The importance of intellectual property rights to the plant biotechnology industry

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Abstract

The main objective of this article is to point out the importance of intellectual property rights (IPR) as institutional mechanisms that are able to ensure the appropriability of targeted innovation efforts to develop transgenic seeds. The study is related to a science based sector, the seed industry, in which appropriability mechanisms seem to be the core strategic tools to create entry barriers.

This study has developed indicators to measure the blocking power of patents and also the capacity of these documents in order to avoid spillovers that tend to benefit farmers. Indicators adopt the assumption that the number of infringement lawsuits that were established from a patent may be considered a proxy of its legal blocking capacity.

The results provided evidence of the general strategies of appropriability. The main patents related to herbicide tolerance and enabling technologies belong mostly to the company Monsanto. The corporation employed such legal documents to sue American farmers, through the accusation of biopiracy as well as to establish a system of blocking patents toward opponents. Monsanto did so by essentially preventing competitor's access to the main methods for inserting genetic material into plant cells and for controlling the gene expression process. These biotechnological tools are vital to the development of genetically modified seeds. For more than a decade, the success of this strategy has promoted the endurance of the monopoly status enjoyed by Monsanto's commercial products**.**

Under this context, this study shows that intellectual property rights, in addition to their traditional role of legal protection of knowledge assets, represent a crucial factor to achieve sustainable competitive advantages over competitors.

I- Introduction

Agricultural science-based technologies – whose emergence occurred in the 1970s and 1980s – have been largely benefited by the strengthening of the protection system for intellectual property rights (IPR).

Until 1977 patenting living organisms was not accepted in any country, including the United States. In that year, the US courts ruled that natural products could not be patented *per se*, but only if they presented some modification due to the human intellect intervention. In 1980, as a result of Diamond *vs*. Chakrabarty case, the US Supreme Court decided to grant a patent to the first genetically modified bacteria (DAL POZ, 2006). This case has removed the main legal obstacles to the patenting of genes, genetically modified

organisms (GMO) and general processes that involve cell transformation or protein expression. As result of the strengthening of the existing Intellectual Property System in the US, the entrance of universities and agrochemical companies in the plant biotechnology industry was stimulated (RAUSSER, 1999).

Complementarily, the Bayh-Dole Act was approved in 1982 by the US Congress. This legal act has granted to US universities the permission to request patents over the results of scientific research funded by federal agencies. The Bayh-Dole Act motivated various spin-offs from academic institutions that have given rise to numerous biotechnology-based companies (BBC). These BBC specialized mainly in developing enabling technologies, i.e. the biotechnological tools that must be applied during the development of GMO (GRAFF *et al.*, 2003).

After the start of GMO cultivation in 1996, the *big six companies*[1] increased their research and development (R&D) efforts upon agriculture biotechnologies. These corporations also acquired several BBC through mergers and acquisitions (M&A). Consequently, by the end of the 1990s , the agrochemical corporations have assumed the control of the majority of plant biotechnologies developed in previous decades (DE JANVRY *et al.*, 1999).

The entry of the *big six companies* in the seed market has altered significantly the structure of this economic segment. Large agrochemical corporations showed some lack of interest in the seed industry during the decades before the 80s. The *big six companies* feared that the existing appropriability conditions in agriculture were unable to avoid imitation and ensure the capture of economic benefits from the inventive activities. This skepticism tended to scare off private investment (FERRARI, 2015).

The changes in IPR protection system, raised by the Diamond *vs.* Chakrabarty case (1980), contributed to reduce the uncertainties over the genetic plant breeding programs, especially the risks regarding profit appropriation. Thus, the strengthening of the appropriability conditions has stimulated the entry of the *big six companies* in the seed market, which resulted in the growth of industrial concentration.

In short, the radical changes posed by the emergence of the molecular biology paradigm and by the strengthening of the IPR protection system in the early 80s set the

[1] In this article the term 'big six companies' is used to designate the leading multinational companies from the agrochemical sector that are also involved in the transgenic seed market. We refer to companies: Monsanto, Dupont, Syngenta, Dow, Bayer Cropscience and Basf.

stage for the rise of the plant biotechnology industry. Since then, the market value of seed companies is highly dependent on the development, accumulation and protection of intellectual property rights (RAUSSER, 1999).

Given this context, the main objective of this study is to point out the importance of intellectual property rights (IPR) as institutional mechanisms that are able to ensure the appropriability of targeted innovation efforts to develop GMOs. The main proposition addressed in this article is that market competitiveness is closely related to the appropriability mechanisms constructed by biotechnological firms. Patents are relevant in this sector, since they protect not just the final goods which contain the embedded technology, but also the intermediate or "enabling" technologies. Thus, firm's efforts to acquire patent enforcement rights over the biotechnological tools that must be applied to create GMOs seems to be the core strategy to build entry barriers and thus deter new competitors.

This study has developed indicators to measure the blocking power of patents[2] and the capacity of these documents in order to avoid spillovers that would prove favorable to farmers. The appropriability indicators are based on patent infringement lawsuits statistics.

There are two key assumptions underlying the appropriability indicators: i) firms tend to adopt in lawsuits the patents that have greater possibilities to collect legal victories; ii) in the case of defeat, the juridical authorities tend to invalidate the patents that have given rise the litigation. Given these assumptions, the amount of infringement lawsuits that were established from a patent may be considered a proxy of its legal blocking capacity. In addition to the study of the appropriability indicators, the article also discusses a case study - the legal battle between Monsanto and Syngenta by the control of the GMOs derived from the GA21 gene.

The next section presents a review of the literature about the appropriability mechanisms that have been employed by biotechnology firms. Section 3 presents the hypotheses and the methodology. Section 4 presents the findings and analyses the case study aforementioned. Section 5 presents conclusions, focusing on the main contributions of this study and suggesting ways of moving forward in future.

[2] The legal blocking power of an issued patent can be defined as the document capacity to exclude other competitors from the market (MARCO and RAUSSER, 2008).

II - Biotechnology, agriculture and IPR

A GMO is a plant that has in its genotype one or more genes from others species. These exogenous genes need to be manipulated in laboratory and, then, inserted into host cells by adopting genetic engineering techniques. In turn, these genes are able to encode new useful features for carrying out agricultural activities (QAIM, 2009).

The development of a GMO integrates multiple scientific knowledges and several complex technologies. Graff, Rausser and Small (2003) identified three groups of crucial assets that must be employed during the development of transgenic seeds: i) enabling technologies that correspond to the biotechnological research tools that must be applied to create GMOs, i.e., the genetic engineering techniques used to transfer the DNA from other species into plant cells or to control the gene expression process[3] (GRAFF *et al.*, 2003); ii) genetic code sequences capable of encoding new agronomic features into plant organisms; iii) germplasm banks referring to the agronomic varieties that will have the exogenous genetic material inserted into their genotype.

Overview of intellectual property and patents

Capturing the benefits associated with innovation processes is a key element in the construction and retention of competitive advantages by firms (LAURSEN and SALTER, 2006; HALL, 1999; CEFIS and MARSILI, 2006; CZARNITZKI and KRAFT, 2004). Several studies point to the variety of mechanisms for protection against unauthorized copying or appropriation of R&D efforts by direct competitors (new entrants as well as incumbents), including (a) use of patents and other legal protection mechanisms; (b) deployment of complementary assets and assets associated with sales and marketing, manufacturing, and integration of knowledge in various forms; (c) trade secrets; and (d) first mover advantage (TEECE, 1986; LEVIN *et al.*, 1987; COHEN, NELSON and WALSH, 2000; ARUNDEL, 2001).

Since the early 1980's, the protection of agricultural biotechnologies marketed in the US has been based mostly on patents. These legal documents are considered better instruments for innovation protection than others appropriability mechanisms, due to several specificities present in agriculture (FULTON and GINNAKAS, 2001).

Industrial secrets are much less efficient in seed industry than in other sectors. The cell morphology studies conducted in laboratories tend to reveal important characteristics

[3] The gene expression process consists in the transformation of the genetic sequence in the protein that will originate the new agronomic feature.

about plants' physiology, which inevitably helps to facilitate the imitation efforts (LESSER, 1998). In this scenario, IPR have played a key role in building legal barriers against copying. The risk of costly patent infringement lawsuits is the main threat able to put the imitators away (RAUSSER, 1999; BARTON, 1998).

Genetic plant breeding programs tend to be conducted under the threat of the "adaptive destruction process". This phenomenon is related to the loss of biological and commercial value of transgenic seeds due to the strengthening of pests resistance against biotechnological products. Higher degrees of "adaptive destruction" tend to erode the private return over investments (GOESCHL and SWANSON, 2003; YEROKHIN and MOSCHINI, 2008).

Under the "adaptive destruction threat", the patent systems have contributed to enlarge the expectations regarding the economic viability of GMO development projects. Royalty revenues provided by patenting activities tend to accelerate the pre-operating costs amortization, which contributes therefore to mitigate the losses *vis-à-vis* pests' adaptation against transgenic seeds.

Not coincidentally, the strengthening of the IPR protection system in the US, that started in the 1980's, has stimulated investments from universities, BBC and agrochemical companies in agriculture (POSSAS; SALLES-FILHO; DA SILVEIRA, 1996). Due to this fact, the beginning of the 1990's was characterized by fragmentation of the main agricultural biotechnologies in several patents belonging to many corporations.

The creation of the OGM golden rice in the 1990's illustrates that issue. The scientists had to adopt more than 40 genetic engineering techniques that had been patented by multiple companies. Given this scenario, some authors began to fear that the fragmentation of agricultural biotechnologies were able to generate harmful effects on the "freedom to operate" of economic agents, due to the emergence of patent thickets problems (KRYDER, KOWALSKI and KRATTIGER, 2000).

The patent thickets arise when the owners of research tools or other intermediary technologies also acquire legal patents rights to block the emergence of future inventions or, even, the final products that were built upon these tools (SHAPIRO, 2000; BESSEN, 2003; CHU, 2009). Heller and Eisenberg (1998) point out that the increasing number of patent owners able to block downstream products may cause a market failure called "tragedy of the anticommons".

The GMO are complex products whose development process needs to adopt several biotechnological tools. The “tragedy of the anticommons” hypothesis has proposed that the emergency of an excessive amount of patents owners capable of charging royalties over these tools was the main reason behind the modest research and development (R&D) efforts in agricultural biotechnologies. The expansion of royalty collectors tends to amplify the technological licensing fees and the risks of patent infringement lawsuits, affecting negatively the adoption of intermediary technologies and the pace of emergence of innovations. Thus, the tragedy of the anticommons is, therefore, a market failure opposite to the scenario described by the tragedy of the commons, which foresaw the risk of overuse of economic resources due to the lack of property rights (HELLER and EISENBERG, 1998; KRYDER, KOWALSKI and KRATTIGER, 2000; BENNETT, 2004).

Marco (2004) and Marco and Rausser (2008) suggest that the problems posed by the expansion of biotechnological patent owners have been solved by the merger and acquisitions (M&A) operations conducted by *the big six companies*. The authors developed a model capable of measure the legal blocking power of patent documents, understood as patent´s probability to win IPR infringement lawsuits.

Marco and Rausser (2008) found that the owners of blocking patents are more likely to engage in M&A, acting both like acquiring company and company acquired. The authors conclude that the M&A that have occurred in the seed industry have contributed to reduce the problems caused by overlapping patents, due to the increasing concentration of the main blocking patents in the hands of the big six companies.

Other studies tend to reinforce this perception. As pointed out by Rausser (1999), the development of glyphosate-tolerant maize seeds has adopted several technologies claimed by nine key patents. In the early 90s, these patent documents belonged to five different companies. The M&A operations that occurred over this decade concentrated this set of nine patents in just two companies - Monsanto and Syngenta. The biotechnologies applied in the development of insect-resistant cotton cultivars have experienced a similar process of concentration (DE JANVRY *et al.*, 1999).

III - Methodology

Patent Data Collection

This article performed seven patent searches in the United States Patent and Trademark Office (USPTO) database. The search queries have identified patent documents that were granted by the USPTO from 1976 to 2012. Search No. 1 focused on plant promoters. These biotechnological tools consist in the DNA nucleotide sequence that instructs the plant cells to start the gene expression process (PÉRIER, JUNIER and BUCHER, 1998). We conduct several meetings with molecular biology scientists; the experts gave us a list of the six main promoters employed by industry: *Rice Actin; Phosphoenolpyruvate carboxylase; Opine; Maize Alcohol Dehydrogenase; Cauliflower Mosaic Virus 35S; Ubiquitin.*

The Odysseys Patent Computing System software was adopted to access the USPTO database and undertake a search for patents that present in their abstracts and/or in their claims the name of at least one of the aforementioned promoters. The search also identified the "neighboring patents", i.e., patent documents that do not quote the promoters, but, on the other hand, cite at least one patent that belongs to the first group. The search No. 1 identified 2665 patents.

The remaining six patent searches aggregated three kinds of information: 1) the name of each member of the *big six companies* group - Monsanto, Bayer, Syngenta, Dupont, Dow and Basf; 2) names of the subsidiaries belonging to these multinational corporations; 3) C12N1582[4] technological subclass from the International Patent Classification (IPC). Chart 1 presents the main results of searches number. 2,3,4,5,6 and 7.

Chart I: Patent Searches No. 2, 3, 4, 5, 6, 7.

Search Number	Company	IPC	Patents Identified
2	Monsanto & Subsidiaries	C12N1582	2310
3	Bayer Cropscience & Subsidiaries	C12N1582	408
4	Syngenta & Subsidiaries	C12N1582	593
5	Dupont & Subsidiaries	C12N1582	1742
6	Dow & Subsidiaries	C12N1582	235
7	Basf & Subsidiaries	C12N1582	286

Source: USTPO

[4] According to the IPC hierarchical taxonomy, the C12N1582 code comprises microorganisms, enzymes and genetic engineering tools capable of promoting alterations in the DNA and/or RNA of the plant

All the patents identified were compiled into a single database. The duplicate records were deleted, thus obtaining a final sample of 7234 biotechnological patents. We adopt two bibliometric software in order to extract information from the patent database. Publication numbers corresponding to the 7234 patents were imported to Thomson Innovation™ (TI). The TI is a technological platform provided by Thomson Reuters only for private subscribers.

The TI features allowed us to access, compile and export the following information for each patent document: 1-Publication Number; 2-Title; 3-Assignee ; 4-Publication Date; 5-Application Date; 6-International Patent Classification (IPC); 7-Cooperative Patent Classification (CPC); 8- Count of Cited References – Patent; 9-Count of Citing Patents; 10-Litigation statistics; 11-Family Members; 12- Count of Family Countries.

Patent database was also imported to software Vantage Point™ (VP). The VP tools help us to organize the stats regarding patent infringement lawsuits . Tables 1, 2 and 3 were built upon the VP tools.

Legal Blocking Capacity - Indicator

Marco (2004) and Marco and Rausser (2008) discuss the firm's capacity to keep competitors out of the market through the adoption of blocking patents. This paper also sought to develop indicators capable of measuring the legal blocking power of patent documents. There is an important difference between this article and the previous study. Marco and Rausser (2008) developed a model able to *ex ante* predict the patent's probability to win IPR infringement lawsuits. In contrast, we conduct an *ex post* analysis about the amount of lawsuits derived from each patent.

The *legal blocking capacity indicator* adopts two key assumptions: : i) the firms tend to adopt in lawsuits the patents that have grater possibilities to collect legal victories; ii) in the case of defeat, the juridical authorities tend to invalidate the patents that gave rise the litigation. Given these assumptions, the number of infringement lawsuits that were established from a patent may be considered a proxy of its legal blocking capacity. Thus, patents that started several lawsuits, tend to exhibit strong legal blocking capacity (LBC). The LBC indicator can be expressed as follows:

$$LBC(p) = LSfirms(p) \qquad \text{Equation (1)}$$

where:

LBC(p): legal blocking capacity of patent *p*

LSfirms(p): the amount of lawsuits accusing other firms of patent (*p*) infringement.

Avoidance of spillovers.

A significant agricultural spillover occurs when farmers decide to reproduce transgenic seeds without the approval of seeds suppliers. The later generations will inherit the agronomic feature present in the GMO that was originally marketed. However, farmers will avoid the royalties from technologies that created the transgenic trait. Not coincidentally, the amount of lawsuits accusing farmers of biopiracy has increased dramatically after the start of GMO cultivation in 1996 (BARTON, 1998).

This issue reveals a second appropriability dimension. Firms need avoid the transmission of their technologies through spillovers that tend to benefit farmers (LESSER, 1998; GRAFF, 2003). Under this perspective, the article developed an indicator able to measure patent's capacity to avoid and punish the unauthorized reproduction of transgenic seeds by farmers. The assumptions underlining the *spillover avoidance (SA)* indicator are similar to those assumptions described before. Firms will employ in lawsuits against farmers the legally stronger patents that have greater probabilities of victory. Thus, SA indicator can be expressed as follows:

$$SA(p) = LSfarmers(p) \qquad \text{Equation (9)}$$

where:

SA(p): patent *p* capacity to avoid spillovers that tend to benefit farmers

LSfarmers(p): the amount of lawsuits accusing farmers of patent (*p*) infringement

IV - Results and Discussion

This study identified 163 patent infringement lawsuits that can be classified into two distinct groups: i) 104 lawsuits were filed against American farmers; ii) 59 litigations that register seed companies as defendants.

Patent infringement lawsuits against farmers

Pioneer Seed Company[5] was the main complainant of two litigations; all the remaining patent lawsuits against US farmers were filed by Monsanto. Patent search No. 2 has identified 2310 patents belonging to Monsanto or its subsidiaries (Chart 1). Despite this broad patent portfolio, Monsanto's lawsuits against farmers have involved just three patents, the documents No. US5352605; US5633435 and USRE3924.

We identify 102 litigations brought by Monsanto against farmers. Only two lawsuits - Monsanto Company vs. Dale Knackmus, Filed Feb. 11, 1998, Doc. No. 4:98cv261RWS; and Monsanto Company v. James E. Douglas Jr., ,Filed Mar. 30, 1998, Doc. No. 4:98cv542ERW - do not accuse farmers of infringing at least one of the three aforementioned patents.

Table 1: Spillover avoidance(SA) indicator: patent infringement lawsuits distribution (patents employed in at least two lawsuits).

Patent	Title	SA	Year/Application	Holder
5352605	Chimeric genes for transforming plant cells using viral promoters	63	1993	Monsanto
5633435	Glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthases	46	1994	Monsanto
RE39247	Glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthases	35	2003	Monsanto
4940835	Glyphosate-resistant plants	3	1986	Monsanto
5164316*	DNA construct for enhancing the efficiency of transcription	2	1989	University of British Columbia
5196525*	DNA construct for enhancing the efficiency of transcription	2	1991	University of British Columbia
5322938	DNA sequence for enhancing the efficiency of transcription	2	1992	Monsanto
7169979	Soybean variety XB35C06	2	2006	Pioneer/Dupont

Source: elaborated by the authors using the Thomson Innovation™

* Patents originally filed by the University of British Columbia which were later acquired by Monsanto

Patent No. US5633435 was applied for in 1994 and approved on 27 September 1997. In 2006, Monsanto filed a reissue application in order to correct the errors presented in the original patent. After the re-examination, the USPTO granted the patent No. USRE39247. Thus, both documents protect the same invention, that is, a nucleic sequence capable of encoding the synthesis of *5-enolpyruvylshikimate-3-phosphate*

[5]We are referring to lawsuits: i) Pioneer Hi Bred International, Inc. Does 1-5 W.D. Missouri 5:12cv06046; ii) Pioneer H iBred International, Inc. Nelson Et al C.D. Illinois 1:09cv01246. Pioneer currently belongs to Dupont.

(EPSPS) protein in soybean varieties. Higher levels of the EPSPS protein tends to increase soybean seeds tolerance against glyphosate herbicide.

Patent No. US5352605 claims owner's rights over the nucleotide sequences found in the cauliflower mosaic virus (CaMV) DNA, corresponding to the 35S and 19S promoters. The recombinant DNA technologies have enabled the creation of chimeric genes through the merger of the nucleic sequence claimed by the patent USRE39247 with the 35S promoter. The chimeric gene thus obtained was later inserted by Monsanto scientists into soybean cultivars, which give rise to the commercial product Soybean Roundup Ready I™ (RRI).

Viral Promoter 35S instructs the plant to start the gene expression process after the insertion of the exogenous genetic material. As a result, several Monsanto's commercial products were developed by inserting chimeric genes containing one or more copies of the 35S promoter into plant cells. This group includes, in addition to Soybean RR1, the products: Cotton Bollgard I ™, Cotton Bollgard II™, Maize YieldGard™, Maize RR1 and Maize Roundup Ready II™. By ensuring property rights over the 35S promoter found in the genetic code of the aforementioned products, the patent No. US5352605 provided, from 1996 to 2013, the legal requirements for royalties collection.

Consequently, patent No. US5352605 was also employed in order to sue farmers that have reproduce Monsanto's transgenic seeds without the company's approval. Table 1 reveals that patent No. US5352605 gave rise to 63 lawsuits of biopiracy. It is, therefore, the document which recorded the highest value for the AS indicator.

The legal protection of genetic modified soybean plants was also ensured by patents No. US5633435 and USRE39247. According to Table 1, these patents have been widely deployed by Monsanto to prevent and punish the unauthorized reproduction of transgenic seeds. We identified 70 lawsuits against farmers derived from the patents No. US5633435 and USRE39247 (11 litigation involving both patents; 36 litigations were filed from the patent US5633435 and 24 lawsuits were based only on the patent USRE3924).

Patent infringement lawsuits against seed companies.

Despite of the broad size of the patents sample (7234 documents), this article identified just 132 patents that gave rise to 59 patent infringement lawsuits. According to Table 2, most of lawsuits accusing other companies of IPR violations were built upon patents owned by Monsanto. Among the 132 litigated patents, 61 documents belong to

Monsanto, of which 30 were developed internally while the remaining patents were inherited through the acquisition of companies Calgene and Dekalb.

Table 2: Distribution of litigated patents per assignee

Company	Patent No.
Monsanto	30
Dekalb	28
Plant Genetic Systems	13
RHONE POULENC	10
Carnegie Institution	10
Aventis	9
Bayer Cropscience	6
Dupont	5
Pioneer.	4
Syngenta	3
Calgene	3
Invitrogen Corporation	2
American Cyanamid Company	2
Ribozyme Pharmaceuticals Inc.	2
Novartis AG	1
Mycogen	1
Life Technologies Corporation	1
Hoechst	1
Prolume LTD	1

Source: elaborated by the authors using the Thomson Innovation™

Table 3 presents the documents that were employed in at least two patent lawsuits. The textual information provided by patents' abstracts and claims revealed that most of the litigated documents demands legal protection over biotechnological tools capable of transfering genetic material from other species to plant cells and, also, of improving the gene expression process.

Table 3: Legal blocking capacity (LBC) indicator: patent infringement lawsuits distribution (patents employed in at least two lawsuits).

Patent	Title	LBC	Year/ Applic.	Holder
4940835	Glyphosate-resistant plants	6	1986	Monsanto
5489520	Process of producing fertile transgenic zea mays plants and progeny comprising a gene encoding phosphinothricin acetyl transferase	6	1994	DEKALB
5484956	Fertile transgenic Zea mays plant comprising heterologous DNA encoding Bacillus thuringiensis endotoxin	5	1990	DEKALB
5538880	Method for preparing fertile transgenic corn plants	5	1994	DEKALB
5550318	Methods and compositions for the production of stably transformed, fertile monocot plants and cells thereof	4	1990	DEKALB
6506559	Genetic inhibition by double-stranded RNA	4	1998	Carnegie Institute
5633435	Glyphosate-tolerant 5-enolpyruvylshikimate-3-phosphate synthases	3	1994	Monsanto
5034322	Chimeric genes suitable for expression in plant cells	2	1989	Monsanto
5164316	DNA construct for enhancing the efficiency of transcription	2	1989	University of British Columbia
5188642	Glyphosate-resistant plants	2	1990	Monsanto
5196525	DNA construct for enhancing the efficiency of transcription	2	1991	University of British Columbia
5322938	DNA sequence for enhancing the efficiency of transcription	2	1992	Monsanto
5352605	Chimeric genes for transforming plant cells using viral promoters	2	1993	Monsanto
5378824	Nucleic acid fragment encoding herbicide resistant plant acetolactate synthase	2	1992	Dupont
5500365	Synthetic plant genes	2	1992	Monsanto
5538877	Method for preparing fertile transgenic corn plants	2	1992	DEKALB
5545565	Transformation vectors allowing expression of foreign polypeptide endoxins from Bacillus thuringiensis in plants	2	1995	Plant Genetic Systems
5554798	Fertile glyphosate-resistant transgenic corn plants	2	1995	DEKALB
5767372	Transformation vectors allowing expression of foreign polypeptide endotoxins from Bacillus thuringiensis in plants	2	1995	Plant Genetic Systems
5792930	Chimeric gene for the transformation of plants	2	1995	Rhone Poulenc
5866784	Recombinant plant expressing non-competitively binding insecticidal crystal proteins	2	1995	Plant Genetic Systems
5908970	Recombinant plant expressing non-competitively binding Bt insecticidal crystal proteins	2	1995	Plant Genetic Systems
5990387	Stable transformation of plant cells	2	1994	Pioneer
6013863	Fertile transgenic corn plants	2	1997	DEKALB
6172281	Recombinant plant expressing non-competitively binding BT insecticidal crystal proteins	2	1998	Aventis
6313282	Isolated DNA sequence which can serve as terminator region in a chimeric gene capable of being used for the transformation of plants	2	1997	Rhone Poulenc
6320100	Synthetic DNA sequences having enhanced insecticidal activity in maize	2	2000	Syngenta
6338961	Isolated DNA sequence capable of serving as regulatory element in a chimeric gene which can be used for the transformation of plants	2	1998	Rhone Poulenc
6362396	Chimeric gene for the transformation of plants	2	1998	Aventis
6566587	Mutated 5-enolpyruvylshikimate-3-phosphate synthase, gene coding for said protein and transformed plants containing said gene	2	1998	Bayer CropScience
7538095	Genetic inhibition by double-stranded RNA	2	2002	Carnegie Institute
7560438	Genetic inhibition by double-stranded RNA	2	2002	Carnegie Institute
7622633	Genetic inhibition by double-stranded RNA	2	2002	Carnegie Institute
RE36449	"Chimeric gene for the transformation of plants	2	1998	Rhone Poulenc
RE37287	Chimeric gene for the transformation of plants	2	1998	Aventis

Source: elaborated by the authors using the Thomson Innovation™

The LBC indicator (column 3 of Table 3) also reveals that 19 of the 59 patent infringement lawsuits (almost one third of the total) were established from two patent families developed by Delkab, which were later acquired by Monsanto. The first family includes the patents No. US5484956, US5538877, US5538880, US5554798 and US6013863 while the second covers the documents No. US5489520, US5550318 and US6395966[6]. This set of eight patents claims the main biotechnological tools that must be applied to create genetically engineered maize seeds: i) methods for introducing genetic material into plant cells by particle bombardment[7]; ii) specific promoters for monocotyledon plants; iii) methods for identifying the plants whose genotype was effectively transformed; iv) methods for restoring plants' fertility after the bombardment process.

In short, one third of the patent infringement lawsuits was established from just two patent families that claim the main methods for developing genetically engineered maize seeds. This finding provide a strong evidence favorably to the main proposition of the article: the protection of GMOs against infringement behaviors as well as the threat posed by new entrants tends to prioritize barriers built upon enabling technologies patents. The case study presented below tend to reinforce these conclusions.

Case Study –The legal battle between Monsanto and Syngenta by the control of the GMOs derived from the GA21 gene.

The study has identified two major patent infringement lawsuits that involved Monsanto and Syngenta: i) Monsanto Technology LLC, and Dekalb Genetics Corp. versus Syngenta Biotechnology, Inc., United States Court of Appeals No. 2006-1472 (Decided: October 4, 2007); ii) DeKALB GENETICS CORPORATION versus Syngenta Seeds, Inc., Missouri, Eastern Division, No. 4:06CV01191 ERW. The follow information is based on the judicial sentences of each legal case .

The roots of Monsanto-Syngenta conflict can be found on the triple agreement that was signed in 1991 by the companies Calgene, Aventis and Dekalb. In the early 90s, Aventis and Dekalb had the control over the main biotechnologies capable of encode the glyphosate tolerance into maize seeds. The research efforts performed by Aventis were

[6]According to the European Patent Office (EPO), the patent families are composed, among other reasons, of patents issued by the same patenting office that claim technologies related to the same invention.

[7]The insertion of genetic material by bombardment techniques takes place as follows: Tungsten or gold particles are coated with specific DNA fragments. The particles are placed in the gun gene, where they are accelerated at high speed and pressure, and then, they are launched toward the plants. After penetrating into the cells, the particles insert the DNA fragments into the plant genotype (VIEIRA and BUAINAIN, 2004, p. 402).

able to improve the the *aroA gene*, first discovered by Calgene in 1980´s. In the other hand, Dekalb had the control over the bombardment techniques. Under the 1991 agreement, Calgene and Aventis agreed to license *aroA gene* to Dekalb perform the genetic material insertion into maize cultivars. The GA21 gene was development through these joint research efforts.

In 1994, the original agreement was reformulated. During the negotiations, Dekalb has omitted key information about the field tests with GA21. Dekalb was legally accused by Aventis of violating the 1991 and 1994 agreements. The lawsuit was won by Aventis; as consequence, Dekalb lost all the property rights over the GA21. In contrast, the court reinforced Aventis's exclusive rights upon the OGMs derived from the aforementioned gene. Bayer acquired the GA21 from Aventis in 2002 and, then, resold it to Syngenta.

Monsanto have been developing glyphosate-tolerant seeds by the insertion of the CP4 gene into cultivars. The company has never adopted the GA21. Despite of the preference for the CPA gene, Monsanto has tried hard to legally avoid the emergence of GMOs derived from the GA21 gene, that were seen as commercial threats to its products. In mid-2006, when Syngenta started the field tests with Maize Agrisure ™, Monsanto filed two lawsuits accusing the Swiss company of patent infringement.

The legal case No. 2006-1472 was taken to the United States Court of Appeals. Syngenta was accused of infringing the bombardment technologies claimed by patents No. US5538880 and US6013863. The Federal Court presented several evidences that the insertion of the genetic material into maize cells by particle bombardment was first performed by Dekalb in 1993, during the field tests with the GA21 gene.

The sentence also states that Syngenta did not perform, directly, the bombardment process, since the company legally purchased (from Aventis/Bayer) the maize plants that have had the GA21 gene inserted into their genotype in the past. Consequently, the Federal Court ruled that Syngenta did not infringe the methods for introducing genetic material claimed by patents No. US5538880 and US6013863.

Monsanto and Syngenta have had a second legal dispute over the scope of the legal claim No. 2 presented in patent No. US5554798. The document demands legal protection over a promoter that was employed in the development of a fertile transgenic maize plant. Syngenta denied that its products has infringed this claim. According to the Swiss company, the US5554798 patent does not specify the type of promoter adopted by Monsanto. Under this perspective, the legal claim doesn´t cover the "rice actin" promoter

that was employed to create the Maize Agrisure ™. Monsanto countered that the biotechnological tool called promoter concerns the DNA construct that instructs the cell to start the biochemical processes that will result in the EPSPS protein synthesis. Under this interpretation, the patent No. US5554798 covers all types of promoters.

Unlike the lawsuit judged by the United States Court of Appeals, the sentence promulgated on December 21, 2007 by the Missouri Court (Case No. 4:06CV01191 ERW) was favorable to Monsanto. One year after the sentence, the Swiss company negotiated an agreement with Monsanto. The companies agreed to dismiss all the lawsuits that exist between them. Under this cross licensing agreement, Syngenta has licensed to Monsanto several technologies capable of encode the dicamba herbicide tolerance into plants in exchange of the license over the Round Redady ™ technology.

The discussions about the patent wars between Monsanto and Syngenta have provided new evidences favorable to the propositions presented earlier in this article. Monsanto's control over enabling technologies has been strongly grounded on patent enforcement rights. The ownership right to exclude competitors of "using" the biotechnological tools that are necessary to create GMO has proved to be a valuable legal barrier capable of slow down Syngenta entry into the transgenic seed market.

Final remarks

The seed industry clearly has a dominant company. Over the past four decades, Monsanto has developed and has brought to market the main innovations regarding the GMOs. The evidences presented by this article tend to reinforce this perception. Tables 1, 2 and 3 reveal that the main patents related to herbicide tolerance and enabling technologies belong mostly to Monsanto.

The aforementioned company has employed such legal documents to sue American farmers, through the accusation of biopiracy as well as to establish a system of blocking patents toward opponents. Monsanto did so by essentially preventing competitor's access to the main methods for inserting genetic material into plant cells and for controlling the gene expression process. These biotechnological tools are vital to the development of GMO. For more than a decade, the success of this strategy has promoted the endurance of the monopoly status enjoyed by Monsanto's commercial products.

To return to the start of this paper, the "tragedy of the anticommons" hypothesis has proposed that the emergency of an excessive amount of patents owners capable of charging royalties over upstream process was the main reason behind the modest research and development (R&D) efforts in agricultural biotechnologies. The expansion of royalty

collectors tends to amplify the technological licensing fees and the risks of patent infringement lawsuits, affecting negatively the adoption of intermediary technologies and the pace of emergence of innovations (HELLER and EISENBERG, 1998; KRYDER, KOWALSKI and KRATTIGER, 2000 BENNETT, 2004).

The evidences presented in this article tend to reinforce Marco and Rausser (2008) propositions. The authors have stated that the M&A that have occurred in the seed industry have contributed to reduce the problems caused by overlapping patents, due to the increasing concentration of the main blocking patents in the hands of the big six companies. At no point in our study was it clear that the decline in R&D efforts was due to the excessive amount of patent owners as argued by Kryder, Kowalski and Krattinger (2000).

Instead, we found that the seed industry structure has been shaped by complex innovation systems, sequential technologies, and efficient patenting strategies to raise legal entry barriers in order to guarantee a significant market share. Under this complex scenario, the IPR, in addition to their traditional role of legal protection of knowledge assets, represent a crucial factor to achieve sustainable competitive advantages over competitors. These special features have potential to discourage new entrants from researching agricultural biotechnologies.

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