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ASSESSING THE ECOLOGIC AND ECONOMIC IMPACTS OF GM MAIZE POTENTIAL CULTIVATION IN ROMANIA

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The transgenic maize was modified for agronomic input traits such as herbicide tolerance (HT) and/or insect resistance (IR) (Bacillus thuringiensis-Bt). These traits are likely to impact upon the use of pesticides on this crop. This study estimated the potential environmental and economic impacts (in respect of pesticide usage) linked to the use of glyphosate tolerant and stacked Bt and glyphosate tolerant hybrids if these technologies would be applyied on a large maize growing area in Romania. In order to compare the impacts of the pesticides being presently applied relative to the impact of the pesticides that would be applied to maize we used the Environmental Impact Quotient (EIQ). Assuming that by applying HT technology the cost of weed management would be reduced with only 80 euro/ ha, and that the conventional maize would be replaced with transgenic maize on a quarter of area allocated every year to this crop, 40 million euro could be saved, herbicide use would be decreased by 245.000 kg active ingredients and the associated environmental impact of pesticide use on this crop area would decrease by 31%. The adoption of insect and herbicide tolerant maize varieties on 500.000 hectares, should lead to reductions in pesticide use with 13.750 kg insecticides and 245.000 kg a.i. herbicide. The impact on the environment would be reduced by almost 1.5 millions load units. Furthermore, the cost saving for weed and pest management would be about €41 million, annualy, when compared with conventional systems.

Key words: transgenic maize, pesticides regimes, environmental impact, pest management cost, Romania.

INTRODUCTION

In 2012, 170.1 million hectares of genetically modified (GM) crops were grown worldwide. On a global basis, transgenic crops are 81%, 35%, 81% and 30% of the total soybean, maize, cotton and canola areas, respectively[1].

Stacked traits are an important feature of biotech crops. Around 43.7 million hectares equivalent to 26% of the 170 million hectares were stacked in 2012.[1]

In the USA alone, an acreage of 20 million hectares of Bt corn was cultivated. In the EU, in 2012, only 129.071 hectares of MON810 were cultivated in Spain, Czech Republic, Portugal, Romania and Slovakia.[1]

In 2000, Romania was the only country in Europe approving market release of a HTGM crop, Roundup Ready (RR) soybean. As member of the European Union (EU) beginning with 2007, Romania had to comply with the rules for placing on the market of GM organisms as laid down by EU legislation. Consequently, as of 2007, RR soybean cultivation was banned in Romania. Today, Bt-maize is the only GM crop approved for cultivation in the EU.[2] In 2012, in Romania, Bt hybrids were grown on about 270 ha.

A number of studies focused on the altered use of pesticides on GM crops, mainly in terms of quantities of active ingredient (a.i.), and on the environmental and economic effects of transgenic crop adoption has been published.[3-14] The volume of herbicides used in GM maize decreased by 193 million kg (1996–2011), a 10.1% reduction, while the overall environmental impact associated with herbicide use on this crop decreased by a significantly larger 12.5%. The global farm income gain, for the 16 year period (1996–2011) has been $98.2 billion.[15]

A comprehensive assessment of the effect of GM crop adoption on farm sustainability in the US concluded that "generally, GM crops have had fewer adverse effects on the environment than non-GM crops produced conventionally".[16] In EU, most of the studies at farm level regarding the impact of transgenic crop utilization focused on RR soybean in Romania,[17-21] and on Bt maize in Spain, Poland, Germany, Portugal and Romania.[9,11,15]

Quantifications of the longer-term economic consequences of adopting transgenic crops have been published. The early adoption by Spain of Bt maize led to an economic advantage of €135M, while the decision of France not to adopt over the same 5 year period meant a lost economic opportunity of about €310M.[22]

In order to estimate the environmental consequences of the altered pesticide use on transgenic crops the environmental impact quotient (EIQ) has been applied. EIQ was first described as a tool to assess specific pesticide risks to farm workers, consumers, and the environment.[23] When the amount in kilograms of applied active ingredients is known, using EIQ data Environmental Impact (EI) value can be calculated[24] Despite his limitations[25], EIQ is useful as a rough indicator of the direction of possible environmental impacts from changes in pesticide use within real agricultural conditions.[14]

The EIQ has been adopted for determining if GM crop adoption comes at a higher risk than the existing production system.[6,14,18,26]

To provide appropriate recommendations to growers regarding weed management strategy options, herbicide efficacy, EI and economic profitability should be assessed and given equitable consideration in the decision-making process.

Therefore, the objective of this study was to identify environmental and economic impacts associated with potential changes in the amount of insecticides and herbicides applied to the biotech maize relative to conventionally grown alternatives. Given the fact that both herbicide tolerance and insect resistance deal with pest management and, in particular, with the way that pesticides are used in crops, changes in the types and amounts of pesticides that are used on GM crops can be anticipated.[27]

As the most cultivated crops in Romania, maize production is challenged by the presence of mono- and dicotiledonous weeds, annual and perennial, weeding beeing extremelly differentiated in relation with podoclimatique conditions.[28] Primary data for impacts of commercial maize cultivation on pesticide usage are limited. All identified, representative, previous data collected in field trials has been utilized. In this paper, the pesticide related environmental impact changes associated with GM maize adoption are examined in terms of changes in the volume (amount) of a.i. applied but supplemented by the use of an alternative indicator, the EIQ. Using calculated EIQ of each product, herbicide or insecticide, and the quantities of a.i. applied *per* hectare the impact of weed and insect management technologies used in conventional *versus* specific weed and insect management technologies applied in transgenic maize could be estimated.[28] Data from other sources, including industry, is used where no other sources of (representative) data are available. All sources and assumptions used are detailed in the paper.

MATERIAL AND METHODS

Romania agricultural land area is about 15 million hectares. According to Eurostat data, Romania is in the first place regarding the area cultivated with maize. This is not the same case when yield is considered. The growth in maize production quantity and quality may bring Romania in a leading position on the European market of agricultural foodstuffs, seed and maize derived products.[2]

In Romania, there are no published annual pesticide usage surveys conducted by national authorities.

The only country in which pesticide usage data are collected (by private market research companies) on an annual basis and which allows a comparison between biotech and conventional crops to be made, is the US.[9]

On the Romanian market, there are a large assortment of both pre-emergence and post-emergence herbicides, which offers to farmers the possibility to establish locally adapted herbicide regimes (Table 1).

Environmental Impact

The environmental impact for each herbicide treatment was determined using published EIQ values,[23] except for some a.i. which were calculated according to the EIQ equation (Table 2) using data from technical file of the product or from pesticide book.[29] The EI of each treatment was calculated by multiplying herbicide EIQ by the quantity of a.i. applied in kg a.i./ ha. For herbicide products or tank mixes that contain more than one a.i., the EI was calculated by summing EIQs at the appropriate proportion. The relative risk of the herbicide treatments tested were ranked as very low, low, and medium on the basis of EI values of, >5, >20 and >45, respectively.[30]

Table 1

Commonly used herbicide in conventional maize in Romania

Product name	Active ingredient (a.i.)	Composi-tion (g/l)	Product dose (P l/ha)[a]	Application rate (a.i., kg/ha)	Application
Dual Gold	S-metolachlor	960.0	1.5	1.400	PRE; controls annual and perennial dicots
Gardoprim Plus Gold	S-metolachlor terbuthylazine	312.5 187.5	4.5	1.406 0.844	PRE and POST; controls annual and perennial monocots
	pendimethalin	400			
Dicopur	2,4 D	600	1.0	0.600	POST; annual and perennial dicots
Dicopur Top 464 SL	dicamba+ 2,4-D	120 344	1.0	0.120 0.344	POST; annual and perennial dicots
Roundup	glyphosate	360	4.0	1.440	PRE; controls mono-and dicots
Leone	glyphosate				
Callisto	mesotrione	480	1.0	0.480	POST; annual and perennial dicots
Buctril	bromoxynil	225	1.25	0.281	POST
Buctril Universal	Bromoxynil 2,4-D(ester)	280 280	1.00 1.00	0.280 0.280	POST; annual and perennial dicots
Mistral	nicosulfuron	40	1.3	0.052	POST; controls annual and perennial monocots
Astral	nicosulfuron	40	1.5	0.060	POST; controls annual and perennial monocots
Titus Plus	rimsulfuron + dicamba	3,26% + 60,87%	307 g/ha	0,010 0,186	POST; controls mono-and dicots
Principal	nicosulfiron rimsulfuron	425 107	90g/ha	0.038 0.0096	POST; controls annual and perennial monocots
Equip	foramsulfuron	22.5	1.5	0.056	POST; controls annual and perennial dicots and annual monocots
Cambio	Bentazone Dicamba	320 90	2.5	0.800 0.225	
Merlin Duo	isoxaflutol + terbuthylazine	37.5 375	2.5	0,9375 0,0937	Early PRE- and early POST; controls annual mono- and dicos
Adengo 465 SC	isoxaflutol + thiencarbazon-methyl	225 90	0,4	0.090 0.036	Early PRE and Early POST; controls annual mono-and dicots
Lumax	S-metolachlor terbuthylazine mesotrione	375 125 37,5	3.5	1.312 0.437 0.131	POST; controls annual and perennial dicots and annual monocots
Banvel	dicamba	480	0,6	0,288	POST; annual and perennial dicots
Frontier Forte	dimetenamid	720	1,4	1.008	PRE; controls annual mono-and dicots

Abbreviations: a.i. = active ingredient; P = product; POST= post-emergence; PRE= pre-emergence

EIQ method was applied to the pesticides regimes used in cultures of conventional, glyphosate tolerant and stacked Bt and glyphosate tolerant maize hybrids.

The EIQ incorporates the impacts of active ingredients of formulated products on farm workers, (application and harvest worker) consumers, and ecology (non-target organisms: fish, birds, honeybees, and other beneficial insects) (Table 2). Summing up the individual impacts results in a single number, the EIQ for one specific a.i. EI values for average herbicides quantities of eight pesticide regimes applied on one hectare and on 500.000 hectares of conventional maize, about a quarter of the area allocated to maize anually in Romania, were calculated. Regarding herbicide regimes applied in conventional maize, published data[31,32] and weed technologies recommended by some specialists (personal communication) were used.

Table 2

The rating system used to develop the EIQ of pesticides[23]

Component	Equation	Input variables (ratings)
Farm worker	C(DTx5)+(DTxP)	C = chronic toxicity (1-3-5) DT = dermal toxicity (1-3-5) P = plant surface residue half-life (1-3-5)
Consumer	(Cx(S+P)/2xSY)+(L)	C = chronic toxicity (1-3-5) S = soil half-life (1-3-5) P = plant surface residue half-life (1-3-5) SY = systemicity (1-2-3) L = leaching potential (1-2-3)
Ecology (fish, birds, honeybees, other beneficial insects)	(FxR)+(Dx(S+P)/2x3)+ (ZxPx3) + (BxPx5)	F = fish toxicity (1-2-3) R = surface loss potential (1-3-5) D = bird toxicity (1-3-5) S = soil half-life (1-3-5) P = plant-surface residue half-life (1-3-5) Z = bee toxicity (1-3-5) B = beneficial arthropod toxicity (1-3-5)
Total	(Farmworker + Consumer + Ecology)/3 = {[C(DTx5)+(DTxP)] + [(Cx(S+P)/2xSY)+(L)] + [(FxR)+(Dx(S+P)/2x3)+ (ZxPx3)+(BxPx5)]}/3	
Field-use rating (EI/A)	EIQ x % active ingredient x rate (kg/ha)	

For GMHT maize, EI values of herbicide regimes applied in field trials, in Romania, in 2010,[28] recommended by owner of technology (Table 3) and published as experimental results[30] were calculated.

In order to estimate the CO_2 emission the methodology and the guiding lines of Intergovernmental Panel on Climate Change (IPCC Review of Processes and Procedures which covers all the recent changes to IPCC procedures approved by the Panel in the period 2010-2012) were used, taking into consideration the differences regarding the CO_2 emissions betwwen conventional and transgenic weed management technologies.

In order to assess the economy for water consumption in the case of technology application we multiplied the number of treatments with the quantity of water used per hectar at one spraying.

For the assessement of environmental and economic impacts of GMIR maize cultivation at farm level in Romania data published were used.[11]

Economic impact of herbicide tolerance technology was assessed for herbicide regimes used in field trials, in 2010.[28] For weed management in HT maize field trials two treatments with glyphosate were applied: first, with 2l/ha, when plants had 1–3 leaves; second, with 3l/ha, until the plant developed 8 leaves.[11].

RESULTS AND DISCUSSIONS

Generally, herbicides used for weeds management in maize fields has EI values ranging betwwen 0.86 and 40.21 (Table 3). The EI values of the a.i. rimsulfuron, foramsulfuron, nicosulfuron, bromoxynil, dicamba were 0.1188, 0.86, 1.17, 4.78 and 7.58, respectively. These EI values were lower than the EI values of the herbicides which contain more than one a.i. (Table 3). Thus, the weed management options with herbicides with lower EI values were more environmentally friendly than the options with herbicides with higher EI values (Table 4).

Some typical herbicide regimes applied in non-GMHR and GMHT maize in Romania are presented in Table 4. For these regimes the impact on farm workers, consumers, and ecology was calculated using the EIQ indicator. The "footprint" of the different herbicide regimes used by applying the EI to the quantities of all active ingredient contained, ranging between 23.68 and 59.23, with an average value of 39.37/ha, in case of conventional maize, and between 13.80 and 33.11, with an average value of 27.03, for GM maize weed management (Table 4).

Table 3

Environmental impact of the three main components and EIQ total values of some herbicide used for weed management in maize

Produse	**Active ingredient**	**EItotal**	**EI_f**	**EI_c**	**EI_e**
Merlin Duo	Isoxaflutole	22.5	22.5	8.44	36.56
	Terbuthylazine	1.06	0.66	0.51	2.01
	Total	23.56	23.16	8.95	38.57
Equip**	Foramsulfuron	0.86	0.45	0.39	1.74
Adengo 465 SC	Isoxaflutole +	2.16	2.16	0.81	3.51
	Thiencarbazon-methyl	0.26	0.21	0.14	0.43
	Total	2.42	2.37	0.95	3.94
Gardoprim Plus Gold	S-methaloclor	30.93	16.87	12.65	63.27
	Terbuthylazine	9.28	5.91	4.64	18.15
	Total	40.21	22.78	17.29	81.42
Mistral**	Nicosulfuron	1.17	0.48	0.48	2.55
Principal**	Nicosulfiron	0.74	0.30	0.30	1.62
	Rimsulfuron	0.15	0.08	0.03	0.35
	Total	0.89	0.38	0.33	1.97
Titus Plus**	Rimsulfuron	0.16	0.08	1.49	10.97
	Dicamba	4.90	2.23	0.03	0.36
	Total	6.06	2.31	1.52	11.33
Titus 25DF	Rimsulfuron	0.1188	0.06	0.022	7.38
Roundup*	Glyphosate (4l/ha)	22.08	11.52	4.32	50.4
Lumax 537.5 SE**	S-metholaclor	28.86	15.74	11.80	59.04
	Mesotrione	2.45	2.09	0.92	4.32
	terbuthylazine	4.80	3.06	2.40	9.39
	Total	36.11	20.89	15.12	72.75
Buctril Universal**	Bromoxynil	4.76	3.36	1.68	9.24
	2,4-D (ester)	4.29	2.24	0.84	9.80
	Total	9.05	5.60	2.52	19.04
Buctril	Bromoxynil	4.78	3.37	1.68	9.27
Banvel	Dicamba	7.58	3.46	2.30	16.99
Frontier Forte	Dimethenamide-P	12.09	9.07	4.5	22.73
Cambio	Bentazon	14.94	12.8	7.2	24.80
	Dicamba	5.92	2.7	1.8	13.27
	Total	20.86	15.50	9.00	38.07
Dual Gold	S-metolachlor	30.80	16.80	12.60	63.00
Callisto	Mesotrione	26.88	23.04	10.08	47.52
Casper	Prosulfuron	0.40	0.16	0.16	0.87
	Dicamba	5.27	2.40	1.6	11.8
	Total	5.67	2.56	1.76	12.67

* Preemergence; **postemergence;

Table 4

Quantities of active ingredients and environmental impact of some typical herbicide regimes for conventional and HT maize

Herbicide regimes	**Quqntities of a.i./ha and EI of herbicide regimes**				
	Active ingredient (a.i.) kg/ha	**EI total/ha**	**EI farm worker**	**EI consummer**	**EI ecologic**
Conventinal maize**. Option 1**					
Merlin Duo Titus Plus	**1.087**	**23.68**	**23.22**	**8.97**	**45.95**
Option 2					
Merlin Duo Buctril Universal Equip	**1.647**	**33.47**	**29.21**	**11.86**	**59.35**
Option 3					
Buctril Titus 25 DF Leone	**1.7285**	**26.98**	**14.95**	**6.02**	**67.05**
Option 4					
Buctril Titus Plus Leone	**1.917**	**32.92**	**17.20**	**7.52**	**71.00**
Option 5					
Gardoprim Plus Gold Titus Plus	**2.446**	**47.27**	**25.09**	**18.81**	**92.75**

Table 4 (continued)

Option 6					
Gardoprim Plus Gold Casper **Mistral 4SC**	**1.686**	**48.05**	**25.82**	**30.42**	**96.64**
Option 7					
Gardoprim Plus Gold Mistral Banvel	**2.590**	**48.96**	**26.72**	**20.07**	**100.96**
Option 8					
Roundup Lumax 537.5 SE Principal	**3.368**	**59.23**	**32.8**	**19.78**	**125.12**
Option 9					
Frontier Forte Cambio Principal	**2.080**	**33.84**	**14.95**	**13.83**	**62.77**
Average conventional	2.061	39.37	23.33	15.25	80.17
Herbicide tolerant maize. **Option 1***					
Frontier Plus Roundup 1x3l /ha	**2.088**	**28.64**	**17.71**	**7.74**	**60.53**
Option 2*					
Roundup 2x3 l/ha Roundup 1x2 l; 1x4 l	**2.160**	**33.11**	**17.28**	**6.48**	**75.6**
Option 3**					
Callisto (mesotrione) Roundup 2.5 l/ha	**1.380**	**22.76**	**14.88**	**6.06**	**47.34**
Option 4**					
Roundup 2.5 l/ha Dicamba/diflufenzopyr	**1.100**	**18.54**	**9.37**	**4.1**	**41.92**
Option 5**					
Glyphosate 2.5 l/ha	**0.900**	**13.80**	**7.2**	**2.7**	**31.50**
Option 6**					
Glyphosate 2.5+2.5 l/ha	**1.800**	**27. 60**	**14.4**	**5.4**	**63.00**
Glyphosate 2.0+3.0 l/ha***					
Average HT	1.571	27.03	13.47	5.41	54.06

* Recommended by owner of technology; **[30]; *** used in field trials in Romania

Table 5

Economic and environmental impact of herbicide use in transgenic *versus* conventional maize

Item	Non transgenic	Transgenic resistant herbicide	Difference	Difference, %
Pesticide use (kg a.i/ ha)	2.061	1.571	-490	−23
Pesticide use (kg a.i/ 500 000 ha)	1 030 500	785 500	-245 000	-23.77
Total cost (euro) weed management/ha	125E	15E	-110	- 88
Total cost (euro) weed management/500000 ha	50 000 000	10 000 000	-40 000 000	
Total impact (EIQ/ ha)	39.37	27.03	−12.34	-31.34
Total impact (EI/ 500 000 ha)	196 850	135 150	-61 700	-31.34
Farm worker impact (EI/ ha)	23.33	13.47	-9.86	-42.26
Farm worker impact (EI/500000 ha)	116 650	67 350	49 300	-42.26
Consumer impact(EI/ha)	15.25	5.41	-9.84	-64.5
Consumer impact(EI/500000 ha)	7 625 000	2 705 000	4 920 000	-64.5
Ecology impact (EI/ ha)	80.17	54.06	-26.11	-32.56
Ecology impact (EI/ 500000 ha)	40 085 000	27 030 000	13 055 000	-32.56

* The cost of weed management in the farm where field trial of HT maize was located

EI was medium (more than 45) for 5 herbicide regimes and low for 4 herbicide regimes used on conventional maize cultures (Table 4).

In terms of the EI of HT maize, according to the published results,[30] the glyphosate alone (2.5 l/ha) or in tank mix combination with dicamba/ diflufenzopyr had the lowest EI value while the glyphosate followed by glyphosate or dimethenamid had the highest environment impact. Using HT maize and different herbicide regimes, lower quantities of active ingredients are used than in case of herbicide regimes for conventional maize. The application of pesticide a.i. was lower by 23% in the HT maize. The total EIQ per hectare was lower by 31% (Table 5). The data calculated thus show that the predicted reduction in environmental impact of the pesticides used on GM maize more or less paralleled the reduction in the active amounts of ingredients per hectare.

Regarding subcomponents of EIQ indicator, farm worker impact would be reduced by 42%, consumer impact by 64% and ecological impact by 32% (Table 5). In the same time, 150 millions liter of water used for herbicides spraying, and 1.14 million kg CO_2 emissions as consequence of the fuel savings associated with making fewer spray runs would be saved (relative to conventional maize).

Economic results of growing conventional compared with HT maize evidenced that by utilization of HT technology in field trials a benefit of 40 euro/ha can be obtained, when cost of seeds was higher with 14 euro/ha and the cost of weed management was lower with 110 Euro/ha.Yield was higher with 4% when transgenic maize was used.[28]

Several studies have found no yield differences with various glyphosate weed management programs in glyphosate-tolerant corn (revived by[30]).

Assuming that by applying HT technology the cost of weed management would be reduced whith only 80 euro/ha, and that the conventional maize would be replaced with transgenic maize on a quarter of area allocated every year to this crop, 40 million euro could be saved, herbicide use would be decreased by 245.000 kg a.i. and the associated environmental impact of pesticide use on this crop area would decreased by 31 % (Table 5).

In 2005, the USA National Centre for Food and Agricultural Policy (NCFAP), estimated a benefit of 23.7 $ per hectare, in case of using HTGM maize compared with conventional hybrids and weed management technology. As results, in 2005, farmers who cultivated HT maize on 11.4 millions hectares benefit of 269 milioane USD.[33] Relying largely on the NCFAP studies, a recent report estimates the cumulative farm income benefits of planting HR maize in the USA at $564 million for 1996–2004.[18]

In case of farms with species of weeds difficult to manage (*Phragmites communis*, *Sorghum halepense*, *Cirsium arvense*, *Sonchus* spp., *Solanum nigrum*, *Abutilon teofrasti*, *Xanthium strumarium*), only the use of a total herbicide as glyphosate can keep the field free of weed.[34] In these conditions, we assume that herbicide regimes presented in Table 6 are potentially efficient.

Table 7 provides an overview of the outcomes obtained, in 2010, in field trials with HT maize and with conventional maize. Data collected and results of calculation showed a reduction by 46% of the quantity of herbicide used and by 74% of the associated environmental impact of these pesticides.

Table 6

Quantities of active ingredients and field rate EI of herbicide programmes used on conventional maize culture *versus* transgenic maize cultivated in field trials in Big Island of Brăila

Product name	**Active Ingredient (g/l)**	**Dosage (l, kg/ha)**	**Active Ingredient kg/ha**	**Field Rate EI**	**EI_f**	**EI_c**	**EI_e**
Conventional							
Roundup	glyphosate 0.360	3.0	1.080	16.55	8.64	3.24	32.4
Lumax 537.5 SE	S-metolachlor 0.375	3.5	1.3125	28.87	15.74	11.80	59.04
	mesotrione 0.0375	3.5	0.131	2.45	2.10	0.92	3.93
	terbutilazin 0.125	3.5	0.4375	4.81	3.06	2.41	9.40
Principal	nicosulfuron 42,9%	0.09 kg/ha	0.3861	7.53	3.09	3.09	16.43
	rimsulfuron 10,7%	0.09 kg/ha	0.0096	0.152	0.077	0.03	0.35
Total			3.356	60.36	32.71	21.50	121.55
Transgenic	glyphosate 0.360	5	1.800	27.60	14.40	5.40	54.00

Table 7

Environmental and economic impact of herbicide use in glyphosate tolerant *versus* conventional maize in Big Island of Brăila

Item	**Non transgenic**	**Transgenic, herbicide resistant**	**Difference**	**Difference (%)**
Pesticide use (kg a.i./ ha)	3.356	1.800	-1.556	-46
Weed management cost	419 (100 E)	83 (20 E)	-336	-80
Total impact (EI/ ha)	44.04	27.60	-32.76	-74
Farm worker impact (EI/ ha)	32.71	14.40	-18.31	-56
Consumer impact(EI/ha)	21.50	5.40	-16.10	-76
Ecology impact (EI/ ha)	121.55	54.00	-67.55	-56

Environmental impact of Bt technology

Overall, across Romania, the estimated area that is economically damaged annually by corn boring pests ranges between 0.5 million ha and 0.9 million ha. The regions most prone to ECB damage are in the West, North West, and South (Danube river provinces).[35]

In spite of this, in Romania, only limited use of insecticides has traditionally been made, with 10,000 ha to 33,000 ha receiving sprays in years of high infestation only.[35]

Insecticide treatments are used mostly by farmers in high infestation years and regions at the rate of one or two insecticide treatments per season.

Quantities of a.i./ha and field rate EIQ for conventional and Bt maize cultures in Big Island from Brăila [34] are presented in Table 8.

If Bt technology would be applied on 0.5 million hectares, the estimated area that annually suffers from economic levels of damage from corn boring pests, a reduction in the amount of insecticide active ingredients applied to maize crops of 13.750 kgs and a saving of 620.000 EIQ/0.5 million load units (Table 9) would result. In the same time, the exposure to insecticides for farmers and farm workers would be reduced.

In addition, Bt hybrids cultivation on 0.5 millions hectares would be a benefit for consumers, because there is a direct correlation between the level of corn borer attack and mycotoxin content of the grains.[36] Our results, obtained in 2008 and 2009, with the samples of conventional and Bt maize collected from 6 and 12 farms, respectively, concluded that the use of Bt maize cultivars improved food safety by greatly reducing mycotoxin levels in maize kernels.[37]

In 2008 and 2009, in Romania, the impact of the adoption of Bt maize, at farm level, has been[11]:

- higher average yield benefits with + 9,8%, in 2008, and with +15%, in 2009;
- additional income between €20 and €138/ha, in 2008, and between €37 and €251/ha, in 2009;
- improved profitability of 9% to 263%, in 2008 and of 11% to 418% in 2009.

In 2007, average yield impact was +7.1%, and net increase in gross margin +25.40 €/ha.[38]

Table 8

Field Rate EIQ for Bt and conventional maize production

Technology	Active Ingredient (g/l)	Rate (l/ha)	Active Ingredient kg/ha	Field Rate EIQ
Conventional maize				
Lamdex 5EC	lambda cihalotrin 50g/l	0.15 l	0.0075	0.354
Seizer 10 EC	bifenthrin 100g/l	0.2	0.020	0.887
Total		0.351	0.0275	1.241
Bt maize	–		00	00
Total			00	00

Table 9

Environmental impact of pesticide use in Bt *versus* conventional maize in Romania

Item	Non transgenic	Transgenic Bt	Difference	Difference, %
Pesticide use (kg a.i./ ha)	0.0275	0	-0.0275	-100
Pesticide use (kg a.i./0.5 million ha ha)	13 750	-	-13 750	-100
Insecticide cost/ha	83	0	-83	-100
Insecticide cost//0.5 million ha)	41 500 000	0	+ 41 500 000	
Total impact (EIQ/ ha)	1.241	0	-1.241	
Total impact (EI/ 0.5 million ha)	620 500	0	-620 500	
Farm worker impact (EI/ ha)	0.570	0	-0.570	
Farm worker impact (EI/ 0.5 million ha)	285.000	0	-285 000	
Consumer impact (EI/ha)	0.200	0	-0.200	
Consumer impact (EI/ 0.5 million ha	100 000	0	-100 000	
Ecology impact (EI/ ha)	2.950	0	-2.950	
Ecology impact (EI / 0.5 million ha)	1 475 000	0	- 1 475 000	

* Data from SC Trei Brazi

The overall results of this study therefore indicate that positive benefits can be achieved through the use of GM maize HT and insect resistance. Furthermore, in the near future, crops with other agronomic traits may be introduced that are likely to have a large impact on agrochemical use as well.[3] Both from a scientific and from a policy-based point of view, it would be useful to keep track of the ongoing developments and to estimate the associated impact on the environment.

Data available up to 2012 provided no scientific evidence that the commercial cultivation of transgenic crops has caused any impacts beyond those caused by conventional agricultural management practices.[38] A truly precautionary policy towards approval of transgenic varieties should compare the risk of adoption against the risk of non-adoption.[39].

CONCLUSIONS

The adoption of insect- and herbicide-tolerant maize varieties on 500.000 hectares, both the quantity of pesticides used and environmental impact of these ingredients would be considerable reduced. The use of such biotechnological innovation should lead to reductions in pesticide use with 13.750 kg of insecticides and 245.000 kg a.i. herbicide. The impact on the environment would be reduced with almoust 1.5 millions load units. The use of HR maize only would reduced cumulative environmental impact with almost 30%.

Furthermore, the cost saving for weed and pest management would be about €41 millions, annualy, when compared with conventional systems. The emission of 3420000 kg of carbon dioxid in the environment and use of 900000 liters of water would be avoided.

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