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GENETICALLY MODIFIED CORN ADOPTION IN BRAZIL, COSTS AND PRODUCTION STRATEGY: RESULTS FROM A FOUR-YEAR FIELD SURVEY

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RESUMO

O milho no Brasil é produzido em duas safras durante o ano, sendo que o milho geneticamente modificado (GM) representa 88,4% da área total. Neste artigo, buscou-se identificar a diferenciação de custos para variedades Geneticamente Modificadas e convencionais na primeira e na segunda safras, considerando dados dos anos-safras 2010/11, 2013/14, 2014/15 e 2015/16, em onze estados. A pesquisa utilizou abordagens quantitativa (custos de produção) e qualitativa (aplicação de questionários com produtores). Os resultados mostraram que os custos do milho GM são mais altos quando comparados ao milho não GM, devido aos preços mais altos das sementes GM, que mais do que compensam a diminuição dos custos com inseticidas. Ao comparar a evolução dos custos de milho GM, os custos de sementes tenderam a diminuir em algumas regiões, mas os custos com inseticidas tiveram uma tendência crescente. A pesquisa qualitativa entrevistou 314 agentes, e os resultados mostraram que, na maioria dos casos, redução de risco, potencial genético e baixa disponibilidade de sementes convencionais explicaram a adoção de variedades GM. Esses dois últimos fatores podem refletir uma estratégia comercial das empresas de sementes, uma questão que merece mais atenção.

Palavras-chave: Culturas geneticamente modificadas; Produção de milho; comercialização.

ABSTRACT

Genetically modified (GM) corn accounting for 90% of total area in Brazil since 2015/16 season. In this paper, we report the results of a four-year field survey (2010/11, 2013/14, 2014/15 and 2015/16) on corn production costs in Brazil, for two harvests and eleven states. The survey used both a quantitative and a qualitative approach: the first one compares GM and NonGM varieties costs in the two harvests, as well as the evolution of costs for GM corn, and the second part reports the results of a qualitative field survey. Results showed that GM corn costs are higher when compared to NonGM corn, due to higher GM seed prices, which more than compensate for the decrease in insecticide costs. When comparing the evolution of GM corn costs, seed costs tended to decrease, but insecticides had an increasing trend. The qualitative survey interviewed 314 agents, and the results showed that, in most cases, risk reduction, genetic potential, and low availability of NonGM seeds explained GM adoption. These two last factors may reflect a commercial strategy of seed companies, an issue that deserves more attention.

Keywords: Genetically Modified Crops; Corn Production; Commercialization.

JEL Code: C15, C83, M11, O13, O30, Q10.

INTRODUCTION

Brazilian agriculture showed rapid expansion in the cultivation of Genetically Modified Organisms (GMs), the world´s second largest area with GM technologies. The first transgenic varieties for soybeans were authorized in 1996/97, in 2005/06 for GM cotton, 2008/09 for GM corn, 2011 for GM beans, and in 2015 for GM eucalyptus (CNTBIO, 2017).

Corn is the second largest grain and cereal production in Brazil (CONAB, 2017), second only to soybeans. The supply of the 2015/16 season had a significant reduction compared to the previous crop-year due to climate problems, totalizing 66.5 million tons considering the two harvests. In Brazil, the second harvest for corn accounts for more than 2/3 of the production, usually grown after the soybean harvest. To grow 16.8 million hectares in total (first and second harvests), corn GM seeds occupied 88.4% of the area (CÉLERES, 2017).

In spite of the current importance of GM corn production in Brazil, little information is available in the literature about GM corn production costs, nor on the cost differences with NonGM corn (ALVES et al., 2018). In this paper, we analyze several important differences between GM and NonGM corn. Specifically, we report the results of a four years field survey on corn production, which evaluated costs and other aspects related to GM seeds adoption.

The work was divided into two approaches, one quantitative and one qualitative. In the quantitative approach, we evaluated the production costs of both GM and NonGM corn through field surveys with relevant stakeholders in different regions, where representative production systems were identified in 11 Brazilian states. In this case, the field survey comprised the harvest years of 2010/11, 2013/14, 2014/15 and 2015/16, for both the first and the second harvests – these seasons represent the beginning and consolidation of the cultivation and commercialization of GM corn in Brazil. As for the qualitative approach, questionnaires were applied to participants in survey meetings in the years of 2010/11, 2014/15, and 2015/16. The main goal was to assess the point of view of the decision-makers regarding the differences in the ease of commercialization of the production for each technology, the ease of acquisition of the two types of seeds, and the efficiency in the crop management of the GM corn when compared to NonGM corn.

This paper is structured as follows. Section 2 provides a literature review on the cultivation of NonGM and genetically modified crops. Section 3 presents the strategy for data collection and processing methods. Section 4 brings the results, and the last section summarizes the present work.

LITERATURE REVIEW

After 30 years of GM crops and the emergence of new technologies to improve "plant breeding techniques", some doubts about some critical points on technological performance, economic impacts, and the appropriate regulatory design remain. A large body of controversy can be found, ranging from the advantages and disadvantages of the technology [(BARROWS; SEXTON; ZILBERMAN, 2014), (COTTER et al., 2015), (BRANKOV; LOVROS, 2018), (HICKEY et al., 2019)], to the complex influence of the political economy on agro-biotechnologies regulations [(HERRING; PAARLBERG, 2016), (QAIM, 2016)]. Studies from the consumption perception side have highlighted other important aspects of this problem [(BORGES; SILVEIRA; OLIVEIRA, 2009), (TILLIE; RODRÍGUEZ-CEREZO, 2015), (CAPALBO et al., 2015)], but will not involve the analyzes to be presented in this paper.

Despite the maintenance of unfavorable policies regarding GMO crops in many countries, their adoption processes have not ended and the main drivers of the process have been extensively discussed [(HUANG et al., 2015), (QAIM, 2016), (TALSMA; MELSE-BOONSTRA; BROUWER, 2017), (MIYAMOTO et al., 2017), (SHELTON et al., 2018), (TRIPATHI; NTUI; TRIPATHI, 2019)]. In Brazil, the GM adoption process seems to be still progressing. According to CNTBio (2017), the first authorized genetically modified corn in the country was released for commercialization and cultivation in 2007, involving a herbicide tolerant variety, one resistant to insects and another with both genes. Up to 2016, CNTBio (2017) approved the cultivation and commercialization of 40 genetically modified corn varieties, seven herbicide tolerant, six insect resistant, 24 with both treats, one with fertility restoration properties for seed production, one with increased thermostability of amylase, and one with water stress tolerance.

Some estimates show that the economic benefits generated by the adoption of GM technologies can reach US$ 82.5 billion between 2014/15 and 2023/24, with corn accounting for 25% of the total (CÉLERES, 2015). From another point of view, the non-adoption of GM technologies in the same period would cost US$ 61.1 billion, of which 52% is attributed to corn (CÉLERES, 2015). Adding the value of the benefits plus the cost of not adopting the technologies, the author estimates that Brazilian agriculture would give up US$ 143.6 billion in the period in case only NonGM seeds were cultivated (CÉLERES, 2015).

In general, GM corn seeks to improve crop management, yield, and to reduce costs with inputs, mainly insecticides and herbicides. Coupe and Capel (2016) evaluated the dynamics of agrochemicals use since the introduction of genetically modified organisms in the United States. Results showed that the use of insecticide varies over time due to several factors, such as insect pressure, changes in farming practices, the regulation of chemicals and changes in technologies. The same authors also point out that, from 1995 to 2009, there was an approximate 80% reduction in insecticide application, while US corn area increased by 18%. Osteen and Fernandez-Cornejo (2013) show that the adoption of GM technologies contributed to the reduction in the quantity of insecticides applied, besides the substitution of old compounds for new molecules, which reduces the amount applied per area.

Sanglestsawai et al. (2014) studied if low-productivity producers, who are mostly considered low-income, benefit from the adoption of GM corn in the

Philippines. The authors concluded that the benefits tend to be higher for producers with the lowest productivities (or those at the beginning of the distribution curve).

In a study on the impacts of GM corn cultivation in the state of Nebraska, USA, Gipmans et al. (2014) show that the cost of RR & Bt corn was 9.17% lower than the NonGM corn. The same authors showed that net revenue more than doubled for RR & Bt corn over NonGM corn. Specifically, the authors also compared the values of GM seeds against the benefits proposed by the technology. Results showed that the costs of RR & Bt seeds were 21.49% higher than NonGM ones, while insecticide costs were 83.18% lower compared to NonGM corn.

The genetically modified seed market

Choosing a seed variety is a critical step in determining the potential of a crop. However, according to von Braun (2008) and Bonny (2014), the input industry (which includes seeds) represents a very small share of total sales in the agri-food chain. In spite of that, Bonny (2014) shows that, during the years, there was a concentration in the number of seed companies: the three largest companies in the seed market are agrochemical groups, and the market share of the ten largest companies in global sales rose from 18% in 1996 to 59% in 2012.

Fuglie et al. (2011) show that the market concentration has been growing over the years, accompanying the expansion of other industries in the agricultural sector: in 1994 the eight largest seed companies had a market share of 29%. In 2009, this figure rose to 63%. Still, private companies as seed suppliers are a recent phenomenon, as historically the producers saved seeds, or traded with neighbors, with purchases made in few cases, mainly for stock replenishment.

In addition to market supply concentration, the high value added of GM seeds is a factor to be considered in the technology adoption dynamics. The high technological fees and the contractual requirements of not saving seeds, are the most representative factors in the higher commercialization price of GM seeds (BONNY, 2014).

The higher costs of GM seeds have to be balanced with the advantages and disadvantages (problems of coexistence and resistance to weeds and insects) of the crop. (BONNY, 2014) shows that the viability of using GM seeds varies according to each situation. However, seed companies are charging prices that make it possible for producers to profit and, therefore, a greater adoption of GM technologies is observed.

This brief review of recent literature on Genetically Modified crops has shown the vast span of the technology. An extensive and rigorous analysis of the comparative results of the use of GM varieties in corn could help to fulfill the gap in studies related to Brazil, the second worldwide user of GM crops.

METHODOLOGY

Data source and structure of production costs

The data used in the study were obtained by the Center for Advanced Studies on Applied Economics (CEPEA/ESALQ-USP, 2017) for the 2010/11, 2013/14, 2014/15 and 2015/16 seasons, which collected data through the "panel" method[1]. The panel method consists in meeting with several representative stakeholders who design a representative farm in a region, with a typical cost structure. Cost structures of GM and NonGM corn grown in the first (summer) and second harvest were analyzed. Information on the characteristics of panels can be obtained from (OSAKI et al., 2015)) (IKEDA; OSAKI; ALVES, 2013), (ALVES et al., 2012a) and (ALVES et al., 2012b).

The original production cost structure was separated by the Effective Operational Cost (EOC), items Total Operational Cost (TOC) and Total Cost (TC), according to (MATSUNAGA et al., 1976), and the method of fixed cost allocation discussed by (BORNIA, 1995). In the EOC, all direct expenses represented by cash expenditures are considered, such as inputs (fertilizers, seeds, and agrochemicals), mechanical operation (diesel and maintenance), labor, outsourcing, crop commercialization, transportation, financial expenses, expenses with commercialization taxes and general expenses. The Total Operating Cost (TOC) is composed by the sum of the EOC with the portion of the indirect costs represented by the depreciation of machines and other elements of the fixed capital stock. Finally, Total Cost (TC) is the sum of TOC with the opportunity cost of capital and land. The EOC is the relevant concept for the short run decision-making, and was chosen for our analysis. This cost concept includes expenses with fertilizers, seeds, herbicides, insecticides, fungicides, seed treatment, adjuvants, soil preparation and planting, crop management practices, irrigation, harvesting, transportation of production, labor, general costs (including producers discretionary cash, union expenses, etc.), commercialization and storage, leasing, taxes, insurance, technical assistance and financing of working capital.

Table 1, Table 2 and Table 3 display the regions covered by the study. For the summer (first) harvest, we obtained information from 21 different regions in the nine major Brazilian producing states. In total, the data involved 80 different cost structures, for GM and NonGM varieties.

For the second harvest, which currently accounts for about 70% of the total Brazilian corn supply (CONAB, 2017), we gathered information from 33 different regions in 11 major producing states. In total, the study covered 188 (116 GM) different cost structures, in the four seasons, for the first and second harvests. Table 1, Table 2 and Table 3 bring a brief description of the regions surveyed in the study. The data were deflated by the General Price Index – Internal Availability (IGP-DI), of the Getúlio Vargas Foundation (FGV), with 2015/16 season = 1.00.

[1] Due to operational reasons data was not collected for the 2011/12 and 2012/13 seasons.

Once identified the production costs by region and harvest, we performed a Monte Carlo simulation, in order to check results stability. For each crop year and in each growing period (first and second harvests), distribution functions were identified for each cost item and 10,000 random numbers were generated, which resulted in new EOC, used in the interpretations of results. This procedure is described below.

Table 1. Regions in the cost surveys.

Symbol	City/State	Symbol	City/State	Symbol	City/State
BLS	Balsas/MA;	DRD	Dourados/MS;	RND	Rondonópolis/MT;
BOAE	Boa Esperança/MG	GPVA	Guarapuava/PR;	RVD	Rio Verde/GO;
CALTA	Cruz Alta/RS	JATAI	Jataí/GO	SBRDN	Sobradinho/RS
CHSUL	Chapadão do Sul/MS;	LDN	Londrina/PR;	SGO	São Gabriel do Oeste/MS;
CNOVOS	Campos Novos/SC;	LEM	Luis Eduardo Magalhães/BA;	SNP	Sinop/MT;
CNP	Campo Novo do Parecis/MT;	MNR	Mineiros/GO;	SRS	Sorriso/MT;
CPV	Campo Verde/MT;	NVR	Naviraí/MS;	TPCRT	Tupanciretã/RS;
CRST	Cristalina/GO;	PAF	Pedro Afonso/TO	UBR	Uberaba/MG;
CRZ	Carazinho/RS;	PARIP	Paripiranga/BA;	UNAI	Unaí/MG
CSTR	Castro/RS;	PVL	Primavera do Leste/MT;	URÇ	Uruçuí/PI;
CVEL	Cascavel/PR;	QRC	Querência/MT;	XNX	Xanxerê/SC.

Source: Research data.

Table 2. Regions and seasons for the first harvest corn considered for the analysis.

STATE	REGION	2010/2011		2013/2014		2014/2015		2015/2016	
		OGM	NOGM	OGM	NOGM	OGM	NOGM	OGM	NOGM
BA	LEM	X	X	X		X		X	X
	PARIP							X	
GO	CRST	X	X			X		X	
	MNR	X							
	RVD	X	X						
MA	BLS	X	X	X		X		X	
MG	BOAE			X					
	UBR	X	X	X		X		X	
	UNAI	X		X				X	
MS	CHSUL	X	X	X					
PI	URÇ	X	X	X		X		X	
PR	CVEL	X	X	X					
	CSTR	X	X	X	X	X	X	X	X
	GPVA	X	X	X	X	X	X	X	X
	LDN	X	X						
RS	CRZ		X	X		X		X	X
	CALTA			X					
	SBRDN		X						
	TPCRT	X	X						
SC	CNOVOS	X	X	X		X	X	X	X
	XNX	X	X	X		X	X	X	X
Total		16	16	14	2	10	4	12	6

Source: Research data. Note: For the meanings of the abbreviations, see Table 1.

Table 3. Regions and Crop years for second-crop corn considered for the analysis.

STATE	REGION	2010/2011		2013/2014		2014/2015		2015/2016	
		OGM	NOGM	OGM	NOGM	OGM	NOGM	OGM	NOGM
GO	JATAI			X					
	MNR	X	X	X	X	X	X	X	X
	RVD	X	X	X	X	X	X	X	X
	CRST						X	X	X
MA	BLS		X	X		X	X	X	
MG	UBR			X		X		X	
	UNAI	X	X	X				X	
MS	CHSUL	X	X	X					
	DRD			X	X	X		X	X
	NVR	X	X	X	X	X	X	X	X
	SGO							X	X
MT	CNP	X	X	X	X	X	X	X	X
	CPV	X	X						
	PVL			X	X	X	X	X	X
	QRC			X	X	X	X	X	X
	RND	X	X						
	SNP	X	X	X	X	X	X	X	X
	SRS	X	X	X	X	X	X	X	X
PI	URÇ	X	X	X		X			
PR	CVEL	X	X	X		X		X	
	LDN	X	X	X		X		X	
TO	PAF	X		X		X		X	
Total		14	14	18	9	15	10	17	11

Source: Research data. Note: For the meanings of the abbreviations, see Table 1.

Identification of distribution functions and random numbers generation

For each cost structure (crop year, season and year) and crop item, distribution functions were defined based on the software @Risk™. When necessary, truncations with the value zero were added. The distributions functions were correlated so that they could maintain the original characteristics of relations between the variables.

Based on the distributions, 10,000 random numbers were generated through a Monte Carlo simulation, as described in (HERTZ, 1964) and (HERTZ, 1979), and the random numbers for each variable were aggregated to generate new 10,000 Operational Costs structures. It is important to mention that the software @Risk™ is based on the tests of Kolmogorov and Chi-square ($\chi 2$) to generate the most appropriate answers of random numbers.

Qualitative assessment of the adoption of genetically modified technologies

In addition to the information related to production costs for GM and NonGM corn, the survey tried to identify qualitatively the perception of market agents regarding the purchase and use of GM corn seeds in different Brazilian regions, through the application of questionnaires. The questions asked were and the possible answers are:

Question (a): Acquiring NonGM corn seed, compared to GM seeds is….?
Answers: very hard hard same easy very easy

Question (b): The supply of GM seeds in your region, when compared to GM corn, is…?
Answers: very little little same enough abundant

Question (c): The use of GM corn makes the crop management…?
Answers: very hard hard same easy very easy

Question (d): When selling the final product, the commercialization of GM in relation to NonGM corn, is…?
Answers: very hard hard same easy very easy

It is important to note that the number of answers varied between the questions (Table 4).

Table 4. Amount of answers for each question on the qualitative analysis

Questions	Crop years		
	2010/11	2014/15	2015/16
a) Easiness on acquiring NonGM seeds	119	98	72
b) Level of genetic engineering in NonGM corn seeds compared to GM seeds	120	97	72
c) Easiness on GM Crop-fields management	121	100	74
d) Easiness on selling GM corn compared to NonGM corn	120	100	72

Source: Research data.

In the survey, 314 questionnaires were collected in three different seasons: 2010/11, 2014/15 and 2015/16, using the Snowball Sampling method. According to Biernacki and Waldorf (1981), this method is based on the selection of stakeholders who know the subject, and is deemed to collect information that is private and difficult to obtain, and reaches agents with local knowledge[2]. The questionnaires were applied face-to-face. In the Snowball technique, there is no defined sample size, and the goal is to reach as many agents as possible. The agents interviewed were especially those who also participated in the "panels" to calculate the cost of production. The results were analyzed in aggregate terms and not by region.

RESULTS AND DISCUSSION

Over the years, there has been a reduction in the use of NonGM technologies in relation to GM (Table 2 and Table 3), making it impossible to analyze the evolution of production costs over the years of NonGM technology in the first harvest, being restricted only to GM corn.

[2] For other examples on the use of Snowball Sampling, see (SUBEDI et al., 2003) and (QUANDT et al., 2004).

Initially, we note that, on average, the EOC of the GM corn exceeded the NonGM, both in the first and second harvests. In the summer crops (first harvest), EOC for GM corn was 8.41% higher than NonGM, while in the second crop this percentage was 11.32% (Figure 1). According to Figure 1, out of the 26 comparative data for the first harvest, only Castro/PR in the 2010/11 and 2014/15 seasons presented a lower EOC for the GM corn compared to the NonGM one. For the second harvest, Figure 2 shows that in 42 observations, only the regions of Unaí/MG, Chapadão do Sul/MS and Rondonópolis/MT in 2010/11 and Primavera do Leste/MT in 2015/16 achieved a lower EOC for GM compared to NonGM technology.

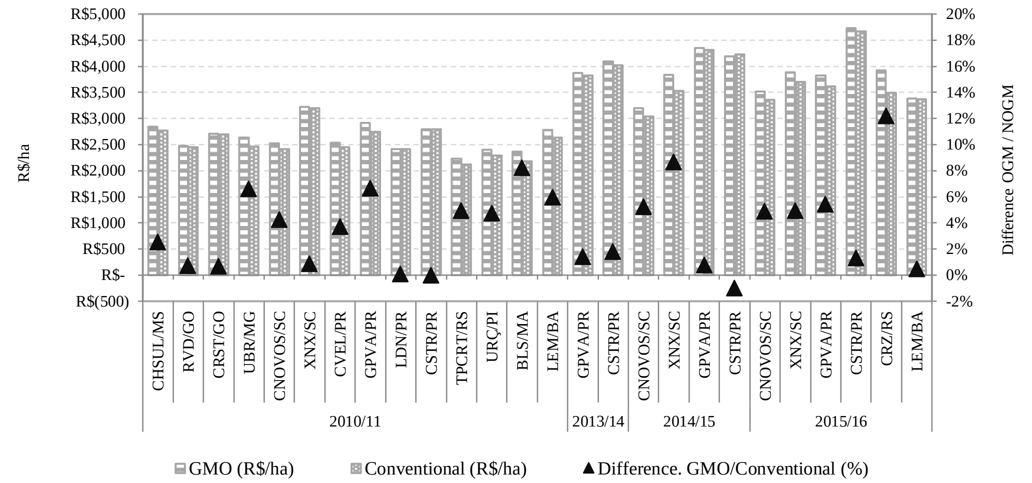

Figure 1 – Operational Costs (OC) for the first-crop GM and NonGM corn varieties, and the difference between the OC in selected regions, in 2010/11, 2013/14, 2014/15 and 2015/16

Source: CEPEA/ESALQ-USP (2017). Note: For the meanings of the abbreviations, see Table 1.

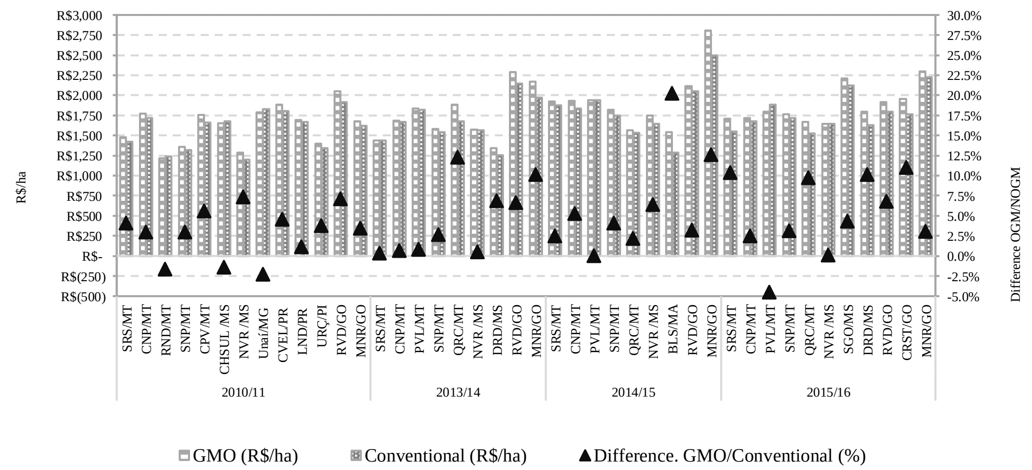

Figure 2 – Operational Costs (OC) for the second-crop GM and NonGM corn varieties, and the difference between the OC in selected regions, in 2010/11, 2013/14, 2014/15 and 2015/16

Source: CEPEA/ESALQ-USP (2017). Note: For the meanings of the abbreviations, see Table 1.

These results are interesting, taking into account the increasing rate of adoption of GM corn in Brazil. Even with the highest investment in seeds and the lowest expenditure on insecticides in GM corn, productivity is very similar between the two technologies. Thus, the average EOC (R$/ton) becomes larger for GM crops. For the first harvest, the cost per unit produced for GM technologies is, on average, 0.6% higher, while in the second crop corn this percentage rises to 2.31%. This result agrees with the ones showed by Coupe and Capel (2016) and Osteen and Fernandez-Cornejo (2013).

Looking at the individual components of production costs, there was a significant difference in the expenditure on GM seeds compared to NonGM, with higher values for GM, mostly due to the cost of technology royalties paind on GM. The highest disbursement in the first crop corn (Figure 3) was in Carazinho/RS in the 2015/16 season, with R$ 871.00/ha. The region also stood out by the difference of 91.43% in relation to the R$ 455.00/ha paid by the NonGM corn. The region of Guarapuava/PR was the only one for the first crop corn that did not observe any difference in the price between the two technologies (R$ 679.18/ha for both).

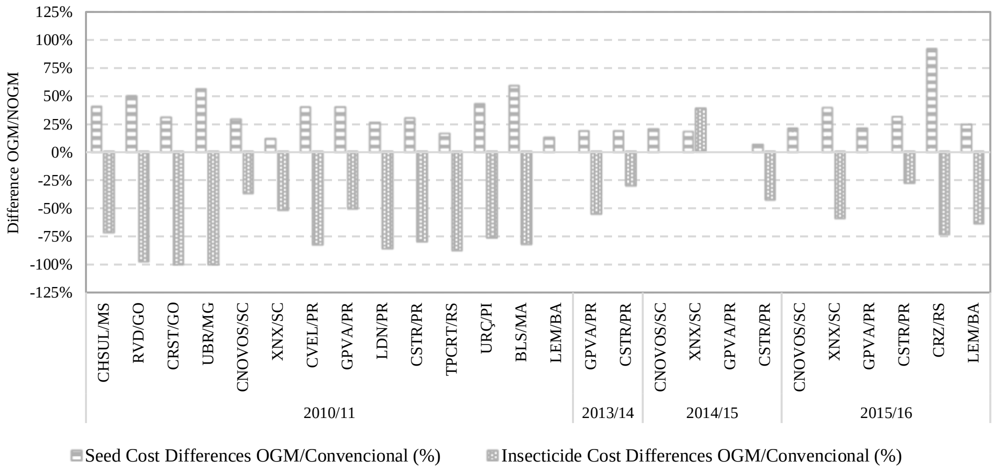

Figure 3 – Difference between GM and NonGM seed and insecticide costs for first-crop corn in 2010/11, 2013/14, 2014/15 e 2015/16.
Source: CEPEA/ESALQ-USP (2017). Note: For the meanings of the abbreviations, see Table 1.

However, the lower expenditure with insecticides is more than compensated by the higher expenditures on GM seeds, although in recent years the cost difference between GM and NonGM technologies has decreased. In the summer crop, (Figure 3) only in Xanxerê/SC in the 2014/15 season showed a higher insecticide cost (38.7%) in the GM compared to NonGM. An interesting point is that in the last few seasons the cost differences in insecticide costs were zero in several regions, indicating either low pest pressure and no need for insecticide applications in NonGM technologies or the inefficiency of GM technologies in controlling pest attack.

For the second harvest corn (Figure 4), one of the highlights was Londrina/PR in the 2010/11 season. The region had the highest value for GM and NonGM seeds, R$ 524.24/ha, and R$ 399.55/ha, respectively. The

Naviraí/MS region in 2013/14 showed a difference of 273.73% between the two technologies: the expenditure on GM seeds was R$ 345.24/ha and NonGM was R$ 92.38/ha.

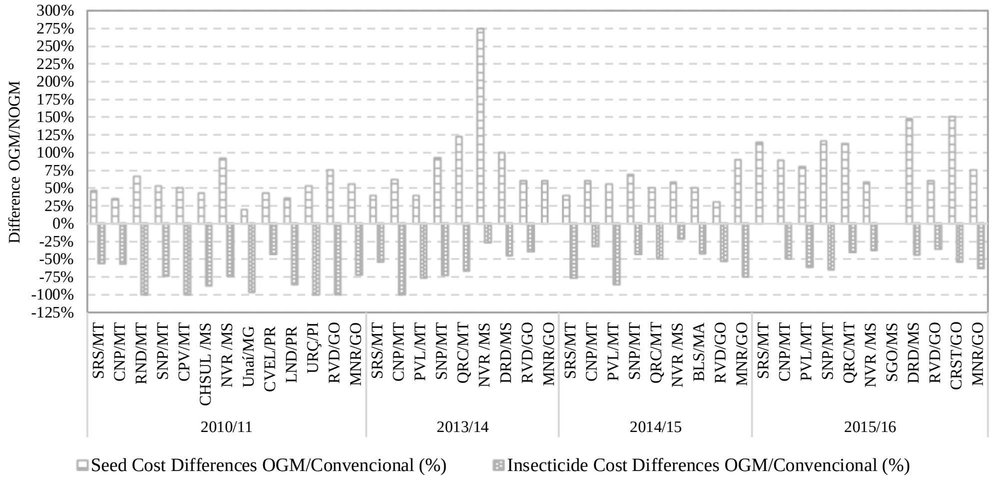

Figure 4 – Difference between GM and NonGM seed and insecticide costs for first-crop corn in 2010/11, 2013/14, 2014/15 e 2015/16

Source: CEPEA/ESALQ-USP (2017). Note: For the meanings of the abbreviations, see Table 1.

In the second harvest, the difference between GM and NonGM seed costs was bigger than insecticide savings in GM crops (Figure 4). The regions of Sorriso/MT and São Gabriel do Oeste/MS in 2015/16 and Mineiros/GO in 2013/14 did not present differences in the cost of applying insecticides between GM and NonGM technologies. The region of Rio Verde/GO was the one that obtained the lowest insecticides costs for the NonGM varieties, with a total of R$ 41.30/ha. In five regions the cost of insecticides in GM technologies was 100% lower than in the NonGM case: Campo Novo do Parecis/MT, in 2013/14; and Rondonópolis/MT, Campo Verde/MT, Uruçuí/PI and Rio Verde/GO in 2010/11. Overall, while in the 2010/11 season the average insecticide cost gap was 80.6%, in 2013/14 it fell to 53.6%, which remained stable in 2014/15 (53.3%), but fell to 41% in 2015/16. Again, there are indications of loss of efficiency in GM technologies.

The data above show that the average difference with seed expenditure has fluctuated over the years, but with an increasing trend, i.e. producers are paying more for GM technology than for NonGM, and the difference with insecticide spending is decreasing [on this issue, see also Bonny (2014)]. Thus, the higher cost of the technology may not be bringing gains to producers, especially considering that productivity was similar between both technologies within the same region.

The cost evolution on GM and NonGM corn varieties

We saw in the previous section that, for most regions, the EOC of GM varieties is higher than that of NonGM varieties. Savings in insecticide use often do not compensate for the extra seed costs in GM corn, making these variables fundamental for a better understanding of how the cost differences between technologies work, as well as providing a better understanding of a cost evolution of GM corn.

In order to analyze the evolution and dispersion of EOCs, seed and insecticide expenditures, the data generated by Monte Carlo simulation were analyzed, considering 10,000 random data for each year and period of cultivation (first and second harvests). The EOC is the sum of the data generated for each of the 18 compounding variables. The analysis was based on the relative and cumulative frequencies charts for the EOC and for seeds and insecticides costs.

Second crop NonGM corn showed an increase in EOC from 2010/11 to 2014/15, again reducing in 2015/16 (Figure 5). Notice that the average cost of NonGM corn seeds has declined over the years (Figure 6). On the other hand, data indicates a higher probability of growth of insecticide costs on NonGM corn during the period (Figure 7), which may have also influenced the reduction of seed prices and/or demand.

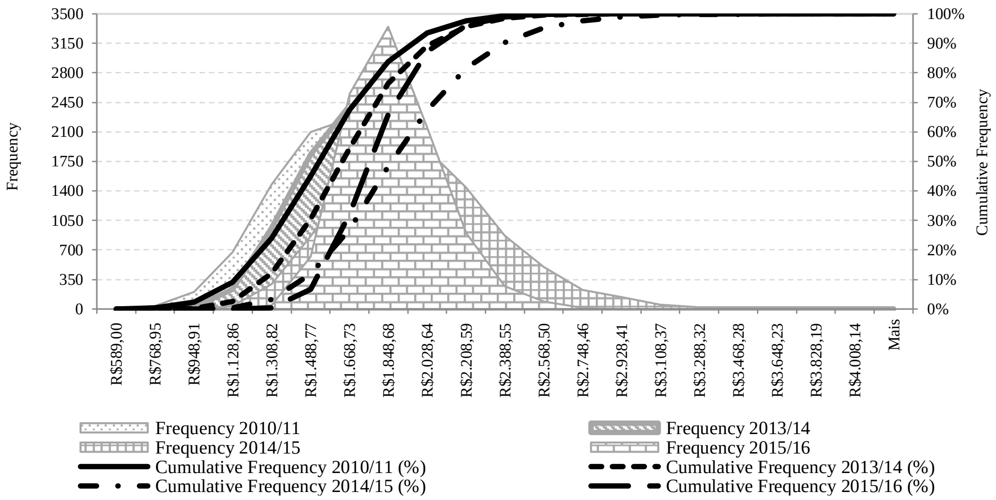

Figure 5 – Frequency and cumulative frequency of the Operational Cost random data, for the second-crop NonGM corn

Source: Research data.

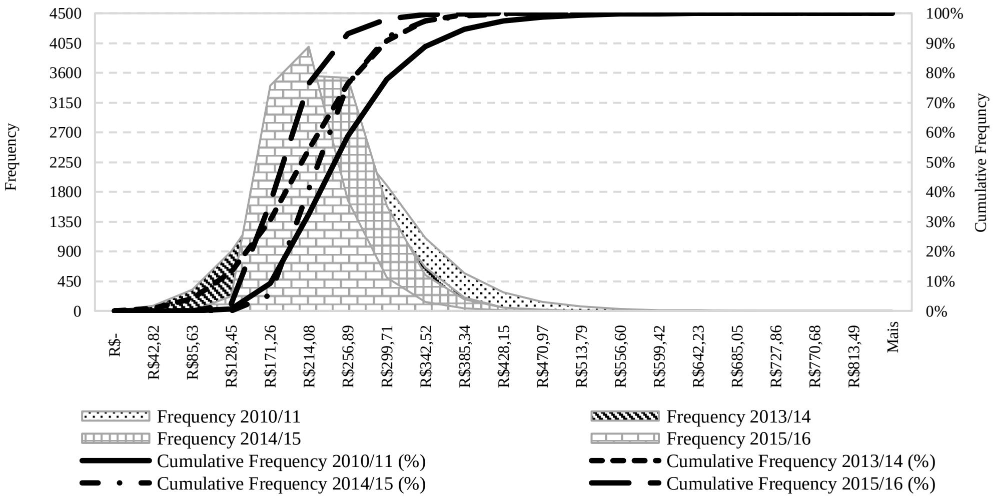

Figure 6 – Frequency and cumulative frequency of the seed costs random data, for the second-crop NonGM corn

Source: Research data.

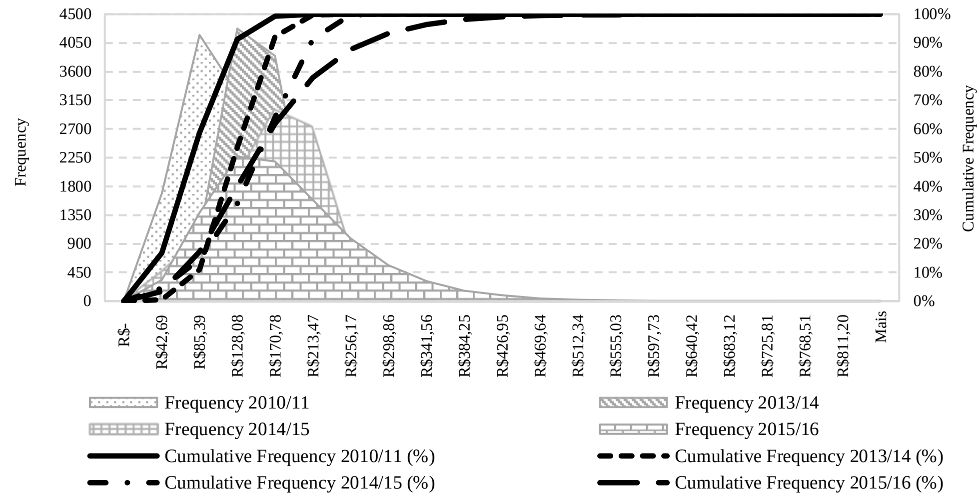

Figure 7 – Frequency and cumulative frequency of the insecticide costs random data, for the second-crop NonGM corn

Source: Research data.

Second crop GM corn varieties showed a rise in the EOC from 2010/11 to 2014/15 and a reduction in the 2015/16 season (Figure 8). However, in all years there were large dispersions of the maximum and minimum data, as observed by the relative frequency distributions. Among other aspects, this is related to seed expenditure, which rose from 2010/11 to 2013/14, decreasing again in 2014/15 and rising in 2015/16 (Figure 9). In this case, one hypothesis is that in the last quarter of 2014, the period of purchase of inputs for the 2014/15 season, there were prospects for new GM seeds commercial authorizations in 2015, and the seed companies opted to negotiate the remaining stocks at lower prices. In the last quarter of 2015, when the new seeds were already in the market (CNTBio, 2017), prices rose again for the 2015/16 season.

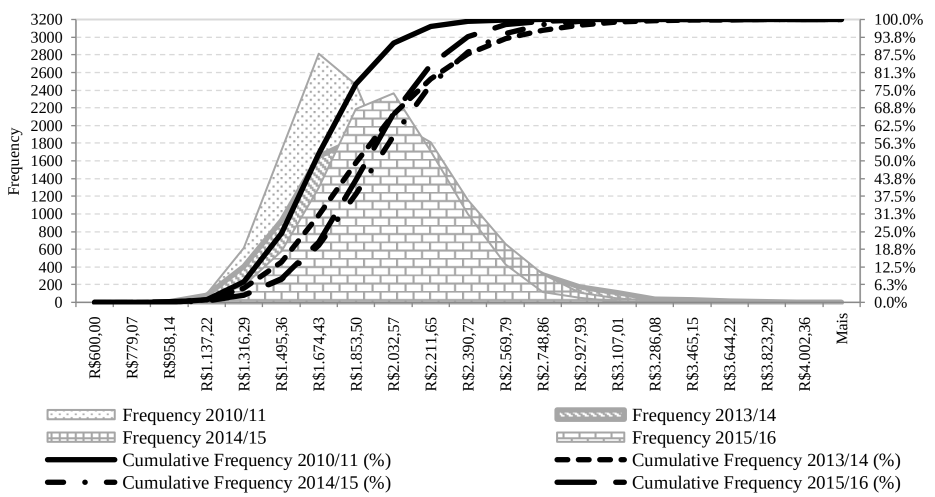

Figure 8 – Frequency and cumulative frequency of the Operational Cost random data, for the second-crop GM corn

Source: Research data.

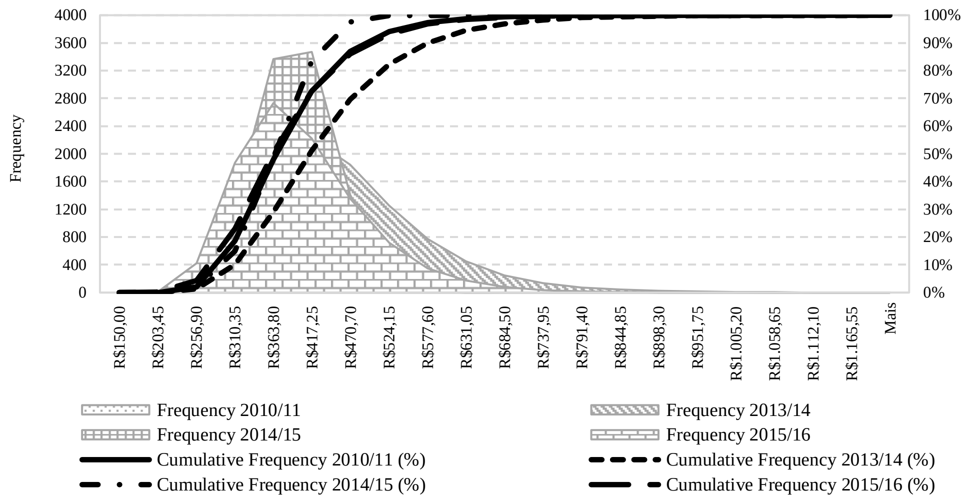

Figure 9 – Frequency and cumulative frequency of the seed costs random data, for the second-crop GM corn
Source: Research data.

The need to use insecticides is low in insect-resistant GM varieties in Brazil, but this need increased with each crop-year (Figure 10). While in 2010/11 there was a 10% probability of disbursing more than R$ 42.00 per hectare with insecticide, in 2015/16 this probability increased to 80% - with a 10% probability, the expenditure with insecticide could exceed R$ 150.00/ha. As much of the raw material from insecticides is imported, the higher exchange rate in recent years increased insecticide costs. Data from (CEPEA/ESALQ-USP, 2017) show that the exchange rate increased from R$ 2.54/USD in the last quarter of 2014 to R$ 3.84/USD in the same period of 2015. In addition, data indicate that the pressure of pests not controlled by BT technology such as that of bugs in the early stage of crops, was higher.

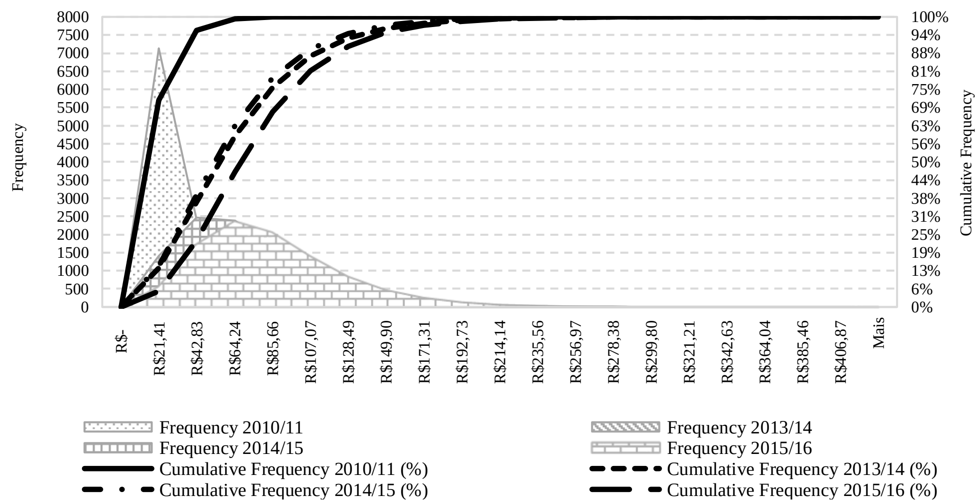

Figure 10 – Frequency and cumulative frequency of the insecticide costs random data, for the second-crop GM corn
Source: Research data.

In the case of first harvest corn (summer), the analysis indicates cost increase at each crop year (Figure 11). In addition, especially in the 2015/16 season, the tails of frequency distributions increased, indicating a greater dispersion of costs between the analyzed regions. In the case of seed costs, cumulative frequencies indicated a rise from 2010/11 to 2013/14, a reduction in the following year (2014/15) and a new increase in 2015/16 (Figure 12). In the second harvest, insecticide costs also increased over the years, even in crops with GM varieties (Figure 13), except for the 2015/16 season. In this case, the weather had a positive effect.

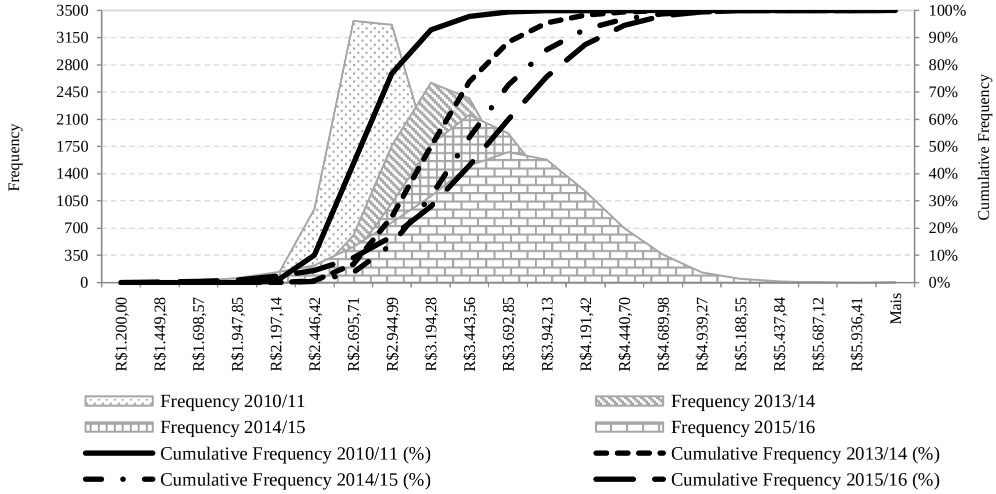

Figure 11 – Frequency and cumulative frequency of the Operational Cost random data, for the first-crop GM corn

Source: Research data.

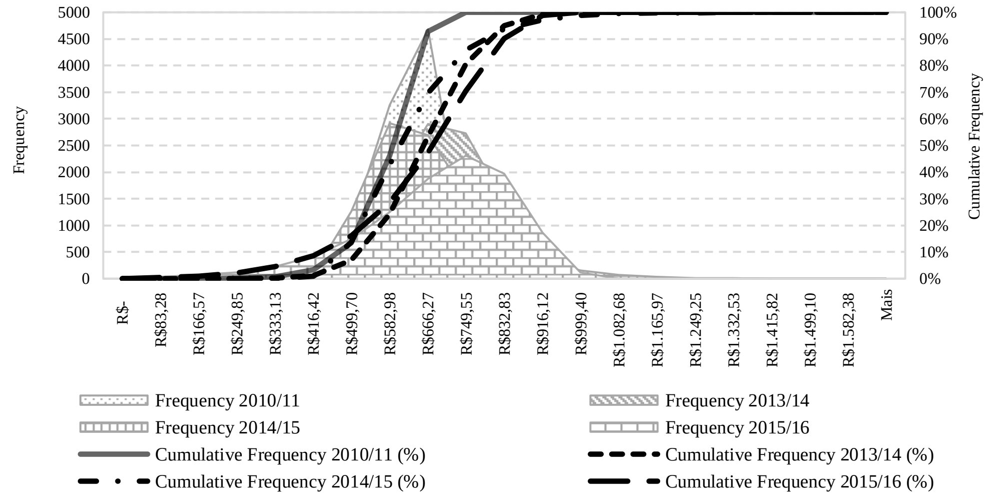

Figure 12 – Frequency and cumulative frequency of the seed costs random data, for the first-crop GM corn

Source: Research data.

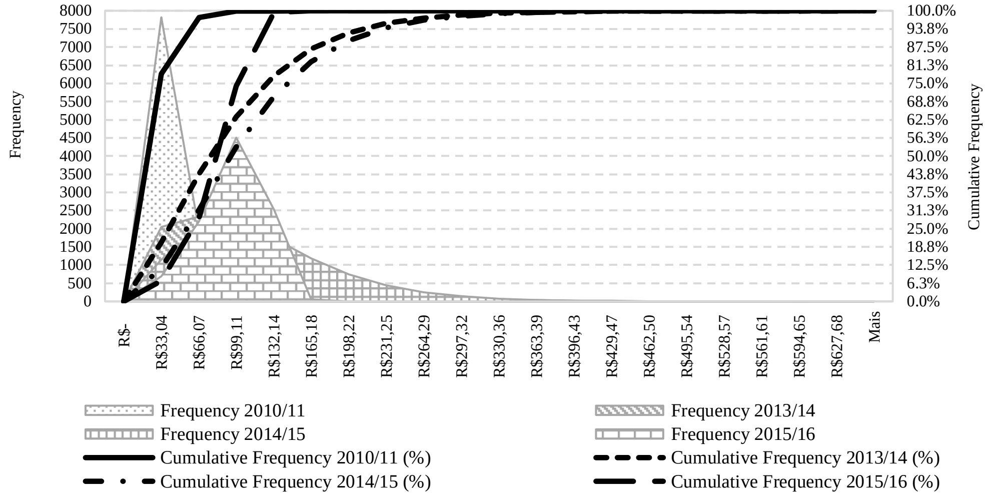

Figure 13 – Frequency and cumulative frequency of the insecticide costs random data, for the first-crop GM corn

Source: Research data.

With increasing costs, few differences in expenditures and productivity between GM and NonGM varieties, along with a higher use of insecticides even in GO varieties, the rapid expansion in GM corn in Brazil is a puzzling phenomenon. The results are different of Brookes and Barfoot (2018). In the next section, we present the results of the qualitative survey performed, which can shed more light on the issue, to understand the point of view of producers (SUBEDI et al., 2003).

Perception of producers and technicians about GM corn adoption

As previously discussed (methodology), this part of the research aimed at identifying agents' perceptions regarding some important aspects relate to GM varieties adoption. More specifically, the survey asked questions about: a) the ease of acquiring seeds of NonGM corn varieties in relation to GM; b) the comparative performance between the NonGM compared to GM varieties; c) whether the use of GM varieties facilitated crop management; and d) whether or not there was any difference between the commercialization of GM and NonGM corn.

When asked about the ease of acquiring NonGM varieties in relation to genetically modified corn seeds (Figure 14), we note that during the three survey´s crop years the response shares for "very hard" and "hard" options increased, although the "same" option is the most representative. This indicates that the availability of NonGM seeds may be decreasing, with supplier companies focusing on marketing seeds with embedded GM technologies. This seems to be an important indicator of the motivation for producers to use GM varieties even though the cost is equal to or greater than the NonGM seeds: NonGM seeds are in shorter supply than GM.

In general, the stakeholders considered that the performance improvement of NonGM cultivars for the region in which they operate is below the observed for GM varieties (Figure 15). Considering the answers "very little" or "little", the proportion of answers on the questionnaires applied in

2010/11, 2014/15 and 2015/16 reaches 64.2%, 72.2%, and 59.7%, respectively.

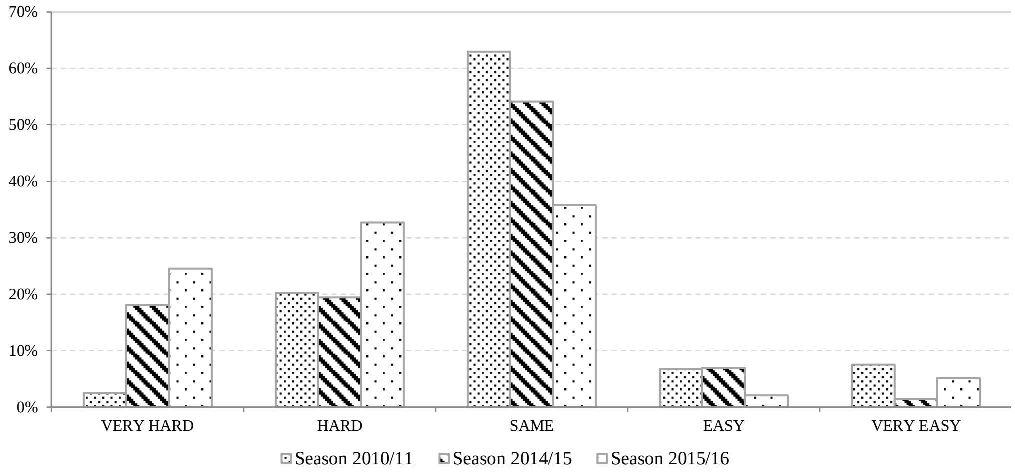

Figure 14 – Easiness on acquiring NonGM seeds
Source: Research data.

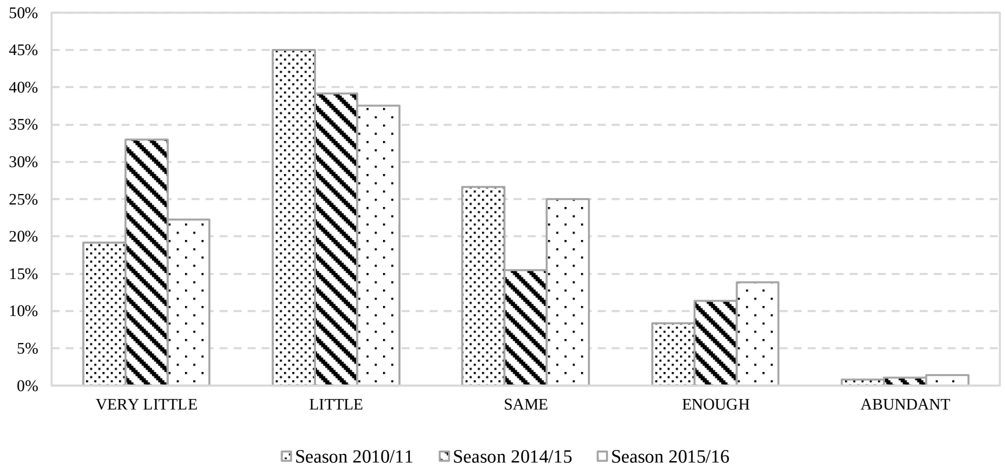

Figure 15 – Level of genetic engineering in NonGM corn seeds compared to GM seeds
Source: Research data.

Another aspect to consider in relation to the attractiveness of the GM seeds compared to NonGM is the easiness of crop management. Likewise, producers would tend to choose risk-reducing technologies. The majority of respondents in the three years cited that GM varieties facilitate crop management practices. For the last two seasons, however, an increasing share of respondents answered that the management difficulty is equal between NonGM varieties and GM (Figure 16). As mentioned before, these results could relate to the increasing need for insecticides spraying even in areas with GM seeds.

Finally, the last question tried to identify the existence of market restrictions to the commercialization of GM corn (Figure 17). In the 2010/11 season, 31.7% of respondents reported being very easy to sell GM corn production, when compared to NonGM, while 10% said it was easy and 47.5% said there was no difference (same). However, this number fell during the last two harvests, and in 2015/16, 90.3% of respondents said there was no difference in the sale of GM varieties compared to NonGM ones, with another 9% saying that it was very easy or easy, indicating no restriction on the commercialization of corn production with GM varieties.

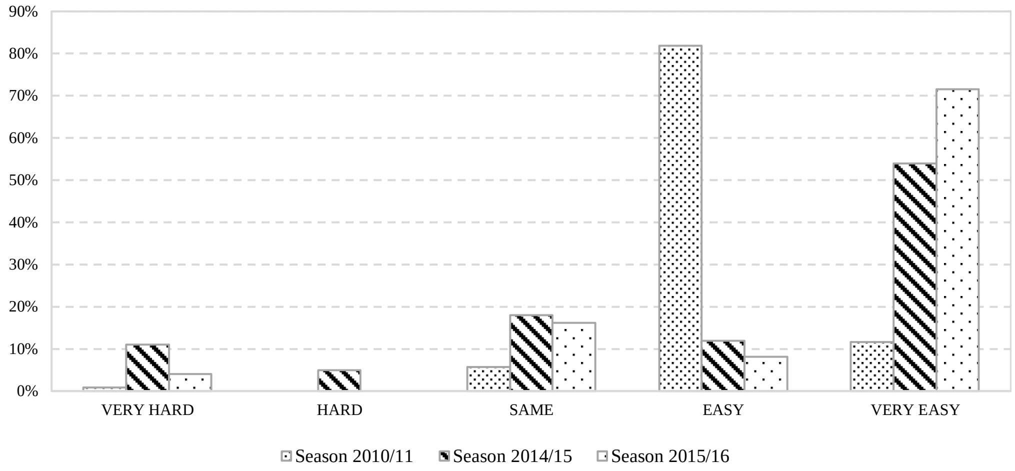

Figure 16 – Easiness on GM Crop-fields management
Source: Research data.

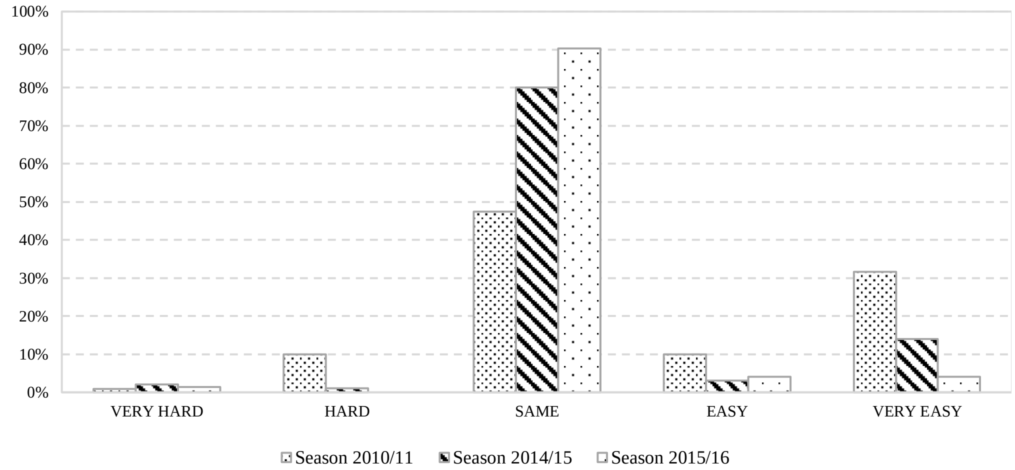

Figure 17 – Easiness on selling GM corn compared to NonGM corn
Source: Research data.

FINAL CONSIDERATIONS

The analysis performed in this paper (the results of a four-year field survey – 2010/11, 2013/14, 2014/15 and 2015/16 –, for two harvests and eleven states) showed that the operational costs for GM corn production in Brazil are higher than that with NonGM seeds. The reduction in insecticide costs in the GM crops do not fully compensate for the increase in the technology costs, and this difference tends to be higher in the second crop areas, in all seasons studied. Results also showed that the differences on the insecticide costs between GM and NONGM varieties decreased over time, contributing to the higher operational costs in GM corn than in the NonGM one. As the productivity obtained was similar for both technologies, the unit cost of production was also higher for the GM varieties.

The qualitative results indicated that the ease in the acquisition of NonGM seeds decreased during the analyzed period, raising the hypothesis of a possible strategy for GM seed companies to boost sales of a higher value-added product. The perception by producers of a low level of genetic improvement (performance) of NonGM varieties also reinforces the hypothesis raised above.

Even though most of the interviewees consider the management of GM crops easier than their GM counterparts, a growing share evaluated that there was no difference during the last two seasons of the survey. This data reflects the importance of using field refugees, aiming to increase the lifecycle of GM technologies. The need for insecticide spraying even in areas with GM seeds points to the loss of efficiency in pest control of the technology. Finally, no market difficulties were reported to commercialize GM corn. Contrary to some countries, where corn is an important food source for humans, in Brazil it is mostly a feedstuff, raising no concerns about its use.

The points discussed above can help explain the rapid diffusion of the GM technology in corn production in Brazil, even in the presence of higher operational costs. Risk reduction seems to be an important explanation for the phenomenon, as discussed previously by Ferreira Filho e Alves (2013). This is particularly true when we consider the increase in the average size of farms in corn production recently when corn started to be produced in the Brazilian center-west, mostly as a second crop after soybeans. The difficulties of pest controls in large areas, especially in the case of initial infestations, can be an important incentive for producers to adopt GM technologies if the perceived value of the risk reduction is higher than the cost increase with GM seeds.

Finally, we note the importance of continuous field monitoring in time, to improve observations quality. Crops results are very sensitive to weather conditions, and more years of observations would be important for results generalization. The observation of a lower supply of NonGM seeds to the producers is a particular point deserving attention in future studies. Even though it can make sense from a private point of view of the seed companies, it is a point to deserve attention for public policies, both for their economic and environmental implications.

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