávia Naiane de Macedo Santos[8], Douglas Martins de Oliveira Bessa[9], Emelly Kethenlly Machado Coutinho[10]

ABSTRACT

With population growth and the ever-increasing need for food, it is clear that innovation and technology must be used to increase productivity in the same geographical space. The implementation of digital transformation on rural properties is no longer a choice, but a fundamental necessity to make Brazilian agriculture more efficient and profitable. In this scenario, soybeans play a crucial role in the country's economic growth, either by bringing in foreign exchange through exports of oilseeds and their derivative products, due to high global demand, or by being used domestically in various by-products essential for the development of other industries, such as poultry and pig farming, which use soybean meal as a fundamental component in the production of animal feed. Thus, the objective of this study is to conduct a bibliographic survey on the concepts of technological innovation in soybean cultivation. For a better understanding of the topic, the following question was asked: what is

[1] Doctorate in Plant Production. Universidade Federal do Tocantins (UFT).
E-mail: rosilene.porto@mail.uft.edu.br
[2] Dr. of the Agronomy course. Universidade Estadual do Tocantins (UNITINS). E-mail: cibelle.cb@unitins.br
[3] Master's student in Biotechnology. Universidade Federal do Tocantins (UFT).
E-mail: vitoria.beatriz@mail.uft.edu.br
[4] Student of the Agronomy Course. Centro Universitário Católica do Tocantins.
E-mail: mariaeduarda.coelho@a.catolica-to.edu.br
[5] Student of the Agronomy Course. Universidade Federal do Tocantins (UFT).
E-mail: marianna.costa@mail.uft.edu.br
[6] Master's student in Plant Production. Universidade Federal do Tocantins (UFT)
E-mail: osmany.herrera@mail.uft.edu.br
[7] Master's student in Plant Production. Universidade Federal do Tocantins (UFT)
E-mail: manuel.gonzalez@mail.uft.edu.br
[8] Professor of the Agronomy Course.Instituto Federal de Educação, Ciência e Tecnologia do Pará (IFPA).
E-mail: flavianaianemacedo@gmail.com
[9] Doctorate student in Biodiversity and Biotechnology of the Legal Amazon (Bionorte). Universidade Federal do Tocantins (UFT). E-mail: douglasdeoliveirabe@gmail.com
[10] Student of the Agronomy Course. Universidade Federal do Tocantins (UFT).
E-mail: emelly.machado@mail.uft.edu.br

the importance of technological innovations and the development of new markets in soybean cultivation? To answer these questions, the research consists of an integrative review, which will analyze articles on the importance of technological innovations and the development of new markets in soybean cultivation. A search was conducted for scientific publications and books in Portuguese and English in the databases of the Virtual Health Library (VHL), Scientific Electronic Library Online (SciELO), Google Scholar, and PUBMED. Therefore, the results showed that the adoption of technology in the soybean market plays a crucial role in the progress of Brazilian agriculture, being considered the main agribusiness product in the country. Advances in soybean production are the result not only of an increase in arable land, but also of recent technological advances, such as modern machinery and equipment, cultivation inputs, and genetically modified seeds, in addition to sustainability when there is a demand for soybean products that are produced in a sustainable manner.

Keywords: Technological Innovations. Soybean Agribusiness. New Markets.

RESUMO

Com o crescimento da população e a necessidade cada vez maior de alimentos, é evidente que é preciso utilizar inovações e tecnologias para aumentar a produtividade no mesmo espaço geográfico. A implementação da transformação digital nas propriedades rurais já não é uma escolha, mas sim uma necessidade fundamental para tornar a agricultura do Brasil mais eficiente e lucrativa. Neste cenário, a soja desempenha um papel crucial no crescimento econômico do país, seja trazendo divisas por meio das exportações da oleaginosa e seus produtos derivados, devido à grande demanda global, ou sendo utilizado internamente em diversos subprodutos essenciais para o desenvolvimento de outras indústrias, como a avicultura e a suinocultura, que utilizam o farelo de soja como componente fundamental na produção de ração animal. Desse modo, o objetivo desse estudo é realizar um levantamento bibliográfico sobre os conceitos de inovação tecnológica na cultura da soja. Para uma melhor abrangência da temática houve um questionamento: qual a importância das Inovações tecnológicas e desenvolvimento de novos mercados na cultura da soja? Para responder aos questionamentos a pesquisa consiste em uma revisão integrativa, que irá analisar artigos sobre a importância das Inovações tecnológicas e desenvolvimento de novos mercados na cultura da soja. Foi realizada uma busca de publicações científicas e livros em português e inglês nas bases de dados da Biblioteca Virtual em Saúde (BVS), Scientific Electronic Library Online (SciELO), Google Acadêmico e PUBMED. Portanto, o resultados evidenciaram-se que a adoção de tecnologia no mercado da soja exerce um papel crucial no progresso da agricultura brasileira, sendo considerada como o principal produto do agronegócio no país, o avanço na produção de soja é resultado não apenas do aumento das áreas cultiváveis, mas também dos avanços tecnológicos recentes, como as máquinas e equipamentos modernos, os insumos de cultivo e as sementes geneticamente modificadas, além da sustentabilidade quando se tem uma demanda de produtos de soja que são produzidos de forma sustentável.

Palavras-chave: Inovações Tecnológicas. Agronegócio da Soja. Novos Mercados.

RESUMEN

Con el crecimiento de la población y la creciente necesidad de alimentos, es evidente que es necesario utilizar innovaciones y tecnologías para aumentar la productividad en el mismo espacio geográfico. La implementación de la transformación digital en las propiedades rurales ya no es una opción, sino una necesidad fundamental para que la agricultura brasileña sea más eficiente y rentable. En este contexto, la soja desempeña un papel crucial en el crecimiento económico del país, ya sea aportando divisas a través de las exportaciones de la oleaginosa y sus productos derivados, debido a la gran demanda mundial, o siendo utilizada internamente en diversos subproductos esenciales para el desarrollo de otras

industrias, como la avicultura y la porcicultura, que utilizan la harina de soja como componente fundamental en la producción de piensos para animales. Así, el objetivo de este estudio es realizar una revisión bibliográfica sobre los conceptos de innovación tecnológica en el cultivo de la soja. Para abarcar mejor el tema, se planteó la siguiente pregunta: ¿qué importancia tienen las innovaciones tecnológicas y el desarrollo de nuevos mercados en el cultivo de la soja? Para responder a las preguntas, la investigación consiste en una revisión integradora, que analizará artículos sobre la importancia de las innovaciones tecnológicas y el desarrollo de nuevos mercados en la cultura de la soja. Se realizó una búsqueda de publicaciones científicas y libros en portugués e inglés en las bases de datos de la Biblioteca Virtual en Salud (BVS), Scientific Electronic Library Online (SciELO), Google Académico y PUBMED. Por lo tanto, los resultados evidenciaron que la adopción de tecnología en el mercado de la soja desempeña un papel crucial en el progreso de la agricultura brasileña, considerada como el principal producto del agronegocio en el país. el avance en la producción de soja es el resultado no solo del aumento de las áreas cultivables, sino también de los recientes avances tecnológicos, como las máquinas y equipos modernos, los insumos agrícolas y las semillas modificadas genéticamente, además de la sostenibilidad cuando existe una demanda de productos de soja que se producen de forma sostenible.

Palabras clave: Innovaciones Tecnológicas. Agronegocio de la Soja. Nuevos Mercados.

1 INTRODUCTION

Nowadays, companies need to stand out to remain competitive. The rapid increase in the global population is generating a growing demand for food, resulting in a continuous search for more efficient and sustainable solutions, such as Digital Agriculture. In this context, Brazil's economy has a considerable contribution from agribusiness, thanks to the increase in production, expansion of cultivation areas and the constant improvement in productivity, driven by gradual and adaptive technological development (Junior; Bispo, 2019; Buainain et al., 2016).

The soybean complex plays an important role in the country's economic growth, either by bringing in foreign exchange through exports of the oilseed and its derived products, due to the great global demand, or by being used internally in several essential by-products for the development of other industries, such as poultry and pig farming, which use soybean meal as a fundamental component in the production of animal feed. Over the years, soybean cultivation has undergone several adaptations and technological advances, aiming to achieve significant improvements in terms of quality and productivity during production cycles (Rangel, 2024; Hirakuri, 2010).

Silva and Cavichioli (2020) point out that, in order to ensure sustainability, it is necessary to promote a transformation in the way food is produced more efficiently. Thus, this indicates the use of technologies as an important tool to boost productivity and sustainability in the current agribusiness scenario, which can be defined as a mechanized crop (Lima et al., 2020; Simionato et al., 2020; Benyam; Sum; Fraser, 2021).

Soybean planting influences Brazil's economy, being one of the main pillars of agribusiness in the country. This sector plays a key role in generating jobs and income, both directly and indirectly, as pointed out by Giacomini (2021). Thus, the technologies currently available allow for a greater improvement in operational and strategic decision-making in the production area, resulting in an increase in productivity, cost reduction more efficiently, and less environmental impact (Simionato et al., 2020; Benyam; Sum; Fraser, 2021).

Soybean planting, as well as any other production method, is no exception to the rule, since it requires advanced technologies to optimize production, ranging from the beginning of cultivation to the storage of products (Montenegro, 2022; OLIVEIRA, Ana Clara de et al., 2024; Silva, Felipe et al., 2022).

To broaden the understanding of the theme, this study sought to answer the following question: what is the importance of technological innovations in soybean crops? It is understood that the application of technologies in soybean production is fundamental for the economy, as it promotes greater agricultural efficiency. The general objective of this research

is to carry out a bibliographic survey about the concepts and impacts of technological innovation on soybean crops. Among the specific objectives, the following stand out: to verify the relevance of technologies in soybean cultivation; identify the main technologies currently employed; and analyze the new markets related to soybeans. This study is justified by the need to discuss and understand the importance of technological innovations in the context of soybean production. From an economic perspective, soybeans play a strategic role in Brazilian agribusiness and, consequently, in the country's economy.

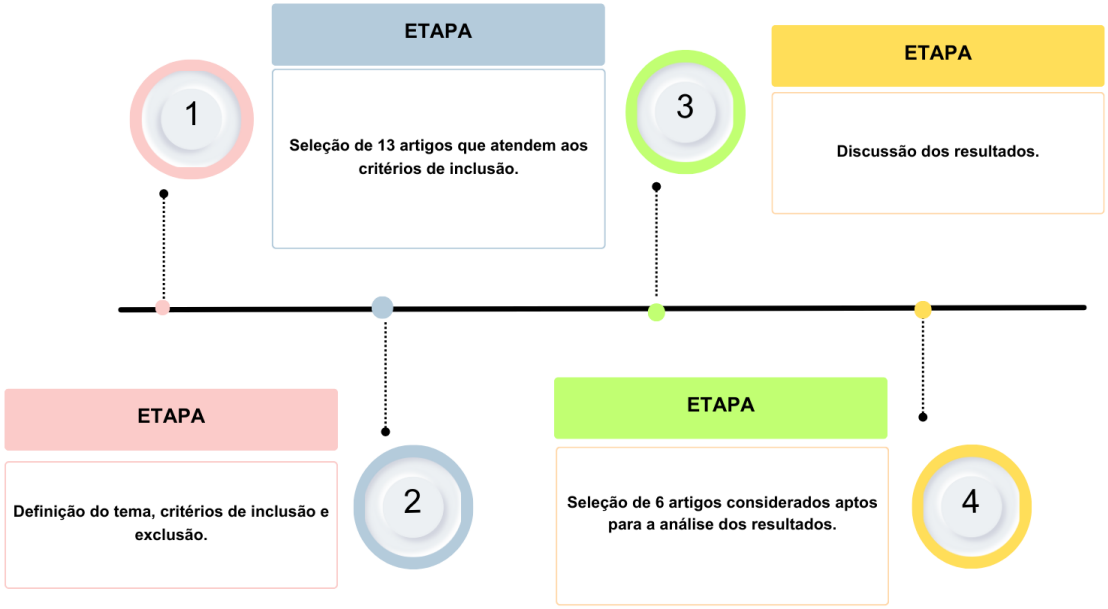
2 METHODOLOGY

The research consisted of an integrative literature review, of descriptive character, whose objective was to analyze scientific articles about the importance of technological innovations in soybean crop. Searches of scientific publications and books in Portuguese and English were carried out in the Virtual Health Library (VHL), Scientific Electronic Library Online (SciELO), Google Scholar and PUBMED databases. As an inclusion criterion, studies published in the last ten years were considered, while, as an exclusion criterion, articles that did not fit the previously established time frame or that did not have a direct relationship with the investigated theme were disregarded. The search for references was conducted using the descriptors "soybean", "innovation", "technology" and "productivity", allowing the selection of works related to the object of study.

The methodological process involved two main procedures: the definition of the subject and the search for references in the aforementioned databases. The organization of the selected articles was carried out in a table prepared in the Microsoft Office Word 2010 software, in a sequential manner, including information such as author and year of publication, objectives, results and conclusions. In this way, it was possible to systematize the data obtained and present the findings clearly, favoring the descriptive and integrative analysis of the literature.

Figure 1

Flowchart of the stages of the article selection process



Source: Author, 2024

3 RESULTS AND DISCUSSION

In the selection process, after applying the inclusion and exclusion criteria, only articles published in the period from 2014 to 2024 and in line with recent advances in technological innovations applied to soybean crops were considered, thus ensuring greater relevance and contemporaneity to the findings of the review. Of the total number of publications initially identified, six articles (Table 1) fully complied with the established parameters and were included for detailed analysis.

Table 1

Databases and Selected Articles

AUTHOR	YEAR OF PUBLICATION	ARTICLE TITLE	GOALS	FINDINGS
Silva *et al.*	2020	The Use of Agriculture 4.0 as a perspective to increase Productivity in the Field.	To address the productivity and profitability of production using agriculture 4.0, also to address the main problems related to food production, how it proposes to solve the challenges of rural producers when dealing with this new era.	Thus, it is understood that agriculture 4.0 aims to employ digital systems, computational methods, sensor network, communication with the machine and data processing. With the use of these tools, it is possible to better plan production, estimating productivity with greater accuracy.

Giacomini	2021	Implementation of precision agriculture in soybean cultivation at the Giacoomini Farm located in Xanxerê-SC.	Implement precision agriculture on a property located in Xanxerê-SC, under soybean cultivation in the 2018/2019 agricultural year.	The implementation of precision agriculture under soybean cultivation showed better efficiency in the use of natural resources (inputs and correctives).
Hirakuri *et a.*	2014	Soybean agribusiness in the global and Brazilian contexts.	To analyze its economic and social importance in the national scenario, as well as limiting the competitiveness of Brazilian soybeans	Soybeans are an oilseed of great importance for agribusiness in Brazil and in the world. This is mainly due to the economic return and versatility, which can be used by the veterinary industry, food industry, pharmaceutical industry, cosmetics, paints, adhesives and plastic
Sznitowski	2017	Sources of knowledge/techno logy for soybean agribusiness in Mato Grosso.	Present the sources of knowledge/technolog y in the field of soybean agribusiness in Mato Grosso	In this sense, the investigation focused on suppliers of knowledge/technology for the grain production process, such as input resellers, sources of specialized knowledge such as the National Agricultural Research System (SNPA), among others. Thus, the contribution of the work is to present the sources of innovation and their dynamics in a contextualized way.
Dalbem	2023	Digitalization index and technologies of Brazilian soybean producers	Search and map the various precision and digital agriculture technologies used by Brazilian soy farmers.	The results showed through statistical tests, and research from other studies, that the adoption and use rates of digital agriculture tools and services of soybean producers in Brazil is at the INTERMEDIATE level, where farmers have been introducing digital agriculture technologies in their properties, and that this scenario has great chances of growing due to the evolution and

				globalization of the world. With regard to environmental issues, the life cycle assessments studied showed that, in terms of greenhouse gas emissions, in general, plastics from renewable sources performed better than those from fossil sources. This result is quite relevant, since the topic of climate change is increasingly known by the population and more studied and thought about worldwide.
Castro	2023	Bioplastics: Environmental Impacts and Market Perspectives	Analyze the state of the art of bioplastics in order to address strategies related to this market	

Source: Author, 2024

Soybean (*Glycine max* L.) is a herbaceous plant belonging to the class Magnoliopsida, order Fabales, family Fabaceae and subfamily Faboideae, characterized by its wide genetic variability. This variability manifests itself both in the vegetative period, which goes from seedling emergence to flower opening, and in the reproductive period, being influenced by environmental factors such as rainfall, soil, and luminosity (Giacomini, 2021). Originally from China, soybeans were initially introduced in Brazil as animal feed, but over time they also began to be cultivated for human consumption, due to the nutritional value of their grains (Furegato; Bonete, 2020). Currently, soybean cultivation plays a central role in the Brazilian agricultural sector, contributing significantly to job creation and income increase, both directly and indirectly (Giacomini, 2021).

In the current context, marked by constant changes and the search for greater efficiency in various sectors, agriculture has also benefited from technological innovations. Historically, technological advancement in agricultural production has aimed to improve working conditions and increase productivity and profitability. Graziano da Silva (2003) points out that technology should not be understood only as a set of material objects, such as machines, seeds and fertilizers, but as the application of scientific knowledge to the production process. In this way, agricultural technology fulfills two interconnected roles: to reproduce social hierarchies within the capitalist system of production and to increase the efficiency of work, promoting higher returns for the owner of capital. Technological innovations applied to agriculture, including those aimed at soybean cultivation, are the result of scientific research and the development of specific studies for this area. Such technologies range from more efficient management methods to the incorporation of digital and

biotechnological tools, whose objective is to enhance the productivity and sustainability of production in agriculture (Benyam, 2023; Gazzoni, 2018; Pavani, 2022).

The implementation of technologies in agriculture has been shown to be an important factor in reducing costs, especially when the cost of depreciation of equipment per unit area decreases as the extent exploited by each worker increases (Mazoyer; Roudart, 2010). In this context, the production goods industries and agro-industries play a strategic role in defining the directions of agricultural modernization. Although market concentration in the agricultural sector is lower than in other industrial segments, the search for continuous profits remains a central feature of the capitalist system, so that technological advancement, although increasing productive efficiency, can also impact income distribution, reducing the earnings of the landowner.

In the case of Brazil, several technological innovations were decisive in positioning the country as the second largest soybean producer in the world, quickly achieving prominence on the global stage. Among these technologies, no-tillage, which reduces soil erosion without high costs; the development of soybean varieties adapted to the Brazilian climate; the correction and fertilization of the soil, which made it possible to occupy areas of the Cerrado; and biological nitrogen fixation, reducing the need for nitrogen fertilizers (Gazzoni, 2018).

Pest control and management of invasive plants allowed for greater sustainability and efficiency of cultivation, while agricultural mechanization and the use of multiple annual crops increased productivity. The crop-livestock-forest integration, in turn, represents an advance in terms of sustainability of agricultural production. The transformations observed over the years show that the gains in competitiveness and agility of the sector do not result only from the isolated use of technologies, but from the combination of improved management practices and strategies (Sznitowski, 2017).

The review of studies shows that the technological centers and innovations implemented over the years are part of a dynamic production system, which is important for the sustainability of soybean cultivation in Brazil. Access to advanced technologies has allowed farmers to optimize production efficiency and increase crop yields, while promoting cost reduction and the development of precision agriculture (Dalbem, 2023). In this sense, it is observed that Brazil has a vast repertoire of technologies aimed at basic crops, animal husbandry and tropical agriculture in general, covering both innovations in management practices and technologies aimed at soil fertility and crop productivity (Antoniazzi *et al.*, 2013).

Among these practices, no-tillage, which can increase productivity by up to 50% and reduce soil erosion by 95%; green manure, which reduces the need for chemical fertilizers; and soil correction with limestone or gypsum, increasing drought resistance and increasing

soybean productivity by about 38% (Antoniazzi *et al*., 2013). In the last three decades, the soybean cultivation system in Brazil has undergone a true technological revolution, highlighting the development of varieties adapted to local climatic and production conditions (Gazzoni, 2018). This evolution has allowed the country to consolidate itself as the world's second largest soybean producer, with prospects for global leadership in the near future, as a result of the combination of biotechnology, agriculture 4.0, and other technologies applied in the field (Ribeiro, 2019).

In addition to the increase in productivity, the growth of soybeans contributed to the national economy, generating jobs and revenue through its extensive production chain and standing out as one of the most traded commodities in the futures market. The use of soybeans goes beyond the production of grains for animal or human food, covering the food industry, industrialized products, meat and egg substitutes, food supplements, and beauty and personal care products (Aprosoja, 2014; Lemos et al., 1997; Barbosa *et al*., 2006). In addition, the bioactive components of soybeans, such as proteins, isoflavones, phytosterols and essential minerals, give it nutritional and functional value, contributing to the prevention of chronic and degenerative diseases (Carrão-Panizzi and Mandarino, 1998).

The diversification of products and the expansion into new markets, including plant-based alternatives and industrialized derivatives, demonstrate the ability of soy to meet changing consumption patterns, such as the growing demand for healthy, vegetarian and vegan foods. In the field of sustainability, the development of bioplastics from renewable sources, such as those obtained from soy protein, capable of replacing synthetic plastic materials in hygiene products and packaging (European Bioplastics, 2016; Castro, 2019). These bioplastics have environmental advantages, including biodegradability and the use of renewable sources, and can absorb a large amount of weight relative to their mass, evidencing their potential as a sustainable alternative. However, the adoption of these technologies faces market challenges and uncertainty, requiring strategies such as partnerships with suppliers and consumers, ensuring positive environmental and social impacts throughout the life cycle of the products (Iles; Martin, 2013).

Thus, the review of the studies shows that technological innovations applied to soybeans not only increase the productivity and sustainability of the crop, but also boost the development of new markets, allowing products of higher quality and added value to reach consumers in an efficient and sustainable way. The articulation between technology, agricultural management and product diversification is crucial to consolidate soybean as a strategic commodity in the economic, social and environmental scenario of Brazil.

4 FINAL CONSIDERATIONS

It is understood that soybean production plays a crucial role in the progress of Brazilian agriculture, being considered the main agribusiness product in the country. The increase in the productivity of this crop is evident and unquestionable, as well as the positive impacts brought by its development to this production chain and to the population in general. The advance in soybean production is the result not only of the increase in cultivable areas, but also of recent technological advances, such as modern machinery and equipment, crop inputs, and genetically modified seeds.

Although economic logic is more important than technological, technological innovation has played an essential role in maintaining economic advancement, which often results from gradual improvements in production methods. The improvements aim to constantly improve the production process, with technological innovation being the main driver of progress, establishing technological paths.

The increase in productivity is the determining factor that motivates producers to bet on technology, since it grows according to the efficiency used. As farmers seek to innovate, their profit increases, and with each harvest, with a budget available, they invest more in technologies. The results presented in this research highlight the technological potential with regard to soybean, as well as the viability of new markets that include all sectors of its productivity.

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