Environmental effect of conventional and GM crops of cotton (*Gossipium hirsitum* L.) and corn (*Zea mays* L.)

Efecto ambiental de cultivos transgénicos y convencionales de algodón (*Gossipium hirsitum* L.) y maíz (*Zea mayz* L.)

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ABSTRACT

In the corn belt of Valle de San Juan and in the cotton zone of El Espinal, municipalities in the department of Tolima (Colombia), 10 conventional corn producers, 10 producers of genetically modified corn, five producers of conventional cotton and 15 producers of transgenic cotton were surveyed in the first half of 2009 to contrast the differences in the environmental impact associated with use of insecticides and herbicides, which were evaluated by estimating the environmental index quotient-EIQ. In the case of maize, an EIQ of 42 was found in the conventional type, while transgenic technology had an EIQ of 3.03. In the cultivation of cotton, an EIQ of 263.59 was found for the conventional type while for transgenic technology this value varied between 335.75 (Nuopal BG/RR) and 324.79 (DP 455 BG/RR). These data showed a lower environmental impact using GM technology in the cultivation of maize when compared to the conventional counterpart, in connection with the use of insecticides and herbicides, in the context of time, space and genotypic analysis. This effect was not observed in the case of cotton, where environmental impacts were similar.

Key words: EIQ, use of insecticides, use of herbicides, agricultural technologies, transgenic crops.

RESUMEN

En la zona maicera de Valle de San Juan y en la zona algodonera de El Espinal, municipios del departamento del Tolima (Colombia), en el primer semestre del 2009 se encuestaron 10 productores de maíz convencional, 10 productores de maíz transgénico, cinco productores de algodón convencional y 15 productores de algodón transgénico, para contrastar las diferencias en el efecto ambiental asociadas al consumo de insecticidas y herbicidas, que se evaluaron por medio de la estimación del índice de coeficiente ambiental (*Environmental Index Quotient* EIQ). Para el caso del cultivo del maíz, en la tecnología convencional se encontró un EIQ de 42, mientras que para la tecnología transgénica fue de 3,03. En el cultivo de algodón, para la tecnología convencional se encontró un EIQ de 263,59 en tanto que para la tecnología transgénica este valor vario entre 335,75 (tecnologia Nuopal BG/RR) y 324,79 (Tecnologia DP 455 BG/RR). Estos datos mostraron un menor impacto ambiental del uso de la tecnología transgénica en el cultivo de maíz cuando es comparada con su homólogo convencional, en relación con el consumo de de insecticidas y herbicidas, en el contexto temporal, espacial y genotípico analizado. Este efecto no se observó en el caso del cultivo del algodón, donde los impactos ambientales fueron similares.

Palabras clave: EIQ, consumo de insecticidas, consumo de herbicidas, tecnologías agrícolas, cultivos transgénicos.

Introduction

Transgenic crops play an important role in available agricultural technologies, according to the latest report from the ISAAA (International Service for the Acquisition of Agri-Biotech Applications) in 2010, transgenic technology reached 29 countries occupying an area of 146 million hectares, an increase of 10% over the previous year (James, 2010). However, the debate that was generated from the commercial release of GM crops about the benefits or risks that may result in agroecosystems, for the economy and society in general still remains in force, and in fact becomes increasingly more important due to the lack of studies related to this subject, especially in tropical countries that have this type of crop (Amman and Garden, 2004; Dale *et al*., 2002).

Therefore, the debate on the risks and benefits of GM crops should be expanded from a factual basis with sound scientific research, to provide information on the outlook for GM crops in countries that are implementing this technology. Methodology should be used "case by case" involving a series of data on the GM crop: the introduced gene, vector processing, receptor species and genotype,

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related species, features of the agroecosystem where it is released, and so on. This information allows one to limit the temporal context, spatial and genetic analysis, and determine the environmental and economic differences that occur with the adoption of technology (Dale *et al*., 2002; Brookes and Barfoot, 2006, 2008; Ghosh and Jepson, 2005; Nap *et al*., 2003).

The main research on transgenic technology has been focused on evaluating production costs, environmental effects (use of insecticides and herbicides), use of machinery and association with theñimplify the interpretation of the data, the toxicity of each pesticidal active ingredient and the effect on each environmental factor were grouped into low, medium or high toxicity and ranked on a scale of one to five, one being the lowest and five the highest (Kovach *et al*., 1992; Brookes and Barfoot, 2006).

The EIQ formula is expressed as:

$$\{C[(DT+5)+(DT*P)]+[(C+((S+P/2)*SY)+(L)]+[(F*R)+(D*((S*P)/2*3)+(Z*P*3)+(B*P*5)]\}/3 \quad (1)$$

Where: DT = cutaneous toxicity, C = chronic toxicity, SY = systematic, P = toxicity to fish, L = leaching potential, R = area of potential loss, D = toxicity to birds, S = soil half-life, Z = toxicity to bees, B = toxicity to arthropods, P = plant half-life.

Each of the values of the quotient of the formula derived from an extensive review of data and this index is considered to be universal. (Kovach *et al*., 1992; Brookes and Barfoot, 2006).

Since we know the EIQ of marketed pesticides and their respective active ingredient, its value can be found in the field, where data from dose, number of applications and the active ingredient are used to calculate EIQ_{field} as shown below (Kovach *et al*., 1992; Brookes and Barfoot, 2006):

$$EIQ_{field} = EIQ\text{* Percentage of active ingredient * Dose * No of applications} \quad (2)$$

The field EIQ index has been used widely in different countries and different cultures, demonstrating that the index is easily applicable and that its design can be adapted to different growing conditions and agro-ecological zones. It has been used in Europe on GM maize, which reports a 30% decrease in consumption of insecticides (Brookes, 2008) for cotton in India decreases of up to 77% on varieties resistant to insects has been reported (Keter *et al*., 2007). In other crops, reports are known for apple growing in Mexico (Ramírez and Jacobo, 2002), in the potato crop in Peru (Pradel *et al*., 2009), and from Venezuela in the cultivation of onion (Pierre and Betancourt, 2007).

Materials and methods

Data collected in this study were taken during the first half of 2009 and were taken by direct surveys of producers, thereby collecting the basic information needed to quantify the economic conditions of farming, the use of insecticides, and herbicides in the two agricultural technologies evaluated, for transgenic and conventional.

The 20 producers of corn were surveyed with the following distribution:

- For conventional technology, 10 lots of surveyed producers accounted for 7.24% of total Fenalce data;
- For GM technology, the 10 lots of surveyed producers occupied an area of 190.4 ha, representing 100% of the total acres in the evaluated semester.

The corn hybrid Herculex I® from Dupont SA was released commercially in Colombia by resolution 3745 of 2006 of the Instituto Colombiano Agropecuario (ICA). *Cry1F* contains the gene that confers resistance to certain lepidopteran insect pests, and the *pat* gene that confers tolerance to herbicides whose active ingredient is glufosinate ammonium.

For cotton farms, 20 lots were also surveyed. Of all the 212 farmers who reported Conalgodón for 2009, the 20 lots accounted for 9.4% of the total, located in 10 different villages in the municipality of El Espinal.

In the case of transgenic technology in cotton, the planting of genotypes containing combined events has been authorized in Colombia. In the case of genotypes containing Bollgard® and Roudup Reday® events, release was authorized by resolution 358 of 2007 of the ICA. Bollgard® refers to the *cry1Ac* gene derived from *Bacillus thuringiensis* and which confers resistance to some lepidopteran insects, while Roundup Ready refers to the *cp4epsps* gene derived from *Agrobacterium tumefaciens* conferring tolerance to herbicides whose active ingredient is glyphosate.

With resolutions 1726 and 2203 of 2007, the ICA authorized the planting of genotypes containing Bollgard II® and Roundup Ready Flex® combined events, which improve the original events. Bollgard II contains *Cry1Ac* and *Cry2Ab* genes. These genotypes are owned by the Colombian Agricultural Company (Coacol), a domestic subsidiary of the multinational corporation Monsanto. The varieties

Nuopal BG/RR and DP 455 BG/RR belong to this type of genotypes.

The work guide format used was designed from the framework of information required for analysis using the methodology of Brookes and Barfoot (2006, 2008, 2009) and Kovach *et al*. (1992). The survey was divided into six sections as follows:

I. Details of the property,

II. Property level of the farm,

III. General information of the crop,

IV. Crop production data,

V. Fertilization,

VI. Insect and weed control.

This article focuses on section VI of the survey, from which the information was related to the use of insecticides and herbicides for each crop and in turn for each technology.

Results and discussion

Environmental Index Quotient (EIQ)

With the information gathered in surveys of consumption of insecticides and herbicides (dose and number of applications), the field EIQ was calculated for each product for each crop and each agricultural technology, with these data the average dose used for each pesticide was calculated (kg ha^{-1}) as well as the number of applications.

It is important to note that reports in the literature (in terms of EIQ calculations) have analyzed the technologies of resistance to lepidopteran insects (RLI) and herbicide tolerance (HT) independently.

For the assessed areas, genotypes that have both RIL and TH features together were found in the two crops: the maize hybrid Herculex I® and the cotton varieties Nuopal BG/RR and DP 455 BG/RR. As discussed in the two cases, genomes in which the transgenes are expressed together, the analysis was performed jointly, to calculate a field EIQ for each product type, herbicide and insecticide - and finally the sum of the two indices was taken as the total field EIQ.

EIQ in the cultivation of corn

Tab. 1 shows the reduction of temperature coefficient index (linked to the consumption of insecticides and herbicides) as obtained with the implementation of GM technology in the Corn Belt of Valle de San Juan, because insecticide applications were reduced to zero.

Indeed, the field EIQ value for the conventional technology was 42, but 3.03 for the transgenic technology. The calculated field EIQ shows a difference of 38.97 points in favor of genetic engineering which is a reduction in terms of the numerical value of the index of over 10% with the overall evaluation (insecticides and herbicides).

As mentioned above, the evaluation of the effects of GM crops must be framed by the methodology in each case. The values recorded for conventional maize in other countries like Canada (61.65), United States (26.39) and South Africa 2.92 (Brookes and Barfoot, 2006), show the importance of this methodology and the usefulness of the EIQ. Since, countries share transgenic technologies, which are exposed

TABLE 1. Calculated field EIQ for pesticides and herbicides comparing the conventional and transgenic technology for corn.

Conventional technology											
Insecticide	**EIQ**	**Active ingredient (%)**	**Dose (kg ha^{-1})**	**No. applications**	**Total**	**Herbicide**	**EIQ**	**Active ingredient (%)**	**Dose (kg ha^{-1})**	**No. applications**	**Total**
Match	16.29	0.05	0.30	1.5	0.37	Atrazine	22.85	0.50	1.38	1.0	15.77
Atabron	30.31	0.05	0.50	2.0	1.52	Gramaxo-ne	24.73	0.19	1.50	1.0	7.05
Lorsban	26.85	0.25	1.00	1.3	8.73	Thordon	18.00	0.11	1.60	1.0	3.17
Methomyl	22.00	0.90	0.18	1.0	3.56	Accent	19.52	0.75	0.05	1.0	0.73
						Finale	20.20	0.15	0.50	1.0	1.52
Total EIQ insecticide					14.17		Total EIQ herbicide				28.23
EIQ Total conventional technology											42
Transgenic technology											
Insecticide	**EIQ**	**Active ingredient (%)**	**Dose (kg ha^{-1})**	**No. applications**	**Total**	**Herbicide**	**EIQ**	**Active ingredient (%)**	**Dose (kg ha^{-1})**	**No. applications**	**Total**
This technology does not require insecticides					0	Finale	20.2	0.15	0.50	2.0	3.03
Total EIQ insecticide					0			Total EIQ herbicide			3.03
EIQ total transgenic technology											3.03

under different agro-ecosystems and parameters, and so behavior will be different and to some extent determine the crop response, which in environmental terms can be reflected, as in this case, in different EIQs, showing the importance that each country possess updated databases and complete inventories of transgenic technologies that have been introduced and their possible effects (specifically effects related to the use of insecticides and herbicides).

In addition to the calculation of the field EIQ, the toxicology of each product category was reviewed, the four insecticides applied to control pests in the cultivation of conventional maize differ in their toxicological category (Tab. 2). One of the insecticides used is classified in class I (Extremely toxic), two within category III (averagely toxic) and only one within class IV (slightly toxic).

TABLE 2. Category toxicology of insecticides used in conventional technology in the corn crop.

Insecticide	Active ingredient	Toxicity category*
Atabron	Chlorfluazuron	IV
Lorsban	Chlorpyrifos	III
Match	Lufenuron	III
Methavin	methomyl	I

* Categories established by the ICA per Decree 775 of 1990.

While in the conventional technology, there was an average of 5.8 insecticide applications with four different insecticides and five applications with five different herbicides, in the transgenic technology only one application of one herbicide was recorded with zero insecticide applications. This behavior allows us to suggest that the evaluated crop cycle, growing area and transgenic technology showed an environmental gain, with which is associated a reduction of harmful effects of pesticide application, including: bioaccumulation, damage to target species, reduced diversity, pollution of water sources, soil pollution, elimination of mycotoxins in maize, among others (Carpenter, 2011).

For herbicides, it was found that all batches using transgenic technology applied Finale to control weeds. Tab. 3 indicates that this herbicide is in toxicity category IV (slightly toxic) which is consistent with studies reported by Brookes and Barfoot (2008). These authors concluded that in the case of herbicides, although applications do not always decrease, transgenic technology facilitates the adoption of chemical inputs friendlier to the environment and human health. Herbicides are applied in a maize cycle with conventional technology; highly toxic, moderately toxic and slightly toxic.

TABLE 3. Herbicides applied during conventional and transgenic production cycles of maize.

Herbicide	Active ingredient	Toxicity category*
Accent	Nicosulfuron	III
Atrazina	Atrazine	III
Gramoxone	Paraquat	I
Tordon	Picloram + Acid 2,4-D	III
Finale**	Glufosinate-ammonium	IV

* Categories established by the ICA per Decree 775 of 1990.
** Herbicide applied in the two technologies (conventional and transgenic).

EIQ in cotton

For the cultivation of cotton, a different picture was presented to that found in the cultivation of corn for the two technologies. In this crop, a large number of applications was found as well as a large number of products for the control of both pests and weeds. Because of this and in order to present a more complete analysis, calculations of insecticides and herbicides were reported separately for each technology, and eventually added together to obtain the total field EIQ as mentioned above.

Likewise in transgenic technology in the sampled plots there were two different technologies, therefore calculations for field EIQ were performed for each.

Insecticides

Tab. 5 presents toxicology information on the insecticides used in conventional technology, with 11 different pesticides applied with an average of 1.45 applications (Tab. 4). All insecticides fit into the toxicity categories I, II and III, ie medium to highly toxicity (Tab. 5). The total value of the EIQ for pesticides in the conventional technology was 162.58 (Tab. 5).

TABLE 4. Calculated field EIQ for pesticides in cotton, conventional technology (active ingredient in dose kg ha^{-1}).

Conventional technology					
Insecticide	EIQ	Active ingredient (%)	Dose	No. applications	Total
Match	16.29	0.05	0.40	1.5	0.49
Lorsban 4EC	26.85	0.25	1.13	2.0	15.17
Karate	18.35	0.05	0.50	2.0	0.92
Actara 25W	33.30	0.25	0.70	1.3	7.75
Mectin 1.8 EC	34.68	0.18	0.35	1.0	2.18
Regent 250 FC	88.25	0.25	0.35	2.6	20.54
Methyl	35.20	0.80	2.00	1.5	84.48
Larvin 80	23.30	0.34	1.50	1.0	11.88
Spock 18 EW	36.35	0.18	0.50	1.0	3.27
Nufos 4 E	26.85	0.44	1.20	1.0	14.18
Rimon I	14.33	0.10	1.20	1.0	1.72
Total EIQ (field) insecticides					162.58

TABLE 5. Toxicology category of insecticides used in conventional technology for cotton.

Insecticide	Active Ingredient	Toxicology category
Match E5	Lufenuron	III
Lorsban 4EC	Chlorpyrifos	
Regent 250 FC	Fipronil	
Larvin 80	Thiodicarb	
Nufos 4 EC	Chlorpyrifos	
Rimon I	Novaluron	
Actara 25W	Thiamethoxam	II
Spock 18 EW	Zeta - Cypermethrin	
Methavin 90 PS	Methomyl	
Mectin 1.8 EC	Abamectin	I
Methyl	Methylparathion	I

Tab. 6 shows the EIQ values obtained for the two transgenic technologies found in the field: Nuopal BG/RR and DP 455 BG/RR. For the first, there were 11 different insecticides with an average of 1.53 applications, obtaining an EIQ of 270.87, while for the second technology (DP 455 BG/RR) there were 14 different insecticides with the same average application, and a field EIQ of 252.29.

These results suggest that the value of calculated field EIQ will be affected primarily by the dose and the number of applications, since being a product index, the final value will increase or decrease based on these variables. It can be concluded that a product with a high EIQ is related to the number of times and amount applied.

The insecticides used in the two genotypes of transgenic technology belong to all types of toxicological categories (Tab. 7), including three of category I, which is the highest category of toxicity.

TABLE 6. Calculated Field EIQ for insecticides comparing the two transgenic technologies for cotton (active ingredient in dose kg ha^{-1}).

Transgenic technology Nuopal BG/RR					
Insecticide	**EIQ**	**Active ingredient (%)**	**Dose**	**No. applications**	**Total**
Match E5	16.29	0.05	0.43	1.50	0.53
Lorsban 4EC	26.85	0.25	1.20	1.66	13.37
Actara 25W	33.3	0.05	0.06	1.50	0.15
Mectin 1.8 EC	34.68	0.18	0.63	1.00	3.93
Regent 250 FC	88.25	0.02	0.34	2.25	1.35
Methyl	35.20	0.80	2.00	2.50	140.80
Larvin 80	23.30	0.48	1.44	1.40	22.55
Spock 18 EW	36.35	0.18	0.50	2.00	6.54
Nufos 4 EC	26.85	1.80	1.20	1.00	58.00
Rimon I	14.33	4.80	0.20	1.00	13.76
Methavin 90 PS	22.00	0.90	0.50	1.00	9.90
EIQ (field) Partial for Insecticides					270.87
Transgenic technology DP 455 BG/RR					
Insecticide	**EIQ**	**Active ingredient (%)**	**Dose**	**No applications**	**Total**
Match E5	16.29	0.05	1.40	1.25	1.43
Regent 250 FC	88.25	0.02	0.35	3.33	2.06
Methyl	35.20	0.80	1.80	2.40	121.65
Actara 25W	33.30	0.05	0.08	1.50	0.20
Mectin 1.8 EC	34.68	0.18	0.5	1.00	3.12
Spock 18 EW	36.35	0.18	0.50	3.20	10.47
Larvin 80	23.30	0.48	1.30	1.00	14.54
Lorsban 4EC	26.85	0.25	1.25	1.00	8.39
Latigo EC	36.35	0.50	1.00	1.00	18.18
Lannate 20	22.00	0.90	1.00	1.00	19.80
Orthene 75 SP	24.88	0.75	0.70	2.00	26.12
Efectrina 200	36.35	2.00	0.35	1.00	25.45
Insectrina 20 EC	36.35	0.02	0.35	1.00	0.25
Dimilin 25	25.33	0.25	0.10	1	0.63
EIQ (field) Partial for Insecticides					252.29

TABLE 7. Toxicology Category of insecticides used in the transgenic technology.

Insecticide	Active ingredient	Toxicology category ICA
Dart 15 SC ***	Teflubenzuron	IV
Dimilin 25 ***	Diflubenzuron	
Match E5	Lufenuron	III
Lorsban 4EC	Chlorpyrifos	
Regent 250 FC	Fipronil	
Larvin 80	Thiodicarb	
Nufos 4 EC	Chlorpyrifos	
Rimon I	Novaluron	
Orthene 75 SP ***	Acetate	
Actara 25W	Thiamethoxam	II
Spock 18 EW	Zeta - Cypermethrin	
Methavin 90 PS	Methomyl	
Efectrina 200	Cypermethrin	
Insectrina 20 EC	Cypermethrin	
Latigo EC	Chlorpyrifos	
Mectin 1.8 EC	Abamectin	I
Methyl	Methylparathion	I

*** The only applied Insecticides in technology DP 455 BG / RR.

For the cultivation of cotton, there were no differences in relation to partial EIQ field values for insecticides between conventional technology and transgenic technology. This indicates that for this crop in the municipality of El Espinal and the first half of 2009, transgenic technology offers no environmental benefits compared to conventional technology in pest control since the EIQ recorded higher values and more products with higher average applications. This would suggest that the cotton crop pests are generating some resistance to the transgenic plants.

Reported values for cotton, as mentioned above, are published only for the technology of lepidopteran insect resistance (LIR) or herbicide tolerance (HT), independently. We found that by the year 2009, in China, for LIR technology, conventional cotton earned a EIQ of 126 while the 83-transgenic technology in India for conventional cotton had an EIQ of 70 and for the transgenic technology index, a value of 34 (Brookes and Barfoot, 2011).

So, for other countries, transgenic technology provides benefits in terms of consumption of insecticides when compared with its conventional counterpart, behavior that was not observed in the assessed area.

Herbicides

The Tab. 8 shows the findings with respect to herbicides applied under conventional technology and the two transgenic technologies for cotton. For the case of the conventional technology, there were five different herbicide applications, averaging 1.36 applications and a field EIQ value of 101. For the transgenic genotype Nuopal BG/RR, 3 different herbicides were seen with an average application of 1.23 and a field EIQ 64.87. Finally, for genotype DP 455 BG/RR, four different herbicides were seen with an average application of 1.17 and a field EIQ of 72.51.

TABLE 8. Field EIQ calculated for herbicides comparing the two transgenic and conventional technologies for cotton (active ingredient in dose kg ha^{-1}).

Herbicide	EIQ	Active ingredient (%)	Dose	No. applications	Total
Nuopal BG/RR					
Round up brio	15.33	0.48	2.32	1.71	29.19
Star	15.33	0.41	2.75	1.00	17.28
Glifosol	15.33	0.48	2.50	1.00	18.40
Total EIQ (field) herbicides					64.87
DP 455 BG/RR					
Round up brio	15.3	0.48	2.35	1.71	29.51
Star	15.33	0.41	2.75	1.00	17.28
Glifosol	15.33	0.48	3	1.00	22.08
Finale	20.2	0.15	1.2	1.00	3.64
Total EIQ (field) herbicides					72.51
Conventional technology					
Dualgold	22.00	0.96	1.06	1.00	22.39
Round up brio	15.33	0.48	2.00	1.50	22.08
Karmex	26.47	0.80	1.00	1.66	35.15
Finale	20.20	0.15	1.13	1.66	5.68
Star	15.33	0.41	2.50	1.00	15.71
Total EIQ (field) herbicides					101.01

Unlike findings with insecticide, herbicide applications for the calculated field EIQ showed a reduction for transgenic technologies, about 30 points, compared to the conventional, indicating that for the specific case of weed control, a reduction of the effect environment is linked to the consumption of these products, however it is important to note that this reduction could be because the conventional technology used a greater number of products (five) than the transgenic technology.

All herbicides used in the two transgenic technologies are in toxicity category III, as shown in Tab. 9.

TABLE 9. Toxicology Category of herbicides used in conventional and transgenic technology in cotton.

Herbicide	Active ingredient	Toxicology category ICA
Dualgold	Metolachlor	III
Karmex	Diuron	
Finale	Glufosinate	
R Brio	N Phosphonomethyl	
Star	Glyphosate	
Glifosol		

The results obtained for cotton indicate that it is a crop more susceptible to attack by pests, generates a greater environmental effect linked to the consumption of insecticides, which was also observed in both transgenic technologies evaluated in the field, thus the GM technology did not generate an environmental benefit in the assessed area and period, so case-by-case studies are vital, over time, that may show some variation with respect to the use of insecticides to determine whether or not to implement any transgenic technology effectively in a particular growing area.

Finally, Tab. 10 summarizes the findings for each technology. The total value of the field EIQ for conventional technology was 263.59, for the transgenic genotype Nuopal BG/RR, 263.59 and the transgenic genotype DP 455 BG/RR, 324.79.

Essentially, the results show that for cotton cultivation in the municipality of El Espinal and during the first half of 2009, transgenic technology offered no environmental advantage over its conventional counterpart.

The values reported in this paper are similar to those reported for transgenic crops in other parts of the world. For HT cotton, for example, field EIQ values were reported in China of 1.35, for Mexico 1.62, and Argentina and South Africa, 27, 54 (Brookes and Barfoot, 2006). This is probably explained by the characteristics of tropical agriculture with very high populations of insect pests and weeds expressed

TABLE 10. Calculated field EIQ for insecticides and herbicides comparing the two transgenic and conventional agricultural technologies.

Crop	Technology	EIQ field		
		Insecticide	Herbicide	EIQ total
Cotton	Conventional	162.58	101.01	263.59
	Nuopal BG/RR (GM)	270.87	64.87	335.75
	DP 455 BG/RR (GM)	252.29	72.51	324.79

throughout the culture, and use of varieties developed for temperate conditions, which would be less efficient in tropical ecosystems. This matter deserves a full research program.

On the other hand, legal problems were verified between the guilds of cotton producers and the company that owns the transgenic technology. These problems could lead to a crisis of confidence in the technology by farmers, possibly leading to transgenic genotypes being treated like conventional ones. In any case, the Confederación Colombiana del Algodón (Conalgodón) sued Coacol, the company holding the rights to transgenic technology, based on losses observed in the 2008-2009 cotton season. The ICA, by resolutions 050 and 051, February 18, 2010, imposed an administrative penalty and a fine of $512,000,000 COP against Coacol for misleading propaganda (Portafolio, 2009). Subsequently, by resolution 846 of 17 February 2011, the ICA reversed the sanction, possibly because the process that led to the penalty omitted information and did not comply with the relevant notifications to the multinational (Portafolio, 2011).

A study for 10 years in the U.S. for TH cotton and conventional cotton found EIQ field values of 51.8 and 46.3 respectively (Brookes and Barfoot, 2009). In this study, the authors suggested that there are no numerical differences that can convey an environmental benefit from transgenic technology in cotton cultivation, which coincides with what is being reported in this paper.

For the cultivation of cotton in the area of El Espinal, in the second half of 2009, GM technology offers no environmental benefits since the field EIQ calculated for the two transgenic technologies in the field were higher than that found for the conventional technology. Clearly, this outcome may have influenced the legal problems between the guilds of producers and the company that owns the transgenic technology.

The EIQ index of Kovach *et al.* (1992) allowed us to establish the environmental effects through quantitative analysis, allowing comparisons between different technologies applied to agriculture.

The results of this study are applicable only to the comparative analysis of transgenic technology and conventional technology, used in maize cultivation in the municipality of Valle de San Juan, and cotton cultivation in the municipality of El Espinal in the department of Tolima (Colombia) during the first half of 2009. To reach more general conclusions, we need to monitor crops and technologies in different agro-ecosystems and production for several periods.

The numerical difference found in EIQ values for different countries and the same crop show the importance of case-by-case and region by region studies. For each transgenic event, conventional genotype and determined region, the conditions placed on the crop are different, therefore the range of environmental effects are also different and generate quantitative variations in the calculated index.

Conclusions

With the use of the transgenic corn hybrid Herculex IÒ, insecticide applications are reduced to zero and to only one application of herbicides. While in the conventional technology, there are 5.8 insecticide applications and five herbicide applications. The result was a field EIQ of 3.03 for transgenic technology and 42 for conventional technology. This shows environmental benefits in the application of transgenic technology in the cultivation of corn, in the municipality of Valle de San Juan, in the second half of 2009.

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