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PROFITABILITY OF ADOPTING WINTER BT CORN IN MIDDLE PARANAPANEMA REGION-SP, BRAZIL, UNDER RISK CONDITIONS

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ABSTRACT: The economic benefits at farm level of Bt corn are one of the reasons for its rapid adoption in Brazil. Some of these benefits have been confirmed, such as increases in cost savings in pesticide use and yield. The benefits usually outweigh the costs of technology, for example, the premium paid by corn seed. Considering that benefits and costs are subject to changes in critical variables, the objective of this study was to measure the economic returns of Bt corn adopters in an important producer region of Sao Paulo state, under risk conditions. Net benefits may vary due to four critical variables, such as increased productivity, saving costs of plague control, the price of Bt corn seeds and corn prices. We used Monte Carlo method of simulation to estimate statistical measures of net income, sensitivity analysis of net benefits in relation to critical variables, and the levels of risk adopting Bt corn. The average earnings were US$.72.0.ha^{-1}, and yield increase was the variable that most affected net gains. The adoption of winter Bt corn showed a high probability of generating positive gains (87%). In addition, producers believe that the main advantage of Bt corn is non-monetary gains especially labor savings.

KEYWORDS: transgenic corn, economic benefits, net income, biotechnology costs.

RENTABILIDADE DA ADOÇÃO DO MILHO BT NA REGIÃO DO MÉDIO PARANAPANEMA-SP, BRASIL, EM CONDIÇÕES DE RISCO

RESUMO: Os benefícios econômicos para o produtor de milho Bt são uma das razões para sua rápida adoção no Brasil. Alguns desses benefícios são o aumento da economia de custos no uso de pesticidas e no rendimento da cultura. Os benefícios geralmente superam o custo da tecnologia, dado pelo prêmio pago pela semente de milho. Considerando que os benefícios e os custos estão sujeitos a mudanças nas variáveis críticas, o objetivo deste estudo foi medir os retornos econômicos dos adotantes de milho Bt em uma importante região produtora do estado de São Paulo, em condições de risco. Os benefícios líquidos podem variar devido a quatro variáveis críticas, como o aumento da produtividade, a redução dos custos do controle de pragas, o preço da semente do milho Bt e os preços do milho. Utilizamos o método de simulação de Monte Carlo para estimar medidas estatísticas de renda líquida, análise de sensibilidade dos benefícios líquidos em relação às variáveis críticas e os níveis de risco a que estão expostos os que adotam o milho Bt. O ganho médio da cultura foi de US$. 72.0.ha^{-1}, e o aumento do rendimento foi a variável que mais afetou os ganhos líquidos. A adoção do milho Bt de inverno mostrou alta probabilidade de gerar ganhos positivos (87%). Além disso, os produtores acreditam que a principal vantagem do milho Bt são os ganhos não-monetários, especialmente a economia de trabalho para a condução da cultura.

PALAVRAS-CHAVE: milho transgênico, benefícios econômicos, renda líquida, custos da biotecnologia.

1 INTRODUCTION

The adoption of genetically modified organisms (GMO) technology depends on the relationship between its benefits and costs. In the case of Bt maize, the benefits derive from reduced losses in production and the cost is given by the seed genetically modified higher price compared to the conventional seed.

In Brazil, one of the biotechnologies that had faster spread, was Bt corn, which achieved the adoption rate of 87.8% of cultivated area in only five years, for winter corn crop, and 67% for summer corn crop (Céleres Ambiental, 2013) as result of high economic damages caused by the fall armyworm (*Spodoptera frugiperda)*. Okumura et al. (2013), for example, show the agronomic efficiency of *Bacillus thuringiensis* (Bt) maize hybrids in pests control on Lucas do Rio Verde city, State of Mato Grosso, Brazil.

After the institutional legalization of genetically modified organisms (GMO) planting in Brazil, with the promulgation of the new Biosafety Law (BRASIL, 2005), the adoption of GMO has accelerated.

In 2012, the transgenic technology in maize production represented 76.1 percent of the corm total area (summer and winter crop). In 2008, the harvested area of transgenic maize was ten times smaller, corresponding to

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1.2 million hectares. Among soybeans, corn and cotton, maize is the crop with the highest adoption rate (VIEIRA-FILHO, 2014).

Still, according to Vieira-Filho (2014), the incorporation of biotechnology has brought indirect benefits to the producer, such as simplificatonf management, cost reduction and productivity gains.

Other important reasons that could explain the high rate of adoption of Bt corn in Brazil is the economic benefits provided by this technology, such as reduced costs of applying insecticides, and increased gross income due to increases in productivity, as a result of reduced losses caused by armyworm infestation (DUARTE; GARCIA; CRUZ, 2009).

Vieira-Filho (2014) also associates the higher rate of corn adoption with gains in learning from soy production, which was the first GM crop cultivated in Brazil. On the other side, the cost of technology related to the premium paid for the transgenic seed can be an obstacle to the adoption of this biotechnology.

Many studies point out the positive net benefits in Bt corn adoption, but several factors may influence the amount of economic earnings from this action. These factors may vary significantly depending on the year and location, because the differences of temperatures and humidity that affects the infestation levels, as summarized by Hutchinson (2015).

Assessment of factors that influences economic earnings, like reduced cost of insecticides use, is more complex, but according to Brookes and Barfoot (2017), the adoption of Bt maize reduced in 53% the use of active ingredients for corn borer control from 1996 to 2015.

Cost savings resulting from Bt corn use, also depend on infestation levels. Carpenter and Gianessi (2001) reported that extrapolating trends of reducing insecticide use by introducing Bt technology is a great problem, among other reasons, because the insect populations, or their own nature, are highly variable from year to year, which makes it difficult to discern trends.

The factor that negatively impacts economic benefits of Bt technology is its cost. In Brazil, differential seed prices, like 40-80% higher compared to the price of single and triple hybrid seed, respectively (DUARTE; GARCIA; CRUZ, 2009).

Riesgo, Areal and Rodríguez-Cerezo (2012), in simulations of price premium for conventional maize and the impact on the profitability of Bt maize in some regions of Spain, reported that in order to reduce by 50% the probability of Bt maize being more profitable than the conventional one, a price premium of €17 ton^{-1} for non-GM maize would be necessary.

Even being an economically attractive technology, it is subjected to risks regarding the variation of economic earnings to obtain it. Taking into account factors such as market uncertainties about maize prices, level of increased yield, price paid for technology (Bt corn seeds) and seasons with low level of infestations, there are some economic risk factors concerning Bt corn adoption. We used Monte Carlo method for risk analysis because it presents a series of advantages, such as time and cost reduction, and the possibility of repetition under different conditions of production, if properly modeled.

The traditional methods of economic analysis is based on deterministic data or indicators. However, agricultural activities are subject to variations. To introduce risk in decision making, the Monte Carlo technique is a useful tool, allowing the observation of the performance of a variable of interest that contain elements of uncertainty.

In agriculture, this tool is commonly used to analyze risk in investment projects and profitability of agricultural activities (COELHO JUNIOR et al., 2015; SABAG et al., 2015; OLIVEIRA et al., 2017).

The aim of this work was to measure the economic benefit of winter Bt corn adoption in a region of Sao Paulo State, Middle Paranapanema Region, that is quite relevant in corn production. The amount of benefits was measured under the perspective of risk, considering the probability of changes in some critical variables as corn price, reducing costs of pest control, yield increases and Bt technology cost.

2 MATERIAL AND METHODS

Corn can be found virtually in almost all regions of Sao Paulo state, at various levels of technology, but its adoption is made predominantly by input-intensive producers, which is a characteristic of the Middle Paranapanema region. In this region, main cities achieve about 12,000 ha of corn cultivation and around 360 corn-growing farms. In the Middle Paranapanema region, transgenic corn has its dominant production in the winter season. In the summer, the most common culture is the soy crop. In that region, Bt corn adoption was massive. According to information of four grain traders, a significant part of cooperative farmers has adopted transgenic seed since its launch in 2009, and cooperative members amounted to 90% in the last season.

Approximately 48 producers associated to the main local cooperative were interviewed, using non-probabilistic purposive sampling based on desired characteristics of respondents, such as: a) to have adopted Bt technology for at least 3 seasons, b) have kept regular records of costs, yield and marketing prices of corn, c) to have commercialized corn in the local cooperative, d) to have cultivated winter corn, in fields similar to the region average area of the region (50 ha), and e) to have presented a production system representative of the region.

To estimate net benefits under risk conditions, an analytical model was used which evaluated economic earnings provided by Bt technology, costs paid by Bt producers, and compared them to those of non-Bt corn crop from producers who had adopted it until 2009. This form of data collection was used to minimize effects of different production systems on net benefits, which can occur when comparing Bt and non-Bt producers.

Differences in gross income of Bt corn compared to the former technology (non Bt corn) were estimated based on increased yields and corn market price. In addition, saving costs of plague control were included in the model to estimate the gross benefit. Technology costs were estimated from the difference between Bt seed and conventional hybrid seed prices, as follows:

$$NB = \Delta CC + (\Delta Y \times MP) - \Delta SC \qquad (1)$$

NB = net benefits of adopting Bt corn (US\$ ha^{-1});
ΔCC = difference in pest cost control (US\$ ha^{-1});
ΔY = yield difference (kg ha^{-1});
MP = corn market price (US\$ kg^{-1});
ΔSC = differential seed cost (US\$ ha^{-1}).

This model can be adapted for risk insertion, in which risk variables are expressed as probability distribution function, rather than establishing a deterministic value for net benefit determination, as follows:

$$fNB = f\Delta CC + (f\Delta Y \times fMP) - f\Delta SC \qquad (2)$$

f NB = Probability distribution function of net benefits of adopting Bt corn (US\$ ha^{-1});
f ΔCC = Probability distribution function of difference in pest cost control (US\$ ha^{-1});
f ΔY = Probability distribution function of yield difference (kg ha^{-1});
f MP = Probability distribution function of corn market price (US\$ kg^{-1});
f ΔSC = Probability distribution function of differential seed cost (US\$ ha^{-1}).

Each producer reported values of critical variables based on conventional hybrid yield, which had been previously adopted, and on currently cultivated Bt corn. From this information, the probability distribution functions of critical variables were estimated using the information provided by the selected producer sample. Distribution functions were selected according to criteria of adjustment by the Chi-square test.

To estimate the function distribution of probability of net benefits in adopting Bt corn, we used Monte Carlo method.

In the case of pest cost-control, each producer reported the type and amount of insecticides used to control this pest when conventional hybrids were used, and the amount of cost reduction by adopting Bt corn.

In the region, payment of a premium for conventional corn production occurs only in few marketing squares, because high cost of separation would impose a high premium for conventional corn, hindering its commercialization as informed by the cooperative manager. Therefore, distribution function of prices was estimated using the range of average paid prices of corn, in the period from 2008 to 2013. The price data were coleted in the São Paulo (2013).

Regarding seed costs, producers have used predominantly Bt seed, although other types of transgenic seeds have been available (like RR and RR-Bt corn seeds). Each of the producers informed the seed type used and its price. As the same amount of seed is used, saving costs refer to the differential price between conventional and Bt seed.

Based on the model and estimation of probability distribution functions, the Monte Carlo technique was applied to obtain statistical measures of central tendency and variability of earnings with Bt technology; sensitivity analysis was used to identify risk variables that have greater influence on the variance of net benefits. The correlation (positive or negative) between the indicator of net earnings and main variables that influence the variation of net economic benefits was also estimated.

The data allow to estimate the probability (α) that the benefits of Bt corn adoption (B_{BT}) be higher than the costs of the technology (C_{BT}), as shown in the following formulation:

$$\Pr(B_{Bt} \geq C_{Bt}) = \alpha\% \qquad (3)$$

Results obtained from this formulation allow to establish the probability of obtaining positive net earnings. For example, considering a value of 90%, results show that there is 90% chance of benefits be higher than technology costs. Alternatively, it can be stated that there is a 90% likelihood that the producer will obtain positive net earnings adopting Bt technology.

3 RESULTS AND DISCUSSION

The main difference between Bt corn and conventional corn cultivation is the number of insecticide applications to control armyworm. In conventional hybrids cultivation, 4 types of insecticides (thiodicarb for seed treatment, inidacloprid+betacyflutrin, methomil+ethanol, lephenuron for lepidopterons control) are used, and sprays are usually applied during early morning, due to milder temperatures and higher humidity content which provide greater control efficiency.

The number of applications performed in former crops of conventional corn varied according to the infestation level, but producers reported that historically conventional corn cultivation was carried out using general spray applications with insecticides, with an average cost of US\$ 63.0 ha^{-1}. All producers who adopted Bt corn reported almost total suppression of insecticide use for fall armyworm control.

In relation to yield differences, the producers reported increases ranging from 0 to 960 kg.ha^{-1} of corn, but results varied widely among producers. Most of them reported an increase of 10% for Bt corn yields. The regions with the highest adoption rate are those with the highest productivity indicators. Brazil Southeast has the highest adoption rate (92.5%), which is associated with higher productivity, 5.88 t per hectare (VIEIRA-FILHO, 2014).

These variations of yields were adjusted to probability distribution function. There is no premium price paid for conventional corn commercialized in the local market, because separation costs of Bt corn and conventional corn are prohibitive and the buyers do not pay significant premiums for conventional corn.

Transgenic seeds have higher prices than conventional hybrids, an average cost of US$ 87.0 ha^{-1}, but this differential value varies according to the type of transgenic seed adopted, reaching a value of US$ 124.00 ha^{-1} for some types of seeds compared to the average price of conventional seeds. These cost differences were adjusted to a probability distribution function.

Probability distribution functions of critical variables and their parameters are shown in Table 1.

***Table 1** - Probability distribution functions of critical variables and parameters estimated.*

Critical variable	Distribution function	Parameters
Saving Costs	Exponential	λ = 45.56
Increased Yield	Triangular	Min=0.57; Modal=7.02; Max=19.203
Corn price	Uniform	Min=16.78; Max=28.342
Bt seed price differential	Logistics-log	γ=-3033.6; β=3139.6; α=95.3

Source: Own elaboration (2013).

Distribution functions of critical variables were entered in the model of net benefits and statistical results for descriptive analysis are presented in Table 2.

These results show that the maximum net benefit that could be obtained is US$ 427.89 ha^{-1} and minimum net benefit implies losses of US$. 167.23 ha^{-1}. On average, earnings can be US$ 72.73 ha^{-1} with a standard deviation of US$.66.15 ha^{-1}. Asymmetry value greater than zero means that the distribution shows a slight positive asymmetry, that is, it is more common to observe values lower than the mean value. Kurtose value shows that distribution of net benefits tends to be leptokurtic, which indicates lower level of data scattering in relation to the normal distribution function. Mode value indicates the most frequent value of net benefits, that is, US$ 55.60 ha^{-1}.

***Table 2** - Measures of net benefits of adopting genetically modified corn seed, Middle Paranapanema Region.*

Statistical indicators	Values US$ ha^{-1}
Minimum (US$.ha^{-1})	-167.23
Maximum (US$.ha^{-1})	427.89
Mean (US$.ha^{-1})	72.73
Standard Deviation (US$.ha^{-1})	66.15
Variance (US$.ha^{-1})^2	4,376.70
Skewness	0.28
Kurtosis	3.36
Median (US$.ha^{-1})	69.52
Mode (US$.ha^{-1})	55.60

Source: Own elaboration (2013).

Table 3 shows maximum levels of net benefits which can be obtained at several risk levels. This result derives from the cumulative probability distribution function of net revenue and allows the choice of an alternative, based on certain possibility to guarantee net income at a given level of risk acceptance by the decision maker.

***Table 3** - Economic risk of transgenic corn adoption, Middle Paranapanema Region.*

Risk Percentile	Profit Value (US$..ha^{-1})
0%	-167.23
10%	-8.36
20%	17.72
30%	36.07
40%	53.14
50%	69.53
60%	86.10
70%	103.92
80%	126.79
90%	160.05
100%	427.89

Source: Own elaboration (2013).

For a producer with low risk acceptance, e.g. 10%, maximum net benefit is -US$ 8.36, or near zero, which indicates that for a producer with a very low risk acceptance profile the cultivation of Bt instead of conventional corn would be indifferent. However, producers tend to accept higher levels of risk depending on the actual characteristics of agricultural production. In this case, corn adoption would be recommended, as at the next risk level (20%), the net benefits have already become positive.

As the level of risk is established, the producer can decide if the maximum net benefit which would be obtained is acceptable. For example, a producer with a profile of moderate tolerance to risk, around 50%, can decide whether maximum earning of US$ 69.53 ha^{-1} is acceptable.

Most critical variables that affect variability of net benefits can be seen in Figure 1.

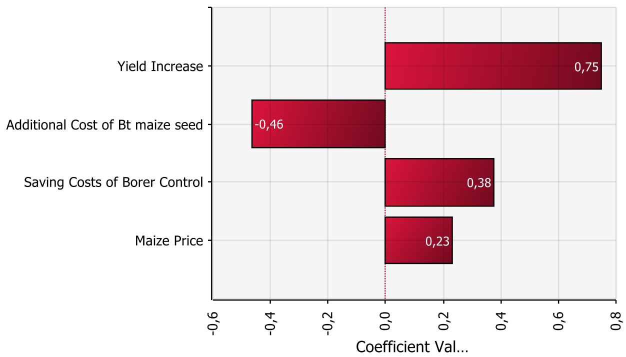

***Figure 1** - Regression coefficients of variables that influence the net benefits of adopting Bt corn.*

A positive sign indicates that increases in productivity differential enhance net benefits. Value of 0.75 indicates that a 10% increase in productivity is related to 7.0% increase in net economic benefits. The increased price of Bt corn seeds leads to a net benefit reduction of 4.6%. Current prices of Bt corn also increase economic benefits of Bt corn by 2.3%.

Examining the tornado chart, it can be seen that productivity differential is the critical variable that affects net benefits variation, with the highest regression coefficient.

The variables "control cost of fall armyworm", "additional cost of Bt seeds" have almost the same intensity of effect on net benefits. Figure 2 shows the probability that adoption of this technology could generate positive net income for producers.

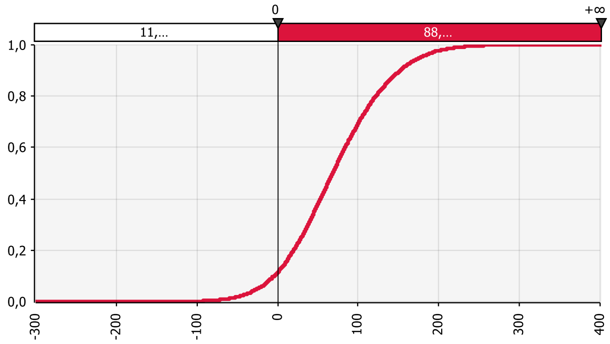

Figure 2 - *Distribution of accumulated net benefits.*

Chances (88.7%) are high that Bt corn seeds adoption generate positive net benefits. Above US$ 100.00 ha^{-1}, chances of rising net benefits start to become smaller, as shown in cumulative distribution of net benefits.

These results are consistent with the opinion of the producers interviewed, 94% of them believe that Bt corn is almost always economically more advantageous than conventional corn.

Although transgenic corn presents high potential for economic earnings, producers tend to consider non-monetary gains as main advantage, such as reduced use of insecticides, exemption from chemical handling, and convenience of dispensing with sprays in early morning.

Almost half producers (48%) believe that the greatest advantage of Bt corn adoption is the convenience of not carrying out spraying operations at night. Others (23%) attribute risk reduction of losses by Lepidoptera attacks as the main advantage of transgenic corn. Although most producers reported higher productivity, only 8% of respondents posed it as the main advantage of Bt corn.

The economic impacts of adopting GM crops may vary according to several factors, most notably pest infestations, increased yield, seed premiums, prices of alternative pest control programs, and any premiums paid for segregated crops. Nevertheless many studies on benefits and cost of Bt corn adoption showed consistently positive net benefits in both developing and developed countries (SMYTH; KERR; PHILLIPS, 2015). In general, GM crops perform better than their conventional counterparts in agronomic and economic (gross margin) terms. Regarding countries' level of development, GM crops tend to perform better in developing countries than in developed countries, with Bt cotton being the most profitable crop grown (AREAL; RIESGO; RODRÍGUEZ-CEREZO, 2013).

All producers who adopted Bt corn reported almost total suppression of insecticide use for fall armyworm control, that resulted in a saving cost of US$.63.0 ha^{-1}. Few studies analyze the impacts on pesticides use. Fernandez-Cornejo et al. (2014), report that in the United States, after the introduction of Bt corn, adopters who had previously controlled corn borer infestations using insecticides lowered their pesticide costs and increased their yields. Adopters who had not previously treated European corn borer infestations with insecticides achieved only yield gains (and may have incurred higher seed costs).

For Brookes and Barfoot (2017), the greatest improvement in yields has occurred in developing countries, where conventional methods of pest control have been least effective, with any cost savings associated with reduced insecticide use be mostly found in developed countries.

In general, GM crops perform better than their conventional counterparts in agronomic and economic (gross margin) terms. Regarding countries' level of development, GM crops tend to perform better in developing countries than in developed countries, with Bt cotton being the most profitable crop grown (AREAL; RIESGO; RODRÍGUEZ-CEREZO, 2013). Few studies have been conducted in developing countries, mostly Philippines and South Africa. Yorobe Junior and Smale (2012), based on a survey of 466 farmers, found thatBt maize increases net farm income. The use of Bt maize has statistically significant net-income increasing effect of 4,300.05 pesos per hectare, that corresponds to US$.104.0 ha^{-1}. According to Mutuc et al. (2012) initial Bt corn adoption in the Philippines provided a modest but statistically significant increase in farm yields and profits. In addition, Bt corn adoption had a negative effect on the likelihood of pesticide use. Moreover, pesticide demand is significantly reduced by Bt corn adoption.

Sanglestsawai, Rejesus and Yorobe (2014), provides some evidence that Bt corn technology has benefited poor corn farmers in the Philippines through higher relative yield effects as compared to the more commercial producers at the upper end of the yield distribution.

Although the profit of Bt corn is very variable between countries and producers, it is possible to say that, in general, the adoption of Bt corn generates positive net benefits.

The variability of results may be due to several factors that affect the amount of benefits. Despite the variation in the results found in this study, they are in accordance with those reported worldwide.

Many studies attribute the variation in benefits of adopting Bt maize to uncertainties in the levels of infestation of worms, because in regions of low infestation or lower insect population, Bt corn may not be economically attractive. But in developing countries, pest damage is significantly higher because there is more intensive infestations and overlapping generations, as these countries, like Brazil, are usually located in the tropics. With Bt maize, there is a significant reduction in pesticide use. Otherwise Afidchao et al. (2014) found negative economic impact on BT corn adoption in reason of the high seed cost and the issues of technological inefficiency.

But in general, in the tropics, the benefits of adopting Bt maize may be higher and involve lesser risks than those in temperate countries, because of more persistent levels of infestation and lower efficiency of insecticides (KLÜMPER; QAIM, 2014).

Non-monetary benefits were identified, such as reducing field operations, which implies labor and energy savings. Regier, Dalton and Williams, (2012) analyzing the impacts of RR and BR modified maize on smallholder risk in South Africa, reported that when family labor accounts for the opportunity cost of time, the additional cost often outweighs the premium paid for seed by GM maize producers.

4 CONCLUSION

As concluding remark, this study sought to provide additional contribution to economic studies regarding Brazil, one of the major world producers of corn, which has increasingly adopted Bt corn and does not have a consolidated literature on impacts Bt crops adoption.

Furthermore, we tried to propose an approach that considered the possible variations of factors that affect the amount of benefits, such as behavior of corn price, differences in productivity, seed cost and savings in pesticide use compared to conventional hybrids. We consider this approach particularly suitable for areas which are in the process of adopting Bt corn.

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