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Analysis of the Evolution of the Number of Biotechnology Patents in the Agribusiness Sector

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HIGHLIGHTS

- Increase in the number of agribusiness biotechnology patents.
- Development of science, technology and innovation in the context of measuring economic growth.
- Increase in the number of patents and better results in agricultural productivity in the field.

Abstract: Agribusiness is the most prominent sector in the Brazilian economy, contributing over the last few years with about 30% of the Gross Domestic Product (GDP) and being responsible for more than 40% of the products exported by the country. During this period, several economic development programs in Brazil were created by the federal government, contemplating the agricultural sector to increase productivity in the field, with actions and intensification of the use of fertilizers, pesticides, creation of agricultural research institutes, training of agronomists, and veterinarians, in addition to facilitating access to credit for rural producers. In this sense, the biotechnology sector great significant greatly influenced the expansion of agricultural production, increasing field efficiency and agricultural production productivity. The objective of this work was to analyze the number of patents in the agribusiness sector to technological development in the biotechnology sector between 1978 and 2018, with data from the Brazilian National Institute of Industrial Property (INPI). There is a growing number of patents over the period, as well as an increase in the number of undergraduate and graduate courses in the field of biotechnology in the country since the sector is considered strategic as a source of innovation in science and technology, supporting the country's development, structuring itself to sustain economic growth, with research, science, technology, and innovation.

Keywords: Innovation; Technology; INPI; Transgenic.

INTRODUCTION

Biotechnology is one of the main tool's humans use in producing goods and services. Its applicability transcends and is also present in engineering, industry, health, and agriculture [1,2].

It was through the use of biotechnology that hitherto unsolvable problems were solved. The benefits of this technique have proved to be highly profitable, justifying the investment and a constant scientific race waged in company laboratories to discover new applicability or even to improve products currently available through the use of biotechnology [3].

The view that there is a symbiosis of humanity with the biotic resources available in the environment was the main reason for increasing the use of Biotechnology in the most varied productive sectors. Before that, Biotechnology used to be applied to only the production of wines and breads [4,5].

Allied to the demands of humanity, Biotechnology somehow demonstrates that all species of life, not only human humans, have relevance, being essential in the production of vaccines, medicines, chemical compounds applied in machines and equipment. Consequently, that have consequences that have had Consequently that has allowed the maintenance of prosperous life for human beings [6,7].

In Brazil, with the creation of EMBRAPA (Brazilian Agricultural Research Corporation] in the mid-1970s, Biotechnology in Agribusiness occupied a prominent position, notably due to the country's vocation in the production of agricultural commodities, that even though other applications and relevant discoveries took place in different industrial, educational, and laboratory segments [7,8].

In this sense, Brazil concentrates on the most enormous most significant volumes of agricultural production; having cultivated more than 50 million hectares with transgenic crops, revealing an unparalleled growth compared to other countries; however, still insufficient to place it in the global leadership regarding the adoption of biotechnology in agricultural production [9].

The 1980s were marked by the movement recognized as the ‘Green Revolution,’ giving notoriety to the development of the Brazilian agricultural sector, increasing productivity crop by crop through the growing use of biotechnology, which has become the main ally of the segment [10].

When the eyes of the world turned to the concept of sustainable development, Brazil had to face the challenges of maintaining the agricultural area with the need to raise productivity levels [11].

In this sense, through Biotechnology, the country managed, with very few mishaps, to reach excellent productivity levels without practically increasing the available area for planting inputs and food [12].

In the 1990s, Brazil hosted the Earth Summit, the world’s leading environmental event. It is also a signatory of climate treaties and reaffirmation of principles. With an eye on the current environmental challenges, the federal government signed the Agreement on Biodiversity, pointing to the idea that Brazil no longer viewed the environment with an anthropocentric vision [13].

In this scenario, the limitations of using pesticides begin with adopting low carbon agriculture and reducing deforestation to protect biodiversity. In this context, modern biotechnology techniques were the only way to be followed, causing the increase of specialization and professionalization of the workforce in agribusiness [14].

However, investments in research are carried out from the economic view of profitability, which will be implemented after the commercialization of advanced biotechnology. On the other hand, exclusivity is combined with profitability, revealing the importance of obtaining patents [15,16].

Brazil was not the only country to face sustainable development challenges. Worldwide, biotechnology research in agribusiness has gained notoriety, mainly due to the international presence of the leading industries in rural technology, as evidenced by the number of patents filed in the respective control and protection bodies [17].

This phenomenon led to an international codification of biotechnology patents, which can provide a more effective analysis of the request for granting exclusivity in exploration and the approval of use by sanitary and environmental agencies. The Brazilian National Institute of Industrial Property (INPI) monitors this international codification and assures researchers of the patent owner in harmony with other countries [18].

In this context, the objective of the present work was to carry out an analysis of the evolution of technological innovation in the biotechnology sector in Brazilian agribusiness.

MATERIAL AND METHODS

The survey of the number of biotechnology patents was carried out using the Brazilian National Institute of Industrial Property (INPI) database, with patent filing dates between 1978 and 2018.

The categorization of patents was carried out according to the methodology developed by [19], in the study on the categorization of the biotechnology sector based on the International Classification of Patents (ICP), in which the classifications considered as ‘Biotechnology’ were compared to the methodologies developed by the Organization for Economic Co-operation and Development (OECD), World Intellectual Property Organization (WIPO), in addition to the BIOTEC-BR study itself.

Thus, patent registrations were grouped into 12 different technological classes according to the area of concentration of each patent. Each area was subdivided into categories when deposited by the ICP.

Based on the composition of the patent concentration areas [18], observed in Table 1, categories 7, 8, and 10 were selected for this study. In the detailing of each subdivision that makes up the concentration areas of biotechnology patents, categories 7, 8, and 10, namely 'Agriculture,' 'Environment,' and 'Food and beverages' classes directly related to activities in the agribusiness sector.

Table 1. Categorization of patent documents related to different areas of biotechnology according to the ICP.

	Biotechnology	Categories	CIP
1	Microorganisms, enzymes, and their compositions		C12N*; C12R*; C12S*
2	Medicine	Medicinal preparations containing peptides or antibodies	A61K38*; A61K39*
		Medicinal preparations containing microorganisms or their materials	A61K35/66; A61K35/68; A61K35/7*; A61K36/06*; A61K36/07*; A61L15/36
		Medicinal preparations containing genetic material Cosmetics	A61K48* A61K8/99
		Medicinal preparations for in vivo testing / Preparations containing radioactive substances for use in therapy or in vivo testing	A61K49/14; A61K49/16; A61K51/08; A61K51/10
		Animal cells for dentures or coating dentures	A61L27/38
3	Fermentations and recovery of fermentation by-products	Fermentations	C12P*
		Recovery of fermentation by-products	C12F*
4	Peptides	Peptides containing more than 20 amino acids	C07K14*
		Immunoglobulins	C07K16*
		Hybrid peptides	C07K19*
		Peptides or proteins immobilized or linked to a carrier	C07K17*
		Peptides containing up to 20 amino acids	C07K4*
5	Measurement and assay involving enzymes or microorganisms		C12Q*
6	Analysis of biological material	Immunoassay; Assays involving ligands	G01N33/53*, G01N33/54*, G01N33/55*, G01N33/56*, G01N33/57*
		Chemical analysis of biological material involving proteins, peptides, or amino acids	G01N33/68
7	Agriculture	New plants or processes for obtaining them; plant reproduction using tissue culture techniques	A01H1*; A01H4*; A01H17*
		Biocides, pest repellents or attractants, or plant growth regulators containing microorganisms	A01N63*
		Organic fertilizers containing additional bacterial cultures, mycelia, or the like	C05F11/08
8	Environment	Biological treatment of water, wastewater, or sewage; Sludge and sludge treatment	C02F3*, C02F9/14, C02F11/02, C02F11/04
		Compositions for optimization methods in the recovery of hydrocarbons characterized by the use of bacteria	C09K 8/582
		Contaminated soil recovery/bioremediation	B09C1/10
		The process to render innocuous (or less harmful] harmful chemical agents	A62D 3/02
		Biological processes of separation of gases/vapors or isotopes	B01D53/84; B01D59/36
		Bacteriological maceration of filamentous or fibrous natural materials	D01C 1/04

Cont. Table 1

9	Apparatus for enzymology or microbiology		C12M*
10	Food and beverages	Dairy products	A23C9/12*, A23C13/16, A23C17/02, A23C19/032; A23C21/02
		Fermentation processes for beer and wine	C12C11*; C12G1/022; C12G1/073; C12G3/02
		Fermented Foods	A23F3/10; A23L1/105 (A23L 7/104]; A23L1/23 (A23L 27/24]
		Treatment and preservation of food	A21D8/04; A23B4/22; A23B5/16; A23B7/155; A23B9/28; A23L3/3571
		Protein-based compositions for food products	A23J1/18; A23J3/20
		Non-alcoholic beverages	A23L2/84
11	Nanobiotechnology		B82Y5/00
12	Genomic and proteomic libraries and their apparatus		C40B10*; C40B20*; C40B30*; C40B40*; C40B50*; C40B60*; C40B70*; C40B80*

(*) indicates that all subgroups of lower hierarchical levels are considered—source: Adapted from [18].

Data were tabulated using electronic spreadsheets in the EXCEL® software. The SIGMPLOT® software was used for graphing and statistical analysis.

RESULTS AND DISCUSSION

A total of 41,567 biotechnology patents were filed, between 1978 and 2018, in the INPI database, which is divided into 12 technological categories. For 40 years, the specialized area of 'Microorganisms, enzymes and their compositions' obtained the most significant number of registrations, totaling 14,304 deposits made between 1978 and 2018, representing about 34.41% of patents. Notably, there was an expressive growth from 2000 and so on.

It is possible to observe, in Figure 1, the total number of biotechnology patents by area of technological concentration in the period between 1978 and 2018.

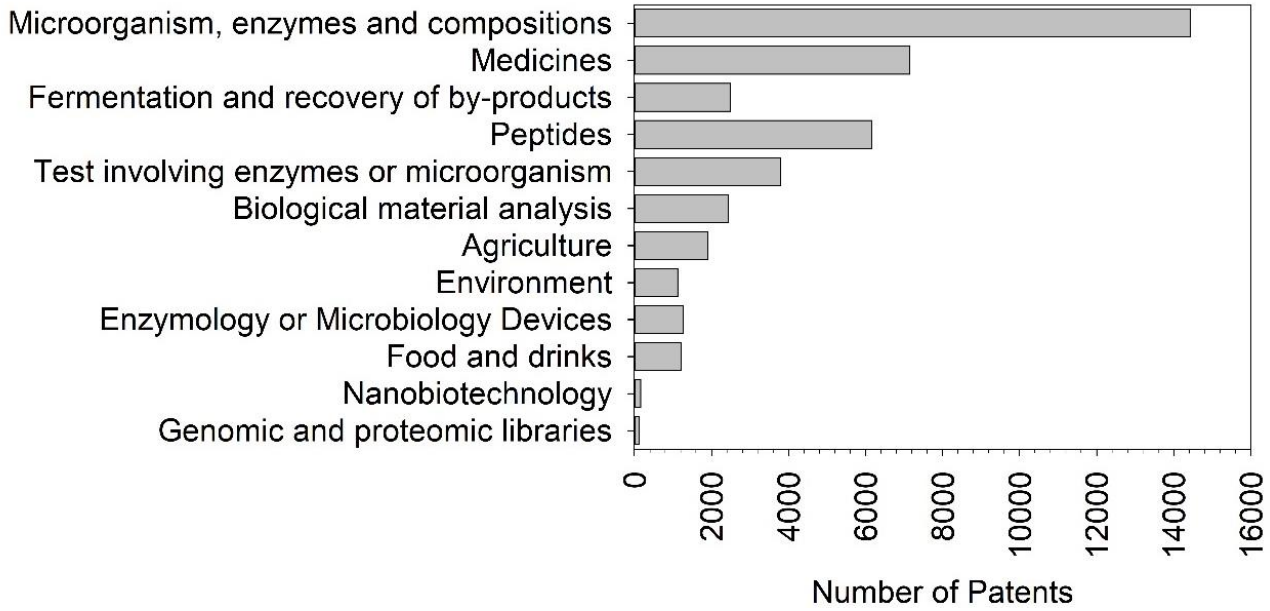

Figure 1. Total of patents accumulated in biotechnology, organized by area of concentration, between 1978 and 2018.

Biotechnology, being endowed with dynamism in the composition of its knowledge structure, encompasses disciplines from different areas, such as biochemistry, molecular and cellular biology, and contemplating areas of engineering, genetics, immunology, and microbiology [20].

In this context, with the refinement of research areas over the years, new areas incite scientific interests and gain volumes of research with unique themes that aim to solve current problems with new knowledge, directly influencing the creation of new undergraduate and specialization courses of biotechnology. With that, 62 new undergraduate courses and nine technologists were created in the last 20 years in Brazil, in addition to 78 specialization courses, predominantly in the areas of human health and well-being [21,22].

Several developed countries consider the biotechnology sector strategic as a source of innovation and economic growth. In that way, developed countries foster innovation as an ally to economic growth and have institutional arrangements based on the Triple Helix model, in which it is sought to join the contributions of universities, industry, and government, something that is essential for the generation of knowledge and technological innovation, promoting a country's economic growth [23].

In this aspect, in 2007, the Action Plan on Science, Technology, and Innovation for National Development (2007-2010] and the Biotechnology Development Policy were created in Brazil to structure and increase production efficiency and capacity for innovation in the country. One of the goals was to improve biotechnological processes and products, corroborating the increase in the offer of technology and biotechnology courses in Brazil as support to leverage economic growth [24].

The growth in the number of biotechnology patent deposits in the period is similar to the growth behavior of the offer of courses in the field of biotechnology in the country, representing a significant growth after the 2000s when several national strategic plans and guidelines were created to encourage science, technology, and innovation [25].

According to [26], some areas become priorities to achieve the desired future based on integrated, innovative, and sustainable biotechnological solutions, namely: agribusiness, health, and environment, in a country with international competitiveness in agribusiness.

Figure 2, below, shows the number of patents filed between 1978 and 2018 for biotechnology in general and biotechnology patents aimed at agribusiness in Brazil.

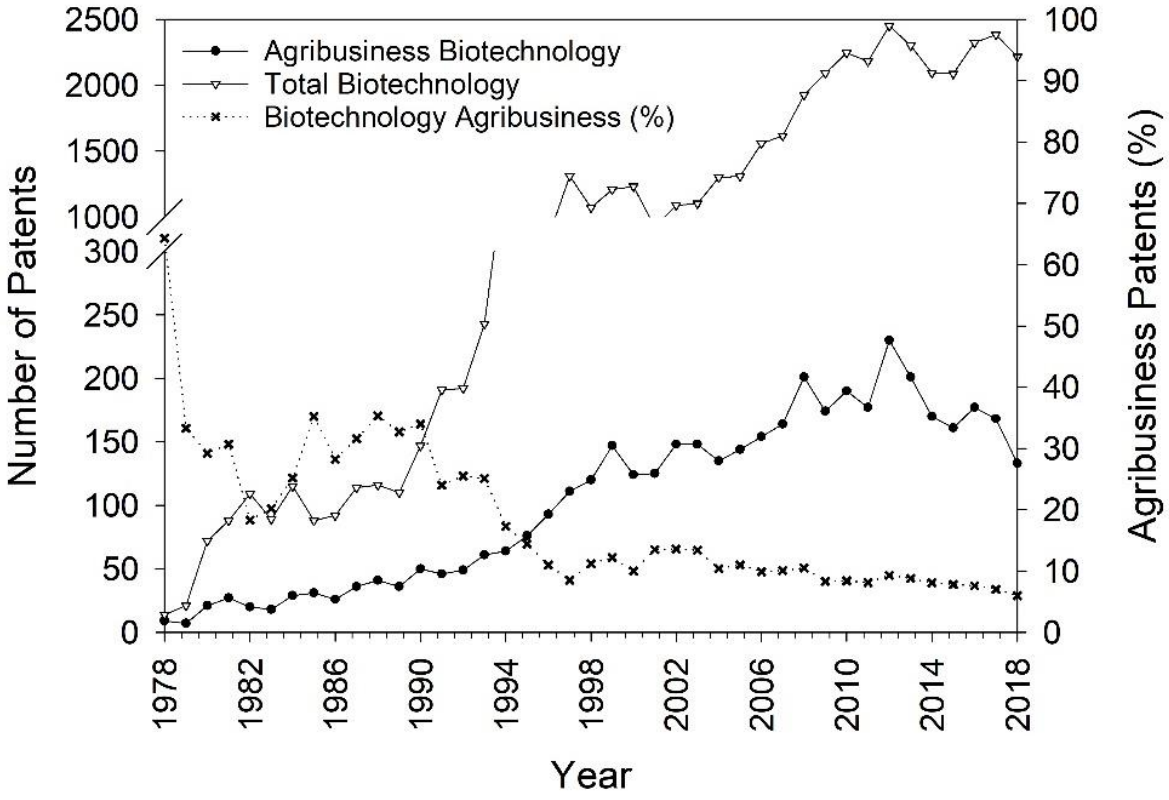

Figure 2. Evolution of the number of biotechnology patents, in general, and agribusiness biotechnology patents in Brazil between 1978 and 2018.

There is a similar behavior between the total biotechnology patent registration numbers and the agribusiness biotechnology area, growing throughout the analyzed period. In addition to that, there was a significant increase in the mid-1990s and 2000, corroborating with the national development plan encouraging research in science, technology, and innovation.

The development of agribusiness in Brazil is marked with the beginning of the Green Revolution in the mid-70s and 80s, with new technologies in the field. That caused an increase in productivity, improved the efficiency of pesticides and fertilizers, generated genetic improvement of seeds, which can all be understood as a result of knowledge acquired from scientific research, using biotechnology in agricultural production [27].

It is noted that, in this period of the Green Revolution in Brazil, until the mid-1990s, biotechnology patents in the agribusiness sector represented between 30% and 50% of patent deposits, contributing to the growth and development of Brazilian agribusiness. Besides, it also increased the competitiveness of Brazil in the world scenario, causing the country to become one of the world's leading food producers and exporters [28].

Next, Figure 3 shows the evolution of agribusiness biotechnology patents according to the technology, agriculture, environment, and food and beverage areas.

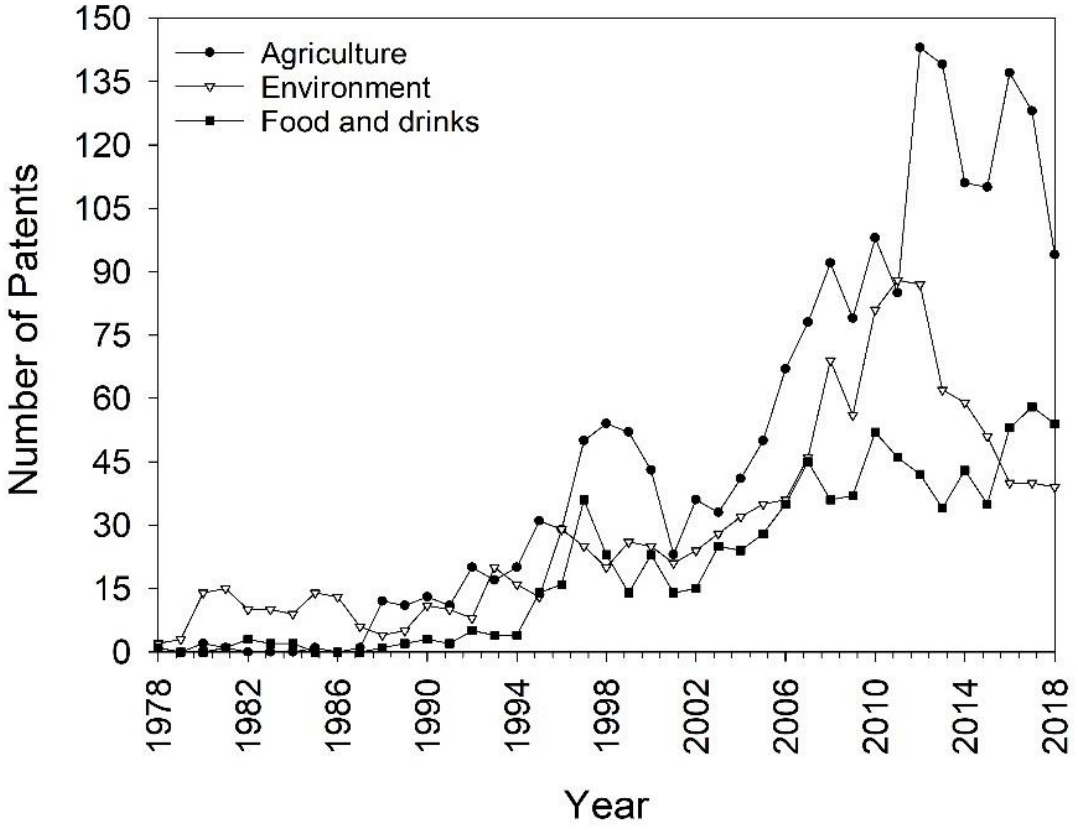

Figure 3. Specialized classes between 1978 and 2018 separated several agribusiness biotechnology patents.

The three specialized classes of agribusiness show significant growth after the 1990s. The same behavior was noted in the other technical courses of biotechnology patents, highlighting the expressive development of the biotechnology area in Brazil presented in the period.

The area of 'Agriculture' has a more significant number of patents developed in the period, divided into three subclasses in the categorization of patents, accumulating 1,917 deposits, followed by patents in the 'Environment' technological class, earning a total of 1,217 patents, and 'Food and Beverages,' with a total of 817 patents in the analyzed period.

The emphasis on the agricultural sector is influenced by the various national policies to encourage agricultural production after the 1960s, such as the Triennial Plan 1963-1965, which aimed to increase agricultural productivity in the country by 7% at the time, through incentives of rural credits and creations of six Institutes of Agricultural Research and Experimentation. In addition to that, there was a series of Basic Plans for Scientific and Technological Development I, II, and III [29,30].

According to the technological class categorization, the total of patent registrations, divided by subclasses, can be seen as described in Table 2.

Table 2. According to subclasses, total agribusiness patents by technological class in the period between 1978 and 2018.

Area		Subclass	Total
7	Agriculture	New plants or processes for obtaining them; plant reproduction through tissue culture techniques	725
		Biocides, pest repellents or attractants, or plant growth regulators containing microorganisms	1,066
		Organic fertilizers containing additional bacterial cultures, mycelia, or similar	126
8	Environment	Biological treatment of water, wastewater, or sewers; Sludge and sludge treatment	1,122
		Compositions for optimization methods in the recovery of hydrocarbons characterized by the use of bacteria	19
		Contaminated soil recovery/bioremediation	34
		The process to make harmful chemical agents harmless or less harmful	12
		Biological processes of separation of gases/vapors or isotopes	30
		Bacteriological maceration of filamentous or fibrous natural materials	0
10	Food and beverages	Dairy products	373
		Fermentation processes for beer and wine	156
		Fermented foods	103
		Food treatment and preservation	169
		Protein-based compositions for food products	27
		Non-alcoholic beverages	22
		TOTAL	**3,989**

Patents in the specialized area of ‘Agriculture’ represent a little more than 48% of the total patent deposits in the agribusiness sector between 1978 and 2018. The ‘Environment’ area is the second most expressive, with 30.5% of the total patent deposits, followed by ‘Food and Beverage,’ with about 21.3%.

In the technological area of ‘Environment’, more than 92% of the patents registered in the period refer to water treatments, corroborating investments made in infrastructure in Brazil, to achieve better human development indexes (HDI), which consists of better health indexes, education, and income, contributing to increasing the life expectancy of the population over the years [2].

It is important to note that, in the same period, the health index of Brazil grew, improving the population health conditions in terms of expanding the basic sanitation structure, carrying out water treatment, and decreasing the rate of hospitalizations by infectious diseases resulting from contaminated water, which affects mainly the poorest among society [31].

However, it is notable that almost half of the deposits made between 1978 and 2018 are records of the ‘Agriculture’ area, motivated by the pressure for greater food productivity in the world due to the population growth rate.

During this period, amid the new incentive policies for the growth and development of agriculture in Brazil, the Government's Economic Action Program (PAEG) had, as its principle, a package of action plans aimed at meeting the ‘technological needs’ of agriculture. The goal was the agricultural export market that demanded an international standard of competitiveness in the global market, justifying the increase of new technologies in Brazilian agriculture [29].

Thus, Figure 4 shows the evolution of the number of patents in ‘Agriculture,’ organized by subclasses of records, between 1978 and 2018.

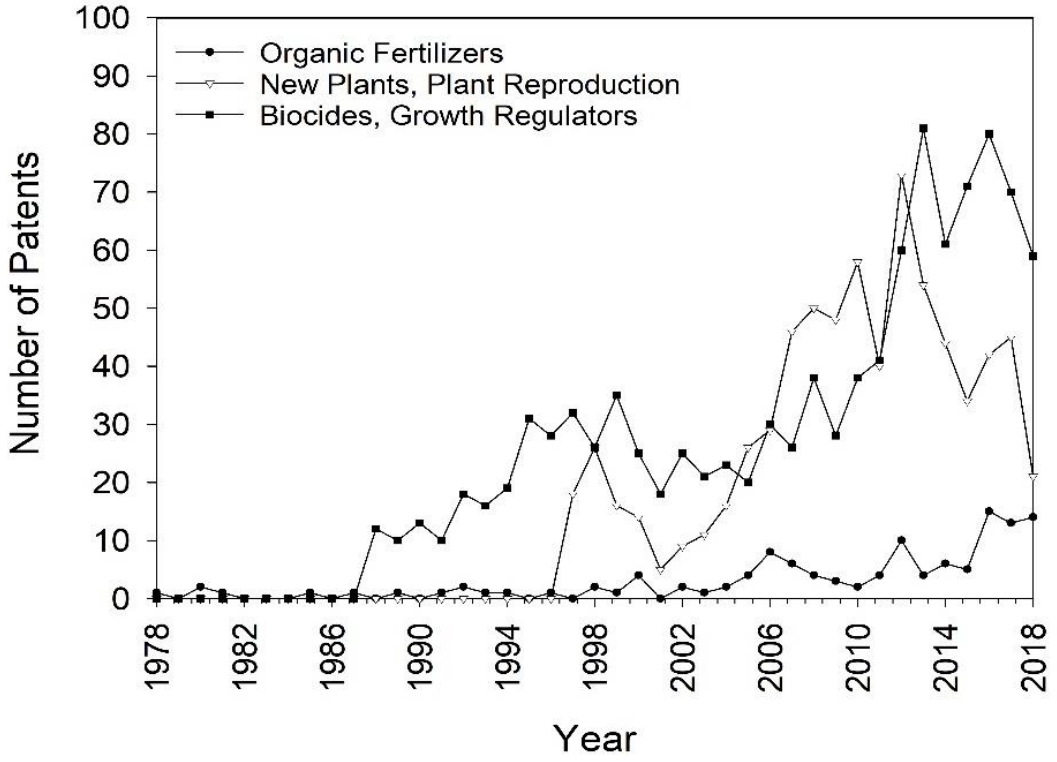

Figure 4. Total patent deposits of the technological class 'Agriculture' in 1978 and 2018, in Brazil.

It is noteworthy that, early in this period, the world was divided by the cold war and fighting for its reconstruction after the end of the Second World War. The main problem to be solved at that historical moment was the hunger of humanity. While the Green Revolution began in the United States and Europe in the mid-50s, in Brazil, this phenomenon only gained importance in the 70s, expanding the agricultural frontier [32].

Monoculture causes considerable ecological imbalance, attracting with it strong pest infestation. However, the eyes of Brazilian food importers-imposed barriers on products impregnated with pesticides, so the development of biocides gained momentum [33,34].

The peak of the biocide patent filing takes place mid-2010, primarily driven by the approval of Law 11,936 of May 14, 2009, which prohibits the manufacture, import, export, maintenance in stock, commercialization, and use of DDT (dichlorodiphenyltrichloroethane), forcing agricultural complexes to search for biotechnological alternatives to compensate for the ecological imbalance caused by large extensions of single-crop plantations [35].

The Brazilian soil has always been highly dependent on fertilizers. The necessary application of such inputs raises the cost of production. It detracts from Brazil's competitiveness in the international scenario because a good part of the essential macronutrients is imported and quoted in US dollars [36].

Between the 70s and 80s, the federal government launched several strategic development programs, including the Strategic Development Program (PED); Goals and Bases Plan I; National Development Plan, and the Brazilian Science and Technology Development Plan (PBDCT), which had, among their proposals, the encouragement of the use of chemical fertilizers and agricultural pesticides to increase the productivity of crops in the field, in addition to intensively using scientific and technological development instruments [28].

In the case of soybeans and some legumes, the use of nitrogen-fixing rhizobia available in the atmosphere, a phenomenon discovered in the 60s, does not require the acquisition of significant doses of nitrogen fertilizers. Nevertheless, between 2006 and 2018, there was an increase in the filing of patents of organic fertilizers, demonstrating the effort of agribusiness to accommodate the costs of fertilization with the ecological footprint [37,38].

Soybeans, which were previously confined to the south of the country due to the semi-tropical climate, are beginning to rise towards the Midwest, thanks to the use of soil improvements in the Cerrado (tropical savanna) region and the cost of deforestation in the north of the country towards the Amazon Forest to shelter cattle herd [39].

CONCLUSION

Over the years, the production growth in the agricultural and livestock areas has been remarkable, making Brazilian agribusiness more and more efficient. As the initial development milestone, The Green Revolution movement marked the country in the mid-1970s.

Technological development in the area took place with field and livestock management techniques, with knowledge derived from scientific research applied in agricultural sciences in favor of better crop yield, through better inputs for production with chemical fertilizers and more efficient agrarian defensives. Concomitantly, mechanization was adopted in the field, with modern machinery coupled with technology.

In addition, during this period, several programs were created by the federal government aimed at the development of the country. Among them, actions that contemplated the Brazilian agribusiness to increase productivity in the field, through the intensification of the use of fertilizers, correctives, and seeds, agricultural defensives, creation of agricultural research institutes, credit programs for rural producers, education, and training of farming technicians to work in the secretariats of agriculture, among others.

In this sense, the use of biotechnology in agribusiness was boosted to solve the problem of productivity in the field and in livestock, arising from the pressure for better yields given the rapid population growth, which made Brazil one of the main foods producing and exporting countries in the world, becoming a reference in the application of technology in the field.

REFERENCES

1. Malajovich MA. [Biotechnology]. 2nd ed. Rio de Janeiro: Axcel Books; 2016. 312 p.
2. Oliveira RB, Sousa EP. [Sustainable human development in Brazil: interaction between social well-being and environmental health]. Ibero-Amer. J. Ecol. Econ. 2020;32(1):47–66.
3. Rocha MCA. [Biopiracy of medicinal plants as an appropriation of traditional knowledge from the Brazilian Amazon] [dissertation]. Santa Maria: Federal University of Santa Maria; 2019. Graduate in Law; 2019. 183 p.
4. Leitão A. [Circular economy: a new management philosophy for the 20th century XXI]. Port. J. Fin. Mngmt. Acct. 2015;1(2):149–71.
5. Barcelos MCS, Lupki FB, Campolina GA, Nelson DL, Molina,G. The colors of biotechnology: general overview and developments of white, green and blue areas. FEMS Microbiol. Lett. 2018; 365(21):1-11.
6. Oliveira HS, Spengler RL. [Innovations in the field of biotechnology in human health in developing countries and their economic and social importance: a reflection on the current scenario and future perspectives]. Rev. Cad. Pedag. 2014;11(1):99–116.
7. Katz L, Chen YY, Gonzalez R, Peterson,TD, Zhao H, Baltz RH. Synthetic biology advances and applications in the biotechnology industry: a perspective. J. Ind. Microbiol. Biotechnol. 2018;45(7):449–461.
8. Marafon GJ, Chelotti MC, Pessôa VLS, eds. [Themes in rural geography]. 2nd ed. Rio de Janeiro: EdUERJ; 2020. 549 p.
9. Oliveira Neto SS, da Silva Nunes JG, Souza M, Calonego JC. Soybean Crop: A Review on the Biotechnological Advances and Expectation for Modern Cultivars. J. Agric. Stud., Macrothink Institute. 2020;8(1):194-207.
10. Novaes HT, Mazin AD, Santos L, eds. [Agrarian question, cooperation and agroecology]. 2019;1(3):368.
11. Giesta LC. [Sustainable Development, Corporate Social Responsibility and Environmental Education in the context of organizational innovation: concepts revisited]. Journal of Administration of UFSM. 2012;5(0):767–83.
12. Rama R, Wilkinson J. Innovation and disruptive technologies in the Brazilian agro-food sector, Food Syst. 2019; (4):51-70.
13. Arruda AFS, Oliveira FM, Moraes LTP. [Nature as a subject of law: analysis of the cases of Mariana and Brumadinho from comparative socio-environmental studies], Cad. Ciênc. Agrár. 2019;11(1):1–8.
14. Buranello R. [Manual of Agribusiness Law]. 2nd ed. São Paulo: Saraiva; 2018. 344 p.
15. Arlindo L, Oliveira AL. Biotechnology, Big Data and Artificial Intelligence, J. Biotechnol. 2019;14(8);1-6.
16. Neves IG A. Neves IG A. [Patent system for sustainable development in Brazil: how to increase Brazil's self-sufficiency in innovations based on Biodiversity]. 1st ed. São Paulo: Editora Dialética; 2020.157 p.
17. Ferrari VEF, Silveira JMFJ, Dal-Poz MÊS. Patent network analysis in agriculture: a case study of the development and protection of biotechnologies, Econ. Innov. New Technol., 2021;30(2):111-33.
18. Zorzal PB. [Biotechnological inventions in Brazil: protection of biological sequences by gender claims in patents]. [thesis]. Vitória: Federal University of Espírito Santo, Postgraduate in Biotechnology of the Northeast Biotechnology Network; 2017. 281 p.
19. Weid IVD, Santos PR, Valadão ABG, et al. [Categorization of the biotechnology sector based on the International Patent Classification and analysis of the panorama of filing patent applications in this sector, in Brazil (2012-2016)]. National Institute of Industrial Property - INPI, Patent Office - DIRPA, General Coordination of Studies, Projects and Dissemination of Technological Information - CEPIT, Division of Studies and Projects - DIESP. 2018;1–28.
20. Massabni AC, Silva GJ. Biotechnology and Industry 4.0: The professionals of the future, Int. J. Adv. Med. Biotech. 2019;2(2):45-53.

21. Castro-Silva II, Ferreira FV, Maciel JAC. Biotechnology research in Brazil: A spatial correlation between H-index and social development. Res., Soc. Dev. 2021;10(1):1-12.
22. Brazil. [National register of higher education courses and institutions]. Brasilia; 2020. Report No.: e-MEC Registration.
23. Pereira TP, Cunha C. [Science, technology, development and postgraduate studies in Biotechnology]. Integ. Knwl. 2022;11(1):109-127.
24. Brazil. [Prohibits the manufacture, import, export in stock, marketing and use of dichlorodiphenyltrichlorethane]. Presidency of the Republic. Law No. 11,939 of May 14, 2009. 2009.
25. Muraro, LG, Castro-Lucas C. [The Challenges of the National Strategy for Science, Technology and Innovation – ENCTI 2016/2022: Federalism and Public Policy on ST&I in Brazil]. Rev. Empreend, Neg. Inov. 2021;6(1):4-30.
26. Bortoluzzi AP, Schneider AH, Dias BL, Peixoto CR, Fontana Simão CA, Fröhlich CE, et al. [Strategic routes for the future of Paraná's industry 2031]. Curitiba: Federation of Industries of the State of Paraná - FIEP; 2017. 116p.
27. Gomes WS, Borém A. [Biotechnology: a new paradigm for Brazilian agribusiness]. Rev. Eletrôn. Adm. 2015;11(1):1–22.
28. Roque P. [OECD-FAO perspectives: Brazil as a food supplier to the world]. Rev. Agroanly. FGV. 2015;35(8):1–40.
29. Quidá MM, Cabral Filho AV. [Technological diffusion in the genesis of Brazilian agribusiness]. Rev. Cambiassu. 2018;13(22):121-137.
30. Santos FB, Freitas CALL, Silva, JRS. [Modernization of agriculture and agrarian reform: is strengthening family farming the way forward?]. UEG Econ. Rev. 2017;13(2):130-148.
31. Jannuzz PM, Barreto RS, Sousa MF. [Monitoring and Evaluation of Human Development: the insensitivity of the Human Development Index to social development policies]. Bra. J. Monit. Eval. 2013;5(1):60-79.
32. Luzzardi RES. [Environmental Education: support for the development of sustainable agriculture]. Electr. J. Mrs. Environ. Educ. 2006;17(1):1–15.
33. Lopes PR. [Characterization of the incidence and evolution of pests and diseases in coffee agroecosystems under different managements] [dissertation]. São Carlos: Federal University of São Carlos, Postgraduate in Agroecology and Rural Development; 2009. 214 p.
34. Hrdlicka H, Neiman Z. [Social and environmental responsibility and the increase in Brazilian exports: a paradox (Environmental Responsibility and the Increase in Brazilian Exports: A Paradox)]. Oñati Socio-Leg. Ser. 2012;2(3):113–38.
35. Brazil, Ministry of Development, Industry and Foreign Trade. National Biotechnology Strategy: Bioindustry Development Policy. Brasilia: MDIC; 2006. Report No.: Biotechnology Competitiveness Forum.
36. Costa P, Amorim M, Alves R, Raymundo J. [Dependence on imports to supply the demand for fertilizers in Brazil and their entry through the port of Santos]. Ind. Prod. & Serv. Magazine. 2018;5(2):53-65.
37. Gonzaga TOD, Vilar CC, Silva Filho AS, Silva VL. [Interaction bradyrhizobium and azospirllum in soybean cultivars (glycine max (l.) Merrill) and its effects on yield]. Sci. Electron. Arch. 2020;13(1): 60-66.
38. González AH. [Promoting the growth of herbaceous legumes using rhizobia isolated from coal mining areas] [dissertation]. Florianópolis: Federal University of Santa Catarina, Postgraduate in Biotechnology and Biosciences; 2015. 105 p.
39. Pais JM, Torres CEG. [Transport Logistics and Soy Production Expansion in the Midwest]. Rev. Econ. CO. 2018;4(2):21–38.