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RESEARCH PAPER

An overview of intellectual property within agricultural biotechnology in Brazil

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Abstract Brazilian agricultural biotechnology has seen great advances in recent decades, especially in the development of GM crops, including soybean, cotton, and maize, which has placed Brazil in second place since 2013 in the ranking of countries with the greatest GM-cultivated area. However, patenting these technologies is somewhat more restrictive in Brazil than in other countries, such as the USA and Japan, especially concerning isolated biological material from nature. Hence, the intellectual protection of crops in Brazil is encompassed by *sui generis* rights and/or the patenting of only the development process. Given the current scenario and the importance of biotechnology for the Brazilian agriculture sector, it is necessary to deeply study the patent system for recently developed technologies to identify opportunities for enterprises and national institutes to act in this area. The application of novel biotechnological strategies to agriculture will contribute to the expanding agriculture sector and become part of the solution to global challenges. Through this study, we can identify the major companies developing and protecting their agrobiotechnologies. Additionally, a more detailed analysis verifies

Abbreviations: BGMV, bean golden mosaic virus; CMV, cucumber mosaic virus; CNBS, National Biosafety Council; CRISPR/Cas9, clustered regularly interspaced short palindromic repeats-associated protein-9 nuclease; CTNBio, National Biosafety Technical Commission; CTP, chloroplast transit peptides; DII, Derwent Innovation Index; DNA, deoxyribunucleic acid; EMBRAPA, Brazilian Agricultural Research Corporation; EMBRAPII, Brazilian Agency for Industrial Research and Innovation; FAO, Food and Agriculture Organization of the United Nations; FAPESP, São Paulo Research Foundation; GM, genetically modified; INPI, National Institute of Industrial Property; IPC, International Patent Classification; ISAAA, International Service for the Acquisition of Agri-Biotech Applications; MAPA, Brazilian Ministry of Agriculture Livestock and Food Supply; OECD, Organisation for Economic Co-operation and Development; PLRV, potato leafroll virus; PRSV, papaya ringspot virus; PVY, potato virus Y; RNAi, RNA interference; TALEN, transcription activator-like effector nuclease; UFRGS, Federal University of Rio Grande do Sul; UnB, University of Brasília; UNICAMP, State University of Campinas; UPOV, International Union for the Protection of New Varieties of Plants; USA, United States of America; USP, University of São Paulo; WIPO, World Intellectual Property Organization; WMV, watermelon mosaic virus; ZFN, zinc-finger nuclease.

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that although there are some restrictions in Brazilian laws, GM patent applicants find ways to obtain intellectual protection for the tools they use in the development of GM crops, which include regulatory sequences, gene constructs and production methodologies. Mechanisms to stimulate investment in Brazilian research companies and public policies must be consolidated, allowing investment and public–private partnerships in this sector, with the aim of applying biotechnological knowledge and turn it into products demanded by society.

Introduction

According to data from FAO (United Nations, 2017), in 2050, the world population will be 29% greater than today, and 70% will be urban. The increasing demand for food in emerging countries, the volatility of food prices, climate change, soil degradation and water shortages will be among the major challenges to fighting hunger, which affects 795 million people worldwide, including 780 million in developing regions (FAO, 2015). These issues confirm the importance of investing in technological alternatives in the agriculture sector that can be tailored to local conditions, aiming to increase the amount of food and to exploit conditions to promote inclusive growth (FAO, 2015).

One of these alternatives continues to be the production of GM plants with traits that confer higher productivity and better alimentary and crop conditions allied with suitable soil exploitation. The first GM crop developed was a tobacco (*Nicotiana tabacum*) variety produced by Monsanto scientists 35 years ago that conferred resistance to aminoglycoside antibiotics (Fraley et al., 1983). Recently, EMBRAPA developed a common bean variety (event 5.1) resistant to BGMV, which shows the impact of this technology in Brazil. Despite the importance of virus-resistant GM plants, most transgenic-growing fields also develop herbicide-tolerant and insect-resistant plants. In this way, different strategies have been employed to genetically modify plants and obtain varieties that are resistant to insect pests, most often by transforming the hosts' genes for protein expression that interferes in the life cycle of insects or that is lethal to them, such as enzyme inhibitors and lectin genes. Cry toxins from *Bacillus thuringiensis* have also been expressed in transgenic cultures and substantially contributed to the efficient control of insect pests, dramatically reducing the use of chemical pesticides (Bravoa, Likitvivatanavong, Gill, & Soberon, 2011).

According to the ISAAA, from 1996 to 2016, there was an accumulation of 2 billion hectares dedicated to GM crop production for the market (ISAAA, 2016). The main GM-growing countries in 2016 were the USA (72.9 million hectares), Brazil (49.1 million hectares), Argentina (23.8 million hectares), Canada (11.6 million hectares) and India (10.8 million hectares) (ISAAA, 2016). In Brazil, there was an increase of 11% in the area used for transgenic crop cultivation from 2015 to 2016, of which soybean, maize and cotton represent the majority of crops, corresponding to 93.4% of the total area growing GM plants (ISAAA, 2016). ISAAA also demonstrated in 2016 that, for soybeans, growers obtained adhesion of 96.5% for GM varieties. For maize and cotton, adhesion was 88.5% and 79%, respectively. Regarding the area increase relative to each crop, from 2015 to 2016, soybean, maize and cotton saw 7.5%, 16.1% and 6.3% increases, respectively (ISAAA, 2016). Hence, the adhesion of GM technology and the cultivation area increased simultaneously. This, however, should be prevented because there is a limit to the area available for cultivation, focusing on environmental preservation.

To couple the adhesion to GM crops to economic development, there are 2 intellectual protection mechanisms used in Brazil: the patent system (Brasil, 1996) and the *sui generis* rights of cultivars (Brasil, 1997). Once protected and released to the market, these plants ensure considerable profits for their technology owners though the payment of royalties.

Regarding the first mechanism, the Law of Industrial Property (N. 9279 from May 14th 1996) specifies that ''the whole or a part of natural living beings and biological materials, even when their genome or germplasm are isolated, as well as natural biological processes'' are not considered inventions. It is important to remark that GM plants and GM animals are considered inventions in Brazil, but they aren't patentable according Article 18 (III according the Law N. 9279/96). The only living beings that can be considered patentable inventions under Brazilian law are transgenic microorganisms, which can be patented if they meet the two conditions of patentability (clarity and descriptive sufficiency) and the 3 patentability requirements (novelty, inventive step and industrial application).

In addition, processes involving living organisms (e.g., methods for the development of transgenic plants), gene constructs (e.g., expression vectors and cassettes), recombinant proteins and compositions of biological extracts are also patentable according to the Brazilian law. This means that in the case of GM plants, the tools and methods for their development can be protected, but not the plants themselves. In this case, it is possible to resort to the second mechanism, known as crop protection, based on *sui generis* rights and ruled by Law N. 9456/97 (Brasil, 1997), which grants owners crop protection for 15 years, except for vines, fruit trees, forest species and ornamental plants, whose protection period is 18 years. Accordingly, considering the impact of GM plants on the Brazilian agriculture sector in the worldwide context, in this work, we provide an outlook on intellectual property in agricultural biotechnology from 2010 to 2016.

Methods

To analyse the situation for patented agrobiotechnologies in Brazil, we first reported the main transgenic events approved by CTNBio based on scientific papers and reports. Next, we searched the database and reports of MAPA, in 2017, for protected and registered crops. We also performed an analysis of patent requests (biotechnology area) from 2000 to 2015 in the WIPO database (WIPO, 2017a) based on the following IPC codes (WIPO, 2017b): C07G, C07K, C12M, C12P, C12Q, C12R and C12S. In this case, two search strategies were performed: (a) patents applied in Brazil and (b) patents of Brazilian origin. A comparative analysis was also performed analysing different countries. In this way, we used strategy ''(b)'' selecting the options for ''Office'' as Brazil/USA/India/Argentina/China/Canada. Finally, we analysed the patent protection system for agrobiotechnologies in the Derwent Innovation Index (DII) database using search strategy based on the International Patent Classification (IPC).

Aiming to provide an overview of patent applications in agricultural biotechnology in Brazil, we created a search strategy based on the IPC used by the OECD from 2010 to 2016, focused on the agriculture sector and restricted to Brazilian documents. Hence, the query sentence used was as follows: IP=(A01H-001/00 OR A01H-004/00 OR A61K-038/00 OR A61K-039/00 OR A61K-048/00 OR C02F-003/34 OR C07G-011/00 OR C07G-013/00 OR C07G-015/00 OR C07K-004/00 OR C07K-014/00 OR C07K-016/00 OR C07K-017/00 OR C07K-019/00 OR C12M* OR C12N* OR C12Q* OR C12S* OR C12P* OR G01N-027/327 OR G01N-033/53 OR G01N-033/54 OR G01N-033/55 OR G01N-033/57 OR G01N-033/68 OR G01N-033/74 OR G01N-033/76 OR G01N-033/78 OR G01N-033/88 OR G01N-033/92) AND PN=BR*. Data retrieved from DII were analysed using Vantage Point software (Georgia Tech/Search Technology Inc., Atlanta, USA).

Results and discussion

Approved GM plants for the Brazilian market

Following the approval of the Law of Crop Protection in Brazil (N. 9456/97), the first GM crop event was released in the Brazilian market in 1998 – the soybean variety Roundup Ready containing the *cp4epsps* gene that conferred tolerance to glyphosate (Brasil, 1998). Thus, it became critical to elucidate the complex intellectual property context for glyphosate-tolerant soybean cultivars and protection strategies in agricultural biotechnology to promote the legal safety of those involved in these technologies, since for the farmers it is hard to correlate sometimes the royalties payment with the intellectual property enterprises right (Rodrigues, Lage, & Vasconcellos, 2011). The Law of Biosafety (N. 11105) was thus created in 2005 (Brasil, 2005a) and provided safety rules and surveillance mechanisms for activities involving GM organisms and their derivatives; it also instituted the CNBS and restructured CTNBio.

In 2005, the first commercial GM cotton (Bolgard I – Monsanto) was also approved, containing the *cry1ac* gene that conferred insect resistance (Brasil, 2005b). In 2007, Monsanto, Bayer and Syngenta companies developed and received approval for their first commercial transgenic maize events in Brazil: MON810 (containing the *cry1ab* gene for insect resistance), Libert Link (containing the *pat* gene for herbicide tolerance) and TL (containing both *cry1ab* and *pat* genes), respectively. Following this, many other GM events were released to the Brazilian market, suggesting that the referred laws were definitive in paving the way for these processes. In addition, the transgenic common bean event 5.1 from EMBRAPA and the higher-productivity eucalyptus from FuturaGene were also approved by CTNBio (Brasil, 2011, 2018a).

In 2016, CTNBio approved 18 GM organisms for the market, of which 9 were GM plants. According to the commission, there are currently 66 transgenic plant events commercially approved in Brazil, of which 40 are maize events, 13 cotton events, 11 soybean events, 1 common bean event and 1 eucalyptus event (CTNBio, 2016; 2017). CTNBio reports (CTNBio, 2016; 2017) show increasing interest from multinational companies in the development of GM plants characterised by insect resistance and herbicide tolerance, especially using gene pyramiding.

Despite a growing number of Brazilian published patents in the general area of biotechnology since the Law of Industrial Property (1996), we notice that Brazil is far behind the USA and China (Table 1), which reveals an urgent need to invest much more in innovation, including patent protection, to help Brazil be more competitive in the biotechnology sector.

Brazilian protected GM crops

According to internal reports from MAPA and an analysis of its protected crop database (MAPA, 2017) there were 2318 protected crops in Brazil, of which 628 had a definitive protection certification: 593 soybean crops, 34 cotton crops and 1 common bean crop (BRS FC401 RMD from EMBRAPA). By June 2017, there were 2214 GM crops registered in MAPA, which means they are ruled for commercial purposes. Of these crops, 51% represent soybean, 45% maize, 3.7% cotton, 0.15% common bean and 0.15% eucalyptus.

Data from Fig. 1 show the tendency towards an increase in the number of registered GM crops in Brazil – especially soybean – and highlight the impact of this technology on Brazilian agribusiness. The decrease shown in Fig. 1 for the more recent years is probably due to a delay in indexing data. In the case of maize, although there are a reasonable number of GM crops, owners usually prefer to protect their technology through secret industrial systems because this species provides hybrid crops.

Agricultural Biotechnology: analysis of Brazilian patent protection

OECD data for 2015 identifies the USA, EU members and Japan as the main countries with patent applications in the biotechnology area for the period from 2010 to 2013 (OECD, 2015).

An analysis of published patents in the biotechnology area in Brazil (Fig. 2) shows that despite the large number of patent applications, most of the patenting effort is of foreign origin, which are simply represented by ''Brazilian documents'', in contrast to ''documents of Brazilian origin'', since Brazilian documents include patents of foreign origin but applied in Brazil, whereas documents of Brazilian origin refer to patents that have first application in Brazil and are usually done by Brazilian. This demonstrates the interest of several international actors in protecting their inventions in the Brazilian market and indicates that given

Table 1 Number of patent documents in biotechnology for the main GM plant-producing countries (2000–2015).

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Argentina	6	6	16	20	24	18	20	25	22	18	16	26	19	21	36	18
Brazil	30	42	72	49	87	70	79	75	107	128	110	114	97	155	165	168
Canada	727	777	1019	1065	1047	916	711	709	692	736	703	748	644	629	706	453
China	424	2563	2169	1291	1508	2266	2433	2746	3835	4511	5573	7211	8840	10,091	11,695	6374
India	48	65	103	172	185	203	224	317	298	231	249	276	298	252	271	318
United States of America	11,011	13,134	17,486	18,578	15,894	15,308	13,350	13,564	13,845	13,929	13,732	14,598	14,190	14,957	17,139	12,905

Source: Created by the authors based on WIPO data (WIPO, 2017a).

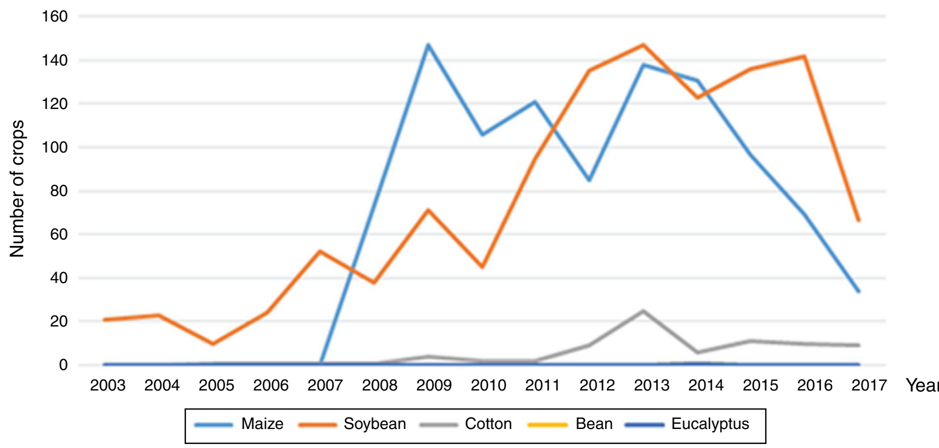

Figure 1 Evolution of the number of GM crops registered in MAPA.
Source: Created by the authors based on MAPA data (WIPO, 2017a).

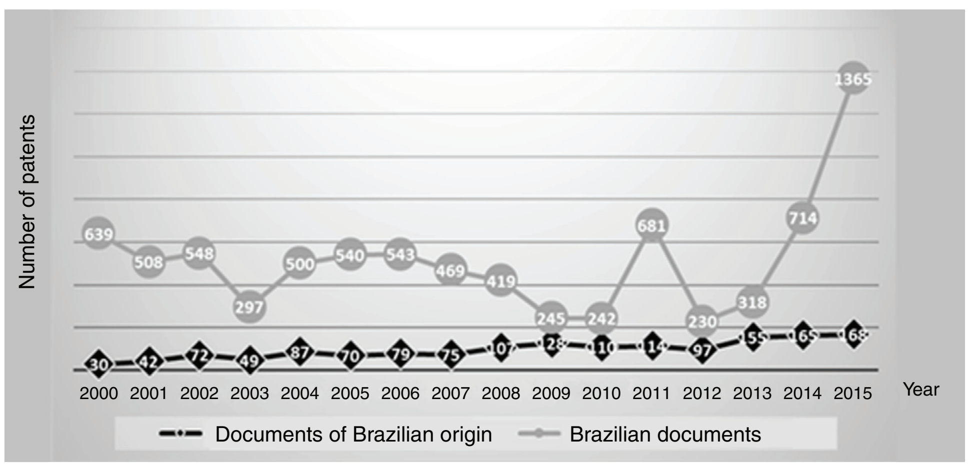

Figure 2 Number of published patents of Biotechnology from 2000 to 2015 in Brazil.
Source: Created by the authors based on WIPO data (WIPO, 2017a).

the important knowledge base built over the years in the field of biotechnology in Brazil, national inventors could demonstrate more significant participation in patenting in this technological field.

A study performed by INPI concerning applied biotechnology patents in Brazil by Brazilian owners from 2009 to 2013 concluded that most of the applications were from companies and universities and were related to the agroindustrial sector, especially those involving GM plants (Verde, Dos Santos, & Guerrante, 2015). INPI also showed UNICAMP as the ranking's leading applicant, with USP and EMBRAPA also being important.

Using the above-mentioned strategy to analyse Brazilian documents representing patent applications in the biotechnology sector from 2010 to 2016, 3711 results were retrieved, of which 916 were retained after refining the search to agricultural biotechnology. Of these, 47% were related to plants, 32% to animals and 15% to microorganisms. Those related to microorganisms mostly involve biofuel production processes using algae but also involve molecule biosynthesis, cultivation methods, fermentation processes, vaccines and cosmetics composition, probiotics and compositions for the biological control of plant pests. Those documents for animals mostly involve vaccines and methods for treating human and animal diseases but also involve GM animals, diets, disease detection methods, synthetic genes for veterinary applications, methods for animal reproduction (e.g., artificial ovaries, sperm enrichment), genotyping chips, molecular markers, cryopreservation, among others. In the case of plants, most (approximately 93%) involve the development of GM plants but also involve culture media, bioreactors, gene mapping, seed analysis, fertilizers, embryo analysis, hybrid production, molecular markers, and grafting.

An analysis of priority countries revealed that most of the Brazilian patent documents from 2010 to 2016 were first applied in Canada (523), the USA (511) and South Korea (260), which strongly suggests that these countries are the main research development sites resulting in patent applications in Brazil. Brazil was the fourth in this ranking (203). The results showed that Australia, China, Japan and the Philippines are also interested in the Brazilian market, possibly due to the extensive area used for agriculture in the country and to well-established GM cultivation. The USA, EU countries and China are other targets of market interest because the USA and China are worldwide leaders

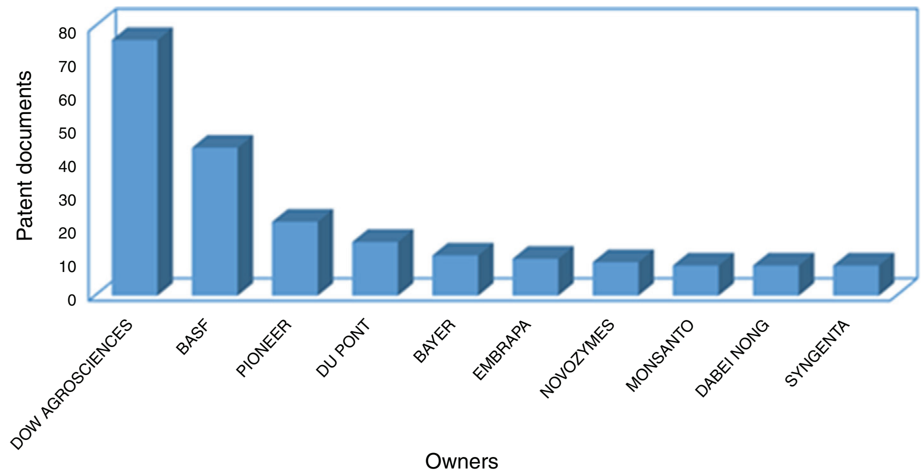

Figure 3 Ranking (Top 10 – legal persons) of the main owners of Brazilian patents involving GM plants (2010–2016).

in most technologies, and EU countries have powerful biotechnology research centres.

Examining the major patent applicants in Brazil, Dow AgroSciences, BASF and DuPont Pioneer were the main patent owners in agrobiotechnologies, and in the national context, EMBRAPA was the main applicant, with 17 published patent documents, representing 6th place in the ranking, followed by the Danish company NOVOZYMES (Fig. 3).

We must also emphasise the acquisition of companies over the years. In 2017, for instance, Dow AgroSciences was merged with DuPont Pioneer (Globo, 2017), Monsanto was bought by Bayer (Valor Econômico, 2017a) and Syngenta was sold to ChemChina (Valor Econômico, 2017b). These three large companies established in the agriculture sector control more than 60% of the worldwide seed and agrochemical markets (Valour Econômico, 2017c).

Considering the 30 main applicants in agricultural biotechnology, EMBRAPA stands out as the most linked with different institutions through partnerships, either Brazilian (e.g., UnB, FAPESP and UFRGS) or foreign (e.g., with BASF). BASF also has a striking link with natural persons, probably because individual inventors are considered owners in the USA. Abbott and Abbvie were also found to be linked, likely because the pharmaceutical company Abbott spun off Abbvie. Danisco was linked to DuPont Pioneer because it was incorporated into DuPont in 2011 (Supplementary Figure 1).

Kenneth E. Narva from Dow AgroSciences is the inventor who figures in the largest number of patent applications of this study; these usually involve insect (Cry 1F, RPA70, RPS6, Cry1Ab, Cry2Aa, Cry1C, Cry1Da, Cry1Be, Cry1Fa, Cry2Aa, Cry1I, Cry1E, Cry-1Da and Cry1 Ca proteins) and nematode (Cry14, Cry 5 and Cry 6 proteins) control.

Analysing these 916 agricultural biotechnology patent documents according to the IPC (WIPO, 2013), we found that most of them were classified as C12N 15/82 (vectors or expression systems especially adapted to plant cells) or A01H 5/00 (angiosperms), confirming results indicating that patent applications mostly involve GM plants. This shows despite the restrictions in industrial property legislation regarding the protection of plants by the patent system, many companies and institutions are interested in protecting related biotechnological tools necessary for the development of GM plants in Brazil.

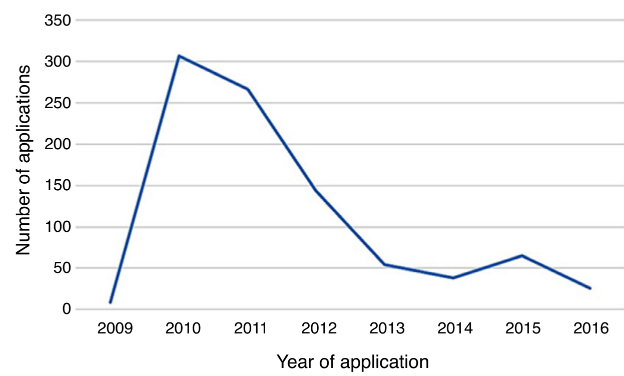

Figure 4 Evolution of Brazilian patent requests per year in Agricultural Biotechnology (2010–2016).

Analysing the evolution of patent applications in Brazil in the field of agricultural biotechnology (Fig. 4), a progressive decline was shown, with some interfering factors: patents still under the secrecy period; a delay in database updates; or disinterest in searching for protection because of, among other factors, (1) the restrictive scope of patent protection from Brazilian law in the biotechnology field or (2) the very slow rate of patent analysis in Brazil. When focusing on requested patents for GM plants in the same period (Fig. 5), it was found that they follow almost exactly the same pattern as that for agrotechnologies in general (Fig. 4).

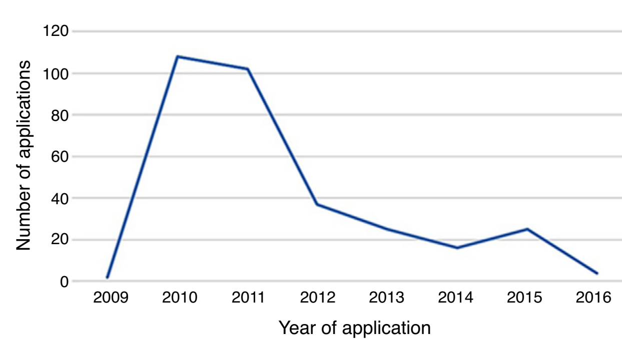

Figure 5 Evolution of Brazilian patent requests per year involving GM plants (2010–2016).

Patenting process for GM crops in Brazil

Despite restrictions in the laws concerning the patent protection of plants, interest clearly remains in protecting biotechnological tools useful for the development of GM crops in Brazil, as 318 out of the 916 refined documents (35%) comprised the development of GM crops. A more detailed analysis places Brazil in the 5th place of applicant countries, with the USA, Canada and South Korea being the main applicants, indicating other countries' growing interest in the Brazilian market.

Regarding the type of protected GM crops, most are related to genes or proteins protecting against insecticidal activity (especially against Lepidoptera, Coleoptera and Hemiptera) and providing tolerance to herbicides (e.g., 2,4-D and glyphosate). In the first case, the most cited target insect-pest species are *Ostrinia nubialis* (Lepidoptera), *Spodoptera frugiperda* (Lepidoptera), *Diabrotica speciosa* (Coleoptera), *Pseudoplusia includens* (Lepidoptera), *Anticarsia gemmatalis* (Lepidoptera) and *Euschistus heros* (Hemiptera), and their control is based on the insertion of genes coding for Cry toxins.

Table 2 lists patent requests from the main owners related to insect resistance. Although requests referring to Dabei Nong relate to Chinese insect pests, these patent applications in Brazil may aim to protect a possibly useful technology if this pest spreads to Brazil. This table also indicates different protection strategies used by owners: gene stacking technologies, transgenic events containing stacked genes and methods for developing insect-resistant GM plants (e.g., through RNAi).

The documentation for the listed patent requests also describes other GM-related technologies such as plant transformation methods, GM organism detection kits, site-directed integration methods such as gene editing tools (e.g., ZFNs and TALENs), function restoring genes for plant male sterility, target loci detection methods for foreign DNA, methods of introgression for transgenic events, plant regulatory sequences (e.g., promoters), devices and GM microorganisms used in plant transformation, GM plants with oil production improvement, CTPs, RNAi strategies, fusion proteins, proteins for nematode control and genes for yield improvement (e.g., increase in biomass and/or seed productivity). Although the use of other genome engineering technologies such as CRISPR/Cas9 is on the rise, few documents based on these were found, perhaps because they were developed recently, and many patent documents may be still within the secrecy period.

Analysing the patent requests related to GM crops made it possible to observe that owners try to include not only the central invention (usually a gene or a protein) but also any surrounding technologies with possible commercial importance, such as the GM plant itself or its parts, gene constructs or cassettes, transgenic-derived products, methods involving invented molecules and even fields containing these organisms. Otherwise, most of these items will have their protection denied in Brazil by the law, although INPI holds that protection of items containing natural biological products must not be considered solely dilutions of non-patentable technologies (INPI, 2015a).

It was also observed that approximately 22% of the identified patent applicants have a ''filed'' status in INPI most of the time due to the lack of payment of annuities. This status may have a number of causes: (1) temporary problems in the INPI's processing of the fees paid due to changes in their value and the need for proof by the applicant, (2) withdrawal by owners or (3) management trouble for active patents. The last cause is less likely because owners have a long protection history. In the cases of withdrawal, a patent examination resulting in the absence of patenting criteria for a technology that was previously experienced abroad may be a reason. This explanation corresponds with the observation that most of the documents are of foreign origin – especially being from the USA – often first applied in the USA, and thus able to retrieve examination results more quickly. Likewise, some patents were requested almost 10 years ago, and none had yet been deferred yet or had technical requirements, confirming the long-lasting patent examination process in Brazil, although efforts are being made in INPI in order to accelerate this process, which can overcome this obstacle and result in a very different scenario in the future.

Conclusion

There is too high an interest among multinational companies in obtaining patent protection for their biotechnological products in Brazil, especially as concerns GM plants. This interest is likely due to (1) Brazil's status as an agricultural power; (2) the progressive adhesion to GM crops in the last decade; (3) the role of GM plants in supporting the development of agriculture; and (4) the capacity of GM plants to reduce environmental damage by diminishing the use of soil and decreasing the use of chemicals such as insecticides.

However, national companies are not able to compete with multinational ones, with the exception of EMBRAPA, which was 6th place in terms of patent applications for agrobiotechnologies. Thus, Brazil is not yet strongly competitive in this area, particularly compared with biotechnology-leadership countries such as the USA and China.

Additionally, we notice that broad protection is the main strategy adopted by large companies in the development of GM plants. This strategy comprises the protection of invented genes/proteins and the derivatives of these inventions, such as gene constructs/cassettes, production methods, parts of GM plants, GM plant-derived products and seed mixtures. Moreover, many companies have protected agrobiotechnologies comprising stacked genes within the same technology, either related to the same trait (e.g., genes for insect resistance) or to distinct traits (e.g., genes for insect resistance and genes for herbicide tolerance). In the case of Brazil, despite more restrictive laws, broad protection may set the expectation that the law could be modified when documents are examined in the future.

Current status and perspectives

We must rethink the need for national investment in projects for biotechnological innovation and consolidate already existing initiatives, such as the National Policies for Biotechnology (Brasil, 2007), the legal mark of science technology and innovation (Law N° 13.243/2016 and Law Decree N°

Table 2 Brazilian patent requests related to insect-resistant GM plants (2010–2016).

Item	Patent application number	Event/Gene/Product/Process	Target insects	Owner
1	BR112012014772	Vip3ab and Cry1fa proteins	Lepidoptera	Dow AgroSciences
2	BR112012015005	Cry1ca-modified proteins	Lepidoptera	Dow AgroSciences
3	BR112012014700	Cry1ab and Cry2aa proteins	Lepidoptera	Dow AgroSciences
4	BR112012014727	Cry1da and Cry1be proteins	Lepidoptera	Dow AgroSciences
5	BR112012014702	Protein stackings: Cry 1Fa-Cry2Aa and Cry 1l-Cry 1E	Lepidoptera	Dow AgroSciences
6	BR112012014803	Vip3ab and Cry1ca proteins	Lepidoptera	Dow AgroSciences
7	BR112012014879	Cry1be and Cry1f proteins	Lepidoptera	Dow AgroSciences
8	BR112012014801	Cry1ca and Cry1fa proteins	Lepidoptera	Dow AgroSciences
9	BR112012014796	Cry1ab and Cry1be proteins	Lepidoptera	Dow AgroSciences
10	BR112012014681	Cry1da and Cry1ca proteins	Lepidoptera	Dow AgroSciences
11	BR102012019434	Insect-resistant soybean event 9582.814.19.1 (Cryl F and CrylAc (synpro) proteins) with tolerance to herbicide (PAT protein)	Lepidoptera	Dow AgroSciences
12	BR102012018662	Insect-resistant soybean event pDAB9582.814.19. 1::pDAB4468.04. 16.1 (CrylF and CrylAc (synpro) proteins) with tolerance to herbicide (AAD-12 and PAT proteins)	Lepidoptera	Dow AgroSciences
13	BR102015025537	Gho/Sec24b2 and Sec24b1 silencing (RNAi)	Coleoptera and/or Hemiptera	Dow AgroSciences
14	BR102013032916	Reptin silencing (RNAi)	Coleoptera	Dow AgroSciences
15	BR102012025724	pp1-87b silencing (RNAi)	Coleoptera	Dow AgroSciences
16	PI1011950	Cry and Dig-11 proteins	Coleoptera	Dow AgroSciences
17	PI1015333	Dig-3 proteins	Lepidoptera	Dow AgroSciences
18	BR102012025759	rpa70 silencing (RNAi)	Coleoptera	Dow AgroSciences
19	BR102014031844	Opposite Ras silencing (RNAi)	Coleoptera and/or Hemiptera	Dow AgroSciences
20	BR102012025657	rps6 silencing (RNAi)	Coleoptera	Dow AgroSciences
21	BR112012014746	Cry1ca and Cry1ab proteins	Lepidoptera	Dow AgroSciences
22	BR112012027140	Cry34ab/35ab and Cry3ba proteins	Coleoptera	Dow AgroSciences
23	BR112012027139	Cry34ab/35ab and Cry6aa proteins	Coleoptera	Dow AgroSciences

Table 2 (*Continued*)

Item	Patent application number	Event/Gene/Product/Process	Target insects	Owner
24	BR112012027218	Cry34ab/35ab and Cry3aa proteins	Coleoptera	Dow AgroSciences
25	BR112012027208	Cry3aa and Cry6aa proteins	Coleoptera	Dow AgroSciences
26	BR112012014804	Cry1fa and Cry1ab proteins	Lepidoptera	Dow AgroSciences
27	BR112012014665	Insect-resistant maize event dp-004114-3 (Cry1F, CRy34Ab1 and Cry35Ab1 proteins) with tolerance to herbicide (PAT protein)	Coleoptera	DuPont Pionner
28	PI0919339	Bt toxins	Lepidoptera	DuPont Pioneer
29	PI1007260	Bt toxins	Lepidoptera	DuPont Pioneer
30	PI0918766	Bt toxins	Coleoptera	DuPont Pioneer
31	PI0924154	Bt toxins	Lepidoptera	DuPont Pioneer
32	PI0924153	Bt toxins	Lepidoptera	DuPont Pioneer
33	PI0919336	Bt toxins	Lepidoptera	DuPont Pioneer
34	BR112012030913	Nezara viridula genes silencing (RNAi)	Hemiptera	DuPont Pioneer
35	PI0823184	Cyt1, Cry4A, Cry4B, Cry10, Cry11, Cyt2 and Cry3 proteins	Coleoptera and/or Lepidoptera	EMBRAPA
36	PI1102841	Alpha-amylase inhibitor mutants	Coleoptera	EMBRAPA
37	PI0906128	Cry8Ha protein	Coleoptera	EMBRAPA
38	BR102012033506	Laccase family genes silencing	Coleoptera	EMBRAPA
39	BR102012033542	Cry1Ia12 protein	Lepidoptera	EMBRAPA
40	BR102013031014	Control strategy against Athetis lepigone based on Cry1A protein	Lepidoptera	Dabei Nong
41	BR102013031821	Control strategy against *Conogethes punctiferalis* based on Cry1F protein	Lepidoptera	Dabei Nong
42	BR102014003618	Control strategy against *Sesamia inferens* based on Cry1B protein	Lepidoptera	Dabei Nong
43	BR102013031822	Control strategy against *Sesamia inferens* based on Cry1F protein	Lepidoptera	Dabei Nong
44	BR102013031734	Control strategy against *Athetis lepigone* based on Cry1F protein	Lepidoptera	Dabei Nong
45	BR102013018436	PIC9-modified protein	Lepidoptera	Dabei Nong
46	BR102013018337	PIC9-modified protein	Lepidoptera	Dabei Nong
47	BR112013000262	Insect-resistant maize events MIR604, BT11 and MIR162 (Cry3A, Cry1Ab and Vip3Aa20 proteins)	Coleoptera	Syngenta
48	PI0922656	Insect-resistant maize event 5307 (FR8 protein and PMI gene marker)	Coleoptera	Syngenta

9.283/2018) (Brasil, 2016, 2018b) and EMBRAPII (Brasil, 2013), which aim to expand partnerships with companies and encourage biotechnological development by national companies and institutes. These efforts will certainly boost innovation and increase the number of biotechnological products in the market and that of patent applications, consequently strengthening the Brazilian economy.

Although examining patent applications in Brazil is a very slow process — which affected our analyses — INPI has created strategies to accelerate it, stimulating applicants to apply for patents in Brazil. Some of these strategies include priority for applications involving *green patents* (INPI, 2016a), which comprise technologies for the environment such as alternative energy sources, energy conservation, the management of residues and sustainable agriculture.

The INPI considers sustainable agriculture to be as follows: (1) reforestation techniques; (2) alternative watering techniques; (3) alternative pesticides and (4) soil improvement (e.g., residue-derived organic fertilizers). GM plants are not included in this panel, despite the potential environmental benefits mentioned above; this is an important topic that should be taken into account by INPI when considering priority application. In parallel, the pilot projects for priority application of requested patents from institutes of science and technology (IST Patents) (INPI, 2017a), micro- and small-sized enterprises (MSE Patents) (INPI, 2016b; 2017b) and of Brazilian origin, with priority rights assured for application in different national or international patent offices (BR Priority) (INPI, 2015b; 2017c), have been initiatives undertaken by INPI to accelerate the examination process.

The protection strategies involving gene pyramiding are another alternative for use by Brazilian companies and institutions. Moreover, knowing the existing technologies may facilitate the development of new technologies and expand opportunities for partnerships with owners. Finally, to better promote the independence of national companies in this sector, using technologies within the public domain is also an alternative, provided that there is the constant monitoring of activity in corresponding patent databases.

Conflicts of interest

The authors declare that the research was performed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Uncited reference

OECD (2005).

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biori.2019.04.003.

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