D02.14
Report on Environmental and Socio-Economic Analysis (WP 2 Task 3)

Diabr-Act -Harmonise the strategies for fighting Diabrotica virgifera virgifera

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Document Abstract

The potential damage costs assessment indicates substantial economic benefits can be gained by controlling *Dvv.* The economic benefits of the Wageningen workshop scenario are about 472 million Euro per year. The economic benefits of control justify eradication and containment strategies of the EU. The environmental and socio-economic analysis of Diabrotica control programs undertaken in this report gives a global idea of what are the benefits and the inconvenient of each possible control strategy (chemical, biological, transgenic) in terms of economic, environmental and health impacts for the different stakeholders involved in such management program.

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Short description

This report reviews the environmental and socio-economic impacts of controlling *Diabrotica virgifera virgifera* LeConte (Dvv.) spreading in Europe. The potential costs of no control are used as counter factual. The results indicate enormous economic benefits can be gained by controlling further spread of the pest. They economic benefits of control range between 143 million Euro in the best case scenario and 2071 million Euro in the worst case scenario. The most likely scenario results I average annula economic benefits of 472 million Euro.

The environmental impacts of the main control strategies such as chemical treatments, transgenic and biological control have been studied with particular focus on the environmental risks of biological control techniques. In addition, the report contains the analysis of the economic, environmental and health implications for the main stakeholders (farmers, industries, consumers, and public authority) of the possible control management programs.

1. Introduction

The design of optimal strategy to control the spread of invasive specie involves both the biological, environmental and economic dimensions. All dimensions have to be considered for the assessment of possible management strategies. The biological and environmental dimension can be included in the economic dimension by pricing pest damages and the environmental impact of management strategies. The overall economic benefits and costs of management strategies will differ depending on the stakeholders and the control strategy considered. Environmental impacts can be either positive or negative and can change the ranking of pest management strategies according to the economic net-benefits.

The assessment of pest damages does play an important role in the economic assessment of pest management strategies. The assessment does provide information about the expected economic benefits of pest management and can be compared with the economic costs of different strategies.

For the case of Dvv. control four main control methods to manage the spreading have been compared at farm level: chemical control, use of Dvv. resistant maize varieties, biological control and cultural control mechanisms (crop rotation) (Fall and Wesseler, 2006, D0202). The farm level assessment does not consider the administrative costs, including the monitoring costs of Dvv. management programmes, environmental implications and the economy wide affects. This is part of the socio-economic assessment presented in this report.

Assessing the environmental impacts of the different control techniques provides a general picture of the environmental impacts implied by each management program. Among the four main control techniques the environmental impacts of chemical treatments are now well-known (Rozen and Ester, 2007, D0102) and global consensus exists on the environmental and human health effects of pesticide use. Dvv. resistant transgenic maize varieties have been applied in the USA since 2003 and an environmental risk assessment has been done showing the environmental risk posed by YieldGard® Rootworm maize is not greater than the environmental risk posed by conventional maize varieties (Ward et al., 2005).

Environmental impact studies about using biological control agents against Dvv. are missing. This is due to the fact that biological products for Dvv. are not yet commercially available. However, a large literature does exist on the environmental impacts of biological control in general. A review of this literature provides information about the extent of environmental impacts of biological control mechanisms for Dvv.

In the context of this report, a special part will be devoted to the analysis of environmental impacts of biological and transgenic control programs. Their main effects for the different stakeholders identified will be analyzed within the socio-economic impacts of these control strategies.

First, the baseline case scenario assessing the damage costs of "no-control" will be presented in section 2. The baseline scenario will be compared with a "control action scenario" in section 3. In section 4 the marginal benefits and costs of different control strategies will be discussed according to the different stakeholders affected, namely farmers, industries, consumers, and public authorities.

2. Economic impacts of controlling *Diabrotica v. virgifera*

The assessment of the economic impacts of the spreading of Dvv. is one of the key instruments of the socio-economic analysis as it provides the basis for the need of actions to control the spreading of Dvv. The main objective is to calculate the economic costs of leaving Dvv. spreads at his natural rate without any control mechanism. The measurement of the damage for maize growers if there are no actions implemented implies the adoption of a set of assumptions on the areas susceptible to be infested and on the yield losses. First we present the assumptions for the baseline scenario and than results for a set of alternative scenarios in the form of a sensitivity analysis.

2.1 Economic impacts of "no control" scenarios

2.1.1 Maize area susceptible to be infested

The area of maize susceptible to be infested by Dvv. depends on climatic conditions, the density of maize in the area and on the spreading rate of the pest over time and space. Baufeld (2003) analyzed the rate of spread of Dvv. in Europe and assumes the rate of spread to range from 60 to 100 km/year if there are no containment measures. Macleod et al. (2004) assume the same range for the maximum and the minimum rates and a typical rate at 80km/year for the purpose of their analysis. Experts at the Wageningen workshop on Dvv. (2007) agreed on a consensus for modeling Dvv. spreading at a rate of 20 km/year in areas where the proportion of maize is less than 50% and 60 km/year in areas where the proportion of maize is higher than 50%. For simplifying the analysis we only consider the area allocated for continuous maize as susceptible for infestation. Further, for calculating the additional damage costs only areas not yet infested will be considered.

2.1.2 Damage function

A consensus exists on the fact that there is a time lag of approximately five years between the first finding of Dvv and reports of severe economic damage in an infested zone. We assume maximum economic damage will be reached five years after first infestation with Dvv. The increase in damage over the first five years is assumed to be linear (see also Macleod et al., 2004).

2.1.3 Yield losses

From the literature there are large disparities on yield losses reported by scientists. Chiang et al. (1980) reported yield losses ranging from 2 to 50% in artificially infested field plots of maize with Dvv. eggs at the time of sowing. Other reports of yield losses are in the range of 10-40% or in extreme cases even 90% (McBride, 1972; Spike & Tollefson, 1991). Apple *et al*, (1977) and Petty *et al*, (1968) found yield losses of 10% to 13% whilst Calvin *et al.* (2001) estimated yield losses for untreated fields in the north-eastern part of the USA to be 6.5 %. We assume maximum yield losses of 10% to 30% in line with European studies (Schaafsma et al., 1999; Baufeld and Enzian, 2005; Macleod et al., 2004).

2.1.4 Economic losses

The annual yield losses are valued by the average price for grain maize and green maize. We discount the annual yield losses using a discount rate of 5% and present the average annual damage costs by multiplying the damage costs in present value with the capital recovery factor for an infinite number of years, which is equivalent to the discount rate in decimal form. We assume that prices and quantities of inputs and factors do not change. Furthermore, to keep the model simple, we assume for each scenario producers face a perfectly elastic demand curve.

2.1.5 Data and Results

Eighteen countries over the EU-27 country members have been considered for the analysis. They include the EU member states Austria, Belgium, Bulgaria, Czech Republic, France, Greece, Germany, Hungary, Italy, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and the United Kingdom and Croatia and Switzerland. The potential area susceptible for infestation depends among others on the climatic conditions. The southern part of Italy, e.g., is not susceptible to the pest because of the warm climate. The same applies for Greece, Spain, and Portugal, while Scotland as part of the United Kingdom will be to cold. The susceptible continuous maize area has been adjusted accordingly as reported in table 1.

Data about the percentage of continuous maize area an the total area allocated to maize have been collected from experts at the Wageningen workshop, except for Germany, Italy, Austria and Belgium for which we apply percentages from Baufeld and Enzian (2005). For Portugal, Greece and Spain, we do not have data on the proportion of continuous growing maize area. We apply for these countries the average proportion of continuous growing maize area in our panel of countries. Also Hungarian proportion of continuous maize area has been applied for Romania and Bulgaria. Price, yield and area data have been collected from EUROSTAT for the year 2005.

Area Susceptible for Infestation

Table 1 provides information about the country size and area susceptible for Dvv. infestation. The countries considered do have a total size of about 3.26 million sqkm. Some areas are not susceptible. This reduces the total area susceptible to Dvv. to about 2.82 million sqkm. Some areas are already infested with Dvv. This is about 265 thousand sqkm or 9.5% of the area susceptible to Dvv. The total area not yet infested but considered a potential area for infestation is about 2.55 million sqkm or about 78% of the total area or about 91% of the susceptible area. This is the area we have used for calculating the additional damage costs for the “no control” scenario.

The Speed of Spread

An important factor driving the damage costs of Dvv. infestation is the speed of spread of the pest. Depending on the average annual speed the infested area will differ substantially. The annually infested area per country has been calculated according to the following equation:

$$IA_{t,i} = \begin{cases} \upsilon \cdot \pi^2 \cdot t & if \quad IA_{t,i} < CAS_i \\ CAS_i & if \quad IA_{t,i} \geq CAS_i \end{cases} \tag{1}$$

and $i = 1,...,n.$

IA is the infested area per year in sqkm, υ is the speed of spread in km per year, π the mathematical constant, *t* the number of years, CAS the country area susceptible to Dvv., *i* is the country indicator and *n* the number of countries considered. The total area infested has been calculated according to equation 2:

$$TIA_t^A = \sum_{i=1}^{i=n} IA_{t,i} \ , \tag{2}$$

with TIA_t^A as the total infested area in sqkm.

Table 1: Country Area Susceptible to Dvv. Infestation and Country Area not yet Infested in Europe

Country	Country Area	Country Area Susceptible		Country Area not yet Infested	
	sqkm	sqkm	(%)	sqkm	(%)[1]
Austria	83870	83870	100	83870	100
Belgium	30528	30528	100	30528	100
Bulgaria	110910	110910	100	110910	100
Czech Rep.	78866	78866	100	39433	50
France	547030	547030	100	547030	100
Germany	357021	357021	100	357021	100
Greece	131990	65995	50	65995	100
Hungary	93030	93030	100	0	0
Italy	301318	225989	75	225989	75
Luxemburg	2586	2586	100	2586	100
Netherlands	41526	41526	100	41526	100
Poland	312679	312679	100	312679	100
Portugal	92391	46196	50	46196	50
Romania	237500	237500	100	237500	100

Slovakia	48845	48845	100	48845	100
Slovenia	20273	20273	100	0	0
Spain	504782	252391	50	252391	50
United King.[2]	166030	166030	100	166030	100
Croatia	56542	56542	100	0	0
Switzerland	41285	41285	100	41285	100
Total	3259002	2819091	86.50	2554123	78.37

Notes: [1] in percentage of total country area; [2] excluding Scotland.

Source: own calculation based on EUROSTAT (2007).

Calculating the annual infested area according to equation 1 assumes that Dvv. enters each country at the same point in time at its geographical center and spreads in form of a circle and no control methods will be applied. This is similar to the introduction of the pest via airports as frequently reported. The results by country do underestimate the speed of spread for larger countries such as France or Germany as encroachment from neighboring countries is not considered. The same applies for the calculation of the speed of spread for the total area.

The results in table 2 indicate that smaller countries can be infested within a short period of time such as Slovenia, Slovakia, and Switzerland. Using the country specific data to calculate the numbers of years till total infestation results in the number of years presented in row Total A.

If we consider that the spread of Dvv. will not stop at national boundaries and sum-up the area infested over all countries:

$$TIA_t^B = \begin{cases} n\left(\upsilon \cdot \pi^2 \cdot t\right) & \text{if} \quad n\left(\upsilon \cdot \pi^2 \cdot t\right) < CAS \\ CAS & \text{if} \quad n\left(\upsilon \cdot \pi^2 \cdot t\right) \geq CAS \end{cases} \tag{3}$$

provides the results in the last row of table 2 (Total B).

Figure 1 shows the link between the number of years till total infestation and the speed of spread. The results show that a reduction of the speed of spread at initial low speed can reduce the number of years until total infestation considerably, whereas in the case of an initially high speed of spread the same absolute reduction does have a much less pronounced effect. Reducing the speed of spread by 20 km per year from 100 km to 80 km per year reduces the time till total infestation by about one year whereas a reduction from 40 km to 20 km per year reduces the time till total infestation by about ten years. If we consider that national borders are not a barrier to spread of Dvv. in the "no control" case the number of years until the total area of 2.82 million sqkm is infested decreases as shown in figure 1.

Please note the years reported for TIA_t^B are based only on countries and country areas not yet infested (2.55 million sqkm). We have used equation 3 for calculating the different scenarios as this simplifies the computations significantly. The reader may expect an overestimation of the damages costs, but the use of average numbers reduces the total damage costs as big countries with relative high maize revenues such as France, Germany and Italy do get less weight (see also country specific results presented in table 6).

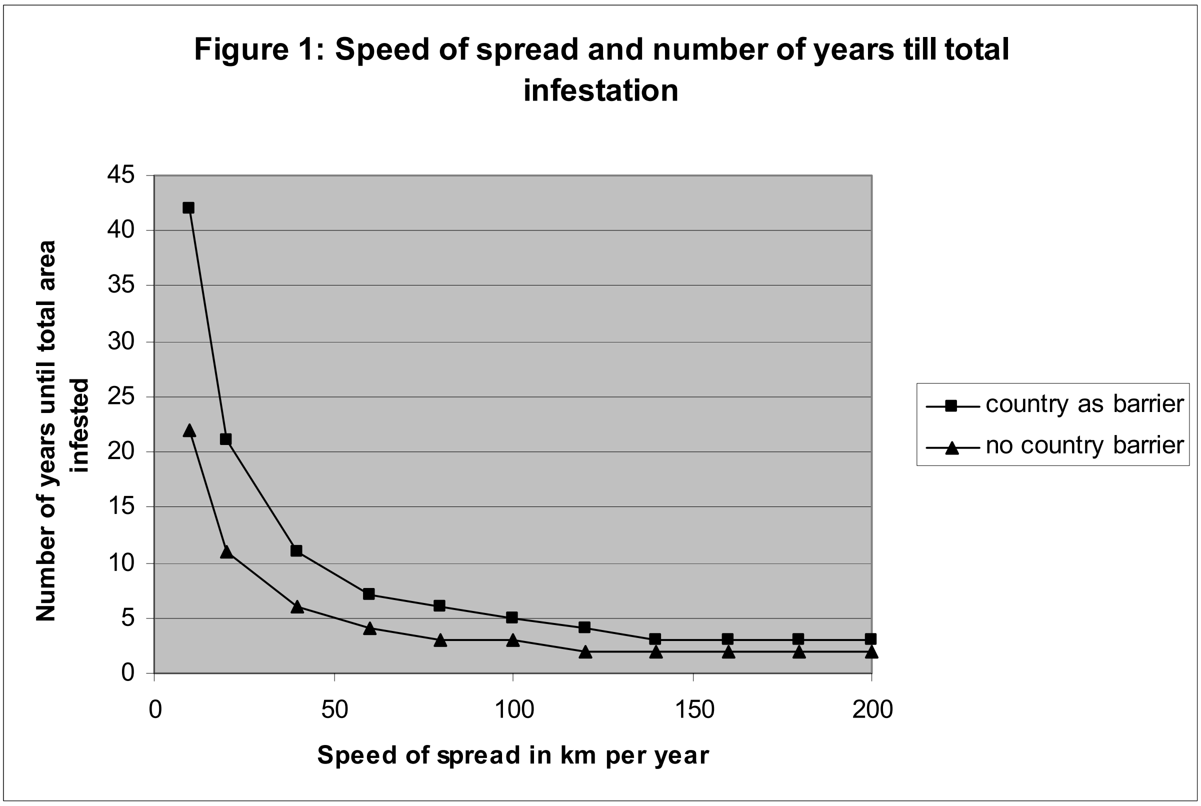
Table 2: Number of Years Until Country Area is Infested for Different Annual Speeds of Spread.

Country	Country Area Susceptible	Number of Years Till Total Infestation										
	sqkm	Annual Speed of Spread in km per Year										
		10	20	40	60	80	10(	12(	14(	16(	18(	20(
Austria	83870	17	9	5	3	3	2	2	2	2	1	1
Belgium	30528	10	5	3	2	2	1	1	1	1	1	1
Bulgaria	110910	18	10	5	4	3	2	2	2	2	2	1
Czech Rep.	78866	16	8	4	3	2	2	2	2	1	1	1
France	547030	42	21	11	7	6	5	4	3	3	3	3
Germany	357021	34	17	9	6	5	4	3	3	3	2	2
Greece	65995	15	8	4	3	2	2	2	2	1	1	1
Hungary	93030	18	9	5	3	3	2	2	2	2	1	1
Italy	225989	27	14	7	5	4	3	3	2	2	2	2
Luxemburg	2586	3	2	1	1	1	1	1	1	1	1	1
Netherlands	41526	12	6	3	2	2	2	1	1	1	1	1
Poland	312679	32	15	8	6	4	4	3	3	2	2	2
Portugal	46196	13	7	4	3	2	2	2	1	1	1	1
Romania	237500	28	14	7	5	4	3	3	2	2	2	2
Slovakia	48845	13	7	4	3	2	2	2	1	1	1	1
Slovenia	20273	9	5	3	2	2	1	1	1	1	1	1
Spain	252391	29	15	8	5	4	3	3	1	2	2	2
United King.[1]	166030	23	12	6	4	3	3	2	2	2	2	2
Croatia	56542	14	7	4	3	2	2	2	1	1	1	1

Switzerland	41285	12	6	3	2	2	2	1	1	1	1	1
Total A	2819091	42	21	11	7	6	5	4	3	3	3	3
Total B	2554123	22	11	6	4	3	3	2	2	2	2	2

Notes: [1]excluding Scotland.

Source: own calculation based on EUROSTAT (2007).



The Maize Area Damaged and Damage Costs

Table 3 presents the area allocated by country to green and grain maize and the area allocated to continuous maize. The area allocated to continuous maize indicates the amount of hectares that can be damaged per year. In table 3 also the yield per hectare and the price per ton of green and grain maize are reported. The average revenue per ha is about 756€/ha for grain maize and about 1204€/ha for green maize and about 939€/ha on average for maize. The results show prices and yields do differ considerably between countries. This indicates the economic importance of the pest on per hectare level will differ by country and damage costs will be regional specific. The revenue per ha ranges between 336€/ha for green maize in Bulgaria to up to 2303€/ha for green maize in Belgium.

The information about the continuous maize area and the average revenue for maize in combination with the speed of spread and the relative damage can be used to calculate the potential damage costs. A number of scenarios have been specified for the calculation of the damage costs. Three damage levels have been considered, 10%, 20%, and 30%. Three different revenue levels have been considered: the average revenue of 939€/ha, the mid-range revenue of 1443€/ha and the upper-quartile range value of 1997€. Two different levels of continuous maize area have been considered: the average level of 1.26% of continuous maize on total land (Table 3) and a higher level of 1.50%.

The revenue values have been used to consider the sharp rise in maize prices over the last two years. An increase in the area allocated to maize has been considered to analyze implications of an increase in continuous maize as the result of on increase in maize as a source for bioenergy.

The damage costs in present value, PVD, for each scenario have been calculated according to equation 3:

$$PVD = \sum_{t=1}^{\infty} TIA_t^B \cdot R \cdot D_t \cdot q^{-t} \ , \tag{4}$$

with R as the annual revenue in €/ha, q^{-t} the discount factor, and D_t the annual percentage loss in revenue R. The annual values for D_t have been calculated according to equation 4:

$$D_t = \begin{cases} D & if \quad t \geq 5 \\ D \cdot \dfrac{t}{5} & if \ t < 5 \end{cases} , \tag{5}$$

with D as the total damage in percentage in decimal form.

The average annual damage, AAD, has been calculated by multiplying the damage costs in present value by the 5% discount rate in decimal form (the capital recovery factor for converting a present value into an infinite annuity):

$$AAD = PVD \cdot i \ . \tag{6}$$

Table 4 illustrates the calculations for the scenario of 1.26% continuous maize, maize revenue of 1443€/ha and 20% damage and speed of spread of 40km per year. Table 5 lists the different scenarios computed and the results and figure 2 visualizes them.

Table 3: Maize area, yield and prices for selected EU countries in 2005

Country	Maize type	Maize growing area	% of continuou area	% continuous maize on total land	Yield	Maize price	Maize revenue
		ha	%	%	t/ha	€/tonne	€/ha
Austria	Grain maize	167226	21.10	0.42	10.31	89.27	921
	Green maize	76987	21.10	0.19	46.76	25.3	1186
Belgium	Grain maize	54256	31.70	0.56	11.69	105.45	1232
	Green maize	163825	31.70	1.70	47.28	48.7	2303
Bulgaria	Grain maize	298712	35.00	0.94	5.31	81.59	433
	Green maize	32211	35.00	0.10	12.61	26.6	336
Czech Rep.	Grain maize	98044	10.90	0.14	7.17	97.11	696
	Green maize	192501	10.90	0.27	35.69	17.8	635
France	Grain maize	1654506	22.80	0.69	8.37	106.24	889
	Green maize	1387564	22.80	0.58	38.82	48.2	1874
Germany	Grain maize	443100	22.30	0.28	9.21	103.80	956
	Green maize	1262500	22.30	0.79	45.53	21.2	968
Greece	Grain maize	241000	29.00	0.53	9.00	100.36	903
	Green maize	7500	29.00	0.02	50.00	27.0	1353
Hungary	Grain maize	1197547	35.00	4.51	7.56	89.98	680
	Green maize	92955	35.00	0.35	30.59	19.3	592
Italy	Grain maize	1119466	43.4	1.61	9.39	106.24	997
	Green maize	271309	43.40	0.39	52.83	48.2	2551
Luxemburg	Grain maize	200	29.00	0.02	7.55	95.09	718
	Green maize	11600	29.00	1.30	36.76	29.1	1070
Netherlands	Grain maize	20748	70.00	0.35	12.20	105.45	1287
	Green maize	235088	70.00	3.96	45.00	48.6	2191
Poland	Grain maize	339342	23.00	0.25	5.73	85.34	489
	Green maize	325674	23.00	0.24	39.12	12.1	477
Portugal	Grain maize	110192	29.00	0.35	4.63	100.36	465
	Green maize	105859	29.00	0.33	44.15	30.7	1357
Romania	Grain maize	2591646	35.00	3.82	4.01	102.18	410
	Green maize	24385	35.00	0.04	21.35	41.4	885
Slovakia	Grain maize	152531	11.00	0.34	7.04	91.08	641

	Green maize	88781	11.00	0.20	26.17	28.4	744
Slovenia	Grain maize	42369	30.00	0.63	8.29	116.42	965
	Green maize	31525	30.00	0.47	46.72	19.7	922
Spain	Grain maize	471300	29.00	0.27	9.87	100.36	991
	Green maize	88400	29.00	0.05	44.16	23.0	1020
United King.	Grain maize			not applicable			
	Green maize	130937	20.00	0.16	40.00	36.9	1478
Croatia	Grain maize	319000	20.00	1.13	6.92	99.75	690
	Green maize	18530	20.00	0.07	31.72	29.3	930
Switzerland[1]	Grain maize	18000	29.00	0.13	7.55	95.09	718
	Green maize	41900	29.00	0.29	36.76	29.1	1070
Total	Grain maize	491726	30.89	0.89	7.99	98.48	756[2]
	Green maize	241405	26.58	0.37	40.63	32.1	1204[2]
	All maize	733132	29.47	1.26			939[2]

Note: [1]The data for Switzerland refer to the year 2006. [2]area weighted average revenue. Data sources: EUROSTAT, 2007; Baufeld and Enzian, 2005; Wageningen workshop, 2007.

Table 4: Average annual damage of Dvv spreading in the EU assuming a speed of spread of 40km per year, yield damage of 20%, maize revenue of 1443€/ha and continuous maize area of 1.26% on total land area

Year	Area	Continuous maize area infested	Additional maize area infested	Annual incremental damage costs per additional maize area infested in million €						Value of yield loss[1]	Discount factor	Present value of yield loss
	sqkm	sqkm	sqkm	additional maize area in sqkm						Mio. €		Mio. €
				1076	3229	5382	7535	9688	5263			
1	85,451	1076	1076	6.21						6.21	0.952381	5.92
2	341,805	4306	3229	12.43	18.64					31.07	0.907029	28.18
3	769,062	9688	5382	18.64	37.29	31.07				87.00	0.863838	75.16
4	1,367,221	17223	7535	24.86	55.93	62.15	43.50			186.44	0.822702	153.38
5	2,136,283	26910	9688	31.07	74.58	93.22	87.00	55.93		341.80	0.783526	267.81
6	2,554,123	32174	5263	31.07	93.22	124.29	130.51	111.86	30.39	521.34	0.746215	389.03
7	2,554,123	32174	0	31.07	93.22	155.37	174.01	167.79	60.78	682.24	0.710681	484.85
8	2,554,123	32174	0	31.07	93.22	155.37	217.51	223.73	91.16	812.06	0.676839	549.63
9	2,554,123	32174	0	31.07	93.22	155.37	217.51	279.66	121.55	898.38	0.644609	579.10
10	2,554,123	32174	0	31.07	93.22	155.37	217.51	279.66	151.94	928.77	0.613913	570.18
11… ∞	2,554,123	32174	0	31.07	93.22	155.37	217.51	279.66	151.94	928.77		11403.67[2]
Total												14506.94

Note: [1]differences possible due to rounding; [2]discounted sum year 11 till infinity in present value. Source: own calculations based on table 3.

Table 5: Average annual damage costs in million Euro per year for different scenarios.

Scenario	Maize area on total land	Maize revenue	Damage	Average annual damage costs in € for different speeds of spread (km per year)										
	%	€/ha	%	10	20	40	60	80	100	120	140	160	180	200
1	1.26	939	10	143	199	236	250	257	262	265	267	268	270	272
2	1.26	939	20	286	398	**472**	500	515	524	531	534	537	541	545
3	1.26	939	30	428	596	707	750	772	786	796	800	805	811	817
4	1.26	1443	10	220	306	363	384	396	403	408	410	413	416	419
5	1.26	1443	20	439	612	725	769	792	806	816	821	826	831	838
6	1.26	1443	30	659	917	1088	1153	1188	1210	1224	1231	1239	1247	1257
7	1.26	1997	10	304	423	502	532	548	558	565	568	571	575	580
8	1.26	1997	20	608	846	1004	1064	1096	1116	1129	1136	1143	1150	1159
9	1.26	1997	30	912	1269	1505	1595	1643	1674	1694	1703	1714	1726	1739
10	1.50	939	10	170	237	281	298	307	312	316	318	320	322	324
11	1.50	939	20	340	473	562	595	613	624	632	635	639	644	649
12	1.50	939	30	510	710	842	893	920	937	948	953	959	966	973
13	1.50	1443	10	261	364	432	458	471	480	486	489	492	495	499
14	1.50	1443	20	523	728	864	915	943	960	972	977	983	990	998
15	1.50	1443	30	784	1092	1296	1373	1414	1440	1458	1466	1475	1485	1497
16	1.50	1997	10	362	504	598	633	652	664	672	676	680	685	690
17	1.50	1997	20	724	1008	1195	1267	1305	1329	1345	1352	1360	1370	1380
18	1.50	1997	30	1085	1511	1793	1900	1957	1993	2017	2028	2041	2055	2071

Note: The bold number indicates the Wageningen workshop consensus and the scenario used for country level calculations.

Source: own calculations based on table 3.

Figure 2: Average annual damage costs of future Dvv. infestation in Europe in million Euro per year

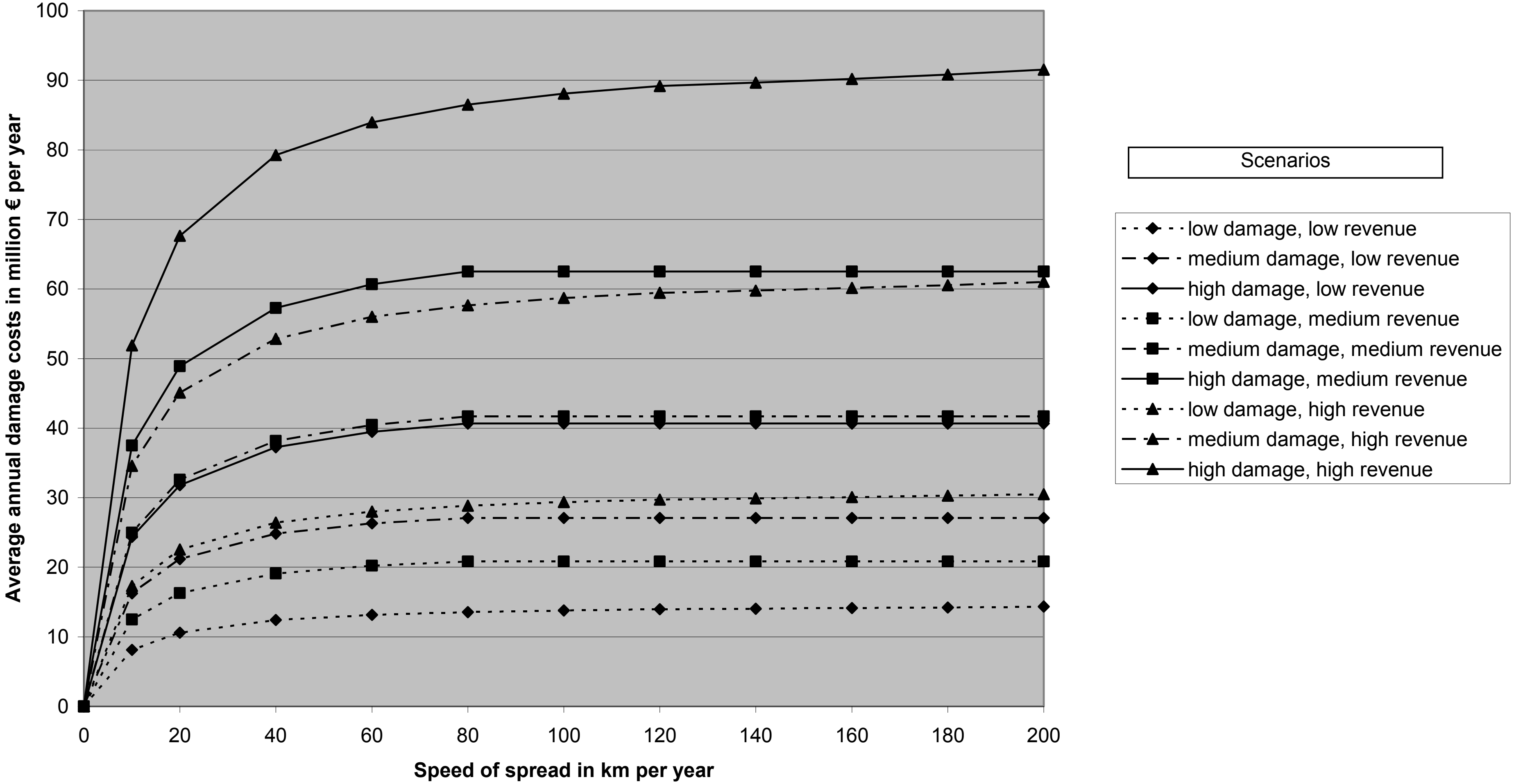


Table 6: Average annual damage costs on country level data assuming 40km speed of spread and 20% yield loss.

Country	Average Maize Revenue	Continuous maize		Average annual damage costs
	€/ha	sqkm	(%)	Million €
Austria	1004	51526	0.61	8.46
Belgium	2036	69138	2.26	24.18
Bulgaria	424	115815	1.04	7.86
Czech Rep.	656	31665	0.40	3.66
France	1337	693690	1.27	124.00
Germany	965	380349	1.07	52.21
Greece	917	72065	0.55	5.47
Hungary	674	451675	4.86	55.32
Italy	1300	603607	2.00	88.45
Luxemburg	1064	3422	1.32	0.66
Netherlands	2118	179060	4.31	64.46
Poland	483	152950	0.49	11.09
Portugal	902	62669	0.68	4.78
Romania	414	915600	3.86	56.69
Slovakia	679	26543	0.54	3.20
Slovenia	947	22170	1.09	3.82
Spain	995	162313	0.32	12.00
United King.[2]	1478	26180	0.16	5.99
Croatia	703	67500	1.19	8.63
Switzerland	965	17371	0.42	2.85

Note: the area infested with Dvv. has been considered as well, assuming additional 20% yield loss. Source: own calculation based on EUROSTAT (2007).

The results presented in table 5 and figure 2 show damage costs will be substantial. Even at the best case scenario we calculate annual average damage costs of about 143 million Euro per year. In the worst case the average annual costs are about 2071 million Euro per year. Both results, the worst and best case are not very likely. Assuming a mid-range maize revenue, medium relative damage of about 20% and a current continuous maize area of about 1.26% on total land area results in average annual damage costs of 1004 million Euro. Scenario 2 with 40km spread per year and average annual costs of

147 million Euro presents the Wageningen workshop scenario and can be seen as the most-likely scenario based on expert assessment.

We must straightforward notice that our results are in line with the potential level of damage estimated by Baufeld and Enzian (2005). They calculated a pecuniary yield loss of 147 million Euro for a group of eight countries (Austria, Belgium, France, Germany, Italy, Luxemburg, The Netherlands and Switzerland) for one year assuming a damage level of 10%. The countries the authors consider account for about 50% of the area considered. If we take the results presented for the first scenario in table 5 (10% damage), we observe all values taken at 50 per cent are below the value calculated by Baufeld and Enzian while most of the values of scenario 4 (10% damage) at 50 per cent are above their damage costs but not considerably.

The results by country as presented in table 6 do indicated substantial differences between countries. By and large the damage costs in Eastern European countries are relatively small, which can be explained by low maize revenues as discussed earlier. While the damage costs for some countries such as Luxemburg appear to be small, we also have to consider that control of Dvv. has a positive impact on neighbouring countries such as France or Germany.

2.2 Economic impacts of "controlling Dvv spreading" scenarios

The main benefits from controlling the spread of Dvv is delaying the time of infestation. A successful eradication programme may even be able to stop further infestation. EU member states do invest considerable amounts of money to monitor and control the movement of Dvv. From the implementing agencies point of view it is important to know whether or not the amount of taxpayer's money being spent for controlling Dvv is worth the effort. The results presented in tables 5 and 6 provide some information for answering such kind of question.

The total benefit of a successful control programme that stops damages from Dvv can be justified if the costs are below total damages of about 472 million Euro per year as under scenario 2 and a speed of spread of 40km per year. A Dvv. control programme should not cost on average per year more than this. The numbers by country do differ significantly. By and large France can expect the highest benefits from a successful control programme of about 124 million Euro per year as reported in table 6.

The numbers presented do include Belgium, The Netherlands and the United Kingdom. If Dvv. will be as damaging as presented is questionable because of the climatic conditions. The average annual costs do decrease by only about 7% if those countries are excluded and does not have important implications for our conclusions.

Dvv. populations are already established in some of the countries listed such as Croatia, Czech Republic, Hungary, Slovenia, and Slovakia and present in Poland and Romania. The numbers presented do provide some indications for the value of eradication programmes within the countries. Take, e.g., the case of Hungary which can be considered being infested by 100%. A successful eradication programme should not cost more than about 55 million Euro per year as reported in table 6.

In the long run total eradication and stopping the spread of Dvv. might not be an option. Under those circumstances reducing the spread of Dvv. becomes an important alternative. Monitoring and eradicating populations immediately delays the pest damages. Again, the average annual damage costs inform us about the benefits of delaying the spread of the pest by one year. The magnitude is about 256 million Euro for scenario 2 and a speed of spread of 40km per year. As long as the annual monitoring, eradication and containment strategies in Europe do not cost more than 256 million Euro per year the economic benefits do outweigh the economic costs of those.

If we only take the countries where the pest is not present but considered to be of economic importance together, such as Austria, France, Germany, and Italy, monitoring and eradication of Dvv. can be justified if this will not costs more than about 110 million € a year for the same scenario.

Interestingly, controlling Dvv. in countries such as Belgium and The Netherlands where the damage might be much lower than calculated and therefore monitoring and eradication not economically at the country level, can provide economic benefits to neighboring countries such as France and Germany by reducing or even stopping the movement of the pest.

The numbers presented for the “no control” do provide benchmark values for monitoring and control. In the following the costs of monitoring and different control options will be analyzed and compared with the potential damage costs. Also, the implications of Dvv. monitoring and control for different stakeholders and the environmental benefits and costs of different control options will be discussed.

3. Monitoring and control costs

3.1 Monitoring and other government costs

Controlling Dvv spreading implies several costs for the public authority. These costs have to be considered in the assessment of the economic impacts of Dvv spreading. They are mainly monitoring and government costs.

The monitoring costs vary with the level of infestation, the size of the area, the trap density, the number of inspections and the characteristics of the monitoring tools. The actual monitoring costs considered in most of the studies on the costs of controlling Dvv spreading (Netherlands, Italy, France) are in general:

- tool costs
- Inspection costs: personnel cost and travel cost

The cost of the material (traps) is the less part of the total cost varying from 3% to 10% (high density) (Furlan, 2007, Wageningen workshop).

In Italy, the trapping system cost varies between 30-50 €/trap (PAL trap) in uninfested region. For high density trapping system for eradication program the cost is between20 and 40 €/trap (PAL). In Austria border area, the costs are 200 €/trap (long distances between traps).

The government costs are the costs of surveillance and administration of a campaign to control Dvv spreading. In the Veneto Region in Italy, the government costs are estimated at 545 000 €. In addition, costs for coordination, monitoring (materials and one researcher), and trials paid by the Department of Agronomy, Padova University over 1999 - 2003 period: € 155 000 covered for 75% by EU funds of Diabrotica project. The total cost of eradication procedure over 1999-2003 is evaluated at 700 000€ for Italy (Wageningen workshop, 2007, D0209). Table 7 gives the different monitoring and government costs gathered from experts for some European countries. Even if we use the highest number reported as the average costs per country, the total monitoring costs amount to about 14 million Euro per year (20 * 0.7). This is much less than the reported annual damage costs even in the best case of 143 million Euro. This calculation only presents part of the costs and does not consider additional eradication costs.

Table 7: Annual monitoring and government costs for some European countries

	Monitoring and Government costs	Number of traps and sites
Slovenia	59 300 €	
United Kingdom	270 032 €	450 sites 1 800 traps
Croatia	14 200 €	
Netherlands	264 113 €	2 464 traps 1 232 sites
Czech Republic	7 000 €	
Italy	700 000 €	

Source : Wageningen workshop, 2007.

3.2 Chemical control costs for eradication and containment

Chemical control strategy to slow down or maintain Dvv spreading under economic damage levels is the common strategy applied in the areas where crop rotation is constrained or economically irrelevant. Chemical treatment costs are the cost of insecticide treatments against adults and larvae and the application costs, or seed treatment costs against larvae. The data for these costs are collected for some of them from scientific articles and for others they have been communicated by scientists in a workshop in Wageningen (ibid.). In Czech Republic, chemical control costs against Dvv are estimated at 80€/ha (expert communication). In the Netherlands, a quarantine status country, Dvv eradication was conducted applying two insecticide treatments against adults in 4 focus zones on 121 ha, at a price of 73€ per ha per application (costs of insecticide + labour) in 2005. Therefore, insecticide treatment costs per ha is evaluated to €146 per ha in the Netherlands. In Alsace (France) the cost of soil treatment for larvae is 30€ per ha plus two aerial treatment adults at 106 €/ha. In the UK, most of maize growers use seed treated with Cruiser® to control Dvv larvae and some use Gaucho®. The extra cost of treated seed is about 22€/ha knowing that normal maize seed costs are around €177/ha to €185/ha (Macleod et al., 2004). Insecticide costs consist of the cost for the actual chemical and cost of application. Chlorpyrifos marketed as Equity® and Dursban® costs approximately €19/ha. Contractor spraying costs, for example, between €11.50 and €17/ha (Nix, 2002) in UK. Thus combined costs could range from around €30.50/ha to €36/ha. Macleod et al. (2004) assume for their analysis a total chemical costs for one treatment application targeting adults in the year of first occurrence of €34/ha and a high clearance spraying extra cost of €3/ha.

Experts (Wageningen workshop) assess the prices for chemicals, like seed treatments, soil insecticides and spraying against adults, to range between 25€ to 80€ per hectares and the application costs of soil insecticides or foliar insecticides to range from 10€ to 50€/ha. That is chemical control costs for the scenario in which action are taken against Dvv spreading may range from 35€/ha to 130€/ha (see also Fall and Wesseler, 2007, D0216).

The assessment of the cost of controlling Dvv spreading has been made by considering the eradication and containment strategies of the EU.

The first case considers a situation of highly effective treatment mechanisms to eradicate Dvv. The eradication plan of the EU considers a focus zone of 1 km and a safety zone of about 5 km. Lammers (2007) estimated the eradication costs in four outbreak zones in The Netherlands to be almost 500000€ over three years or about 50000€ per out break and year. The costs calculated for The Netherlands can be considered to be on the higher side given the high revenues and the high percentage of maize production in the country. Even so, the eradication costs of 50000€ per year are far below the average annual damage costs caused by Dvv. as reported in table 5 if we consider one outbreak per year per country, which will cost about 1.00 million € per year. The monitoring and administrative costs plus the eradication costs sum-up to 15 million Euro per year. This is about only 10% of the average annual damage costs in the "best case" scenario.

The second case considers the containment strategy. This strategy applies to areas where Dvv. has been established and further spread of the pest should be avoided. Considering the fact that Dvv. is present in a number of countries delaying a further spread of Dvv. can be justified if at least this will not costs more than about 128 million Euro per year for "best case" scenario after deducting the 15 million Euro for eradication from the 143 million Euro. Higher average annual costs can be justified for less optimistic scenarios.

4. Environmental impacts of controlling *Dvv.*

Controlling an invasive species will have impacts on the environment. These environmental impacts will vary depending on the management strategy designed to control the invasive pest. The choice of the best management program against an invasive pest shall include an assessment of the environmental impacts involved by the different management options available.

Four main strategies have been identified (Fall and Wesseler, 2006, D0202) to manage the spreading of Dvv.: eradication, containment, area-wide suppression and sustainable production systems. Each of these management strategies involves several control methods for which the mains are chemical, transgenic, biological and cultural control mechanisms.

Eradication is the elimination of the entire population of an alien species, including any resting stages, in the managed area (Wittenberg, 2005). Experts on the Wageningen workshop (WP2-Task 2.3) assert that an eradication program is feasible for isolated populations and could be applied for all crops for commercial use (seed, silage, bio-energy, bio-fuels, grain, organic, sweet corn). Crop rotation with corn grown only every second or third year has been assessed as the most suitable instrument for eradication which is a technique already applied in EU agricultural system.

Containment is aimed to restrict the spread of an alien species and to contain the population in a defined geographical range (Wittenberg, 2005). Containment is suitable for all crops for commercial uses depending on the techniques (natural enemies, biotechnical methods, resistant or tolerant varieties, insecticides, transgenic maize, and crop rotation) applied. Until now information about the containment measures in accordance with the Commission decision 2006/564/EC and the Commission recommendation 2006/565/EC which will allow an evaluation are not available (Baufeld, 2007, D0203).

Area-wide suppression programs define measures based upon area-wide pest management in the infested zone to mitigate the possibilities for further spread of the organism and to ensure a sustainable production (Commission recommendation 2006/565/EC).

Among the control techniques that can be applied under the different management programs insecticide treatments and crop rotation are the ones that are commercially available and commonly applied while biological treatments are under development and transgenic technique is not allowed within the EU.

Over the four main control techniques environmental impacts of chemical treatments are now well-known (Rozen and Ester, 2007, D0102) and global consensus exists now on the negative environmental and human health effects of pesticides uses. Dvv. resistant transgenic varieties are in use in the USA since 2003 and an environmental risk assessment has been done to prove that the environmental risk posed by YieldGard® Rootworm maize is not greater than the environmental risk posed by conventional maize varieties (Ward et al., 2005). In Europe, Dvv. resistant transgenic maize varieties are not used and an environmental risk assessment for the EU is not available. We rely on the general risk assessment of GM plants to describe the potential environmental impacts of potential Dvv. resistant transgenic maize varieties in Europe.

The main lack of environmental impact studies is about biological control agents against Dvv. This is due to the fact that there is no biological product commercially available. However, a large literature does exist on the environmental impacts of biological control in general. A review of this literature provides an overview about the extent of environmental impacts implied by biological control mechanisms.

4.1 Environmental risks of biological control

Biological control is the use of populations of natural enemies, or naturally synthesized substances against pest species to suppress pest populations (Wittenberg, 2005). Wittenberg (2005) distinguishes two groups of approaches concerning biological control. A first group includes approaches which are self-sustaining and a second group concerns approaches that are not self-sustaining, i.e. they have to be applied as direct control measures. The not self-sustaining approaches include:

- **Mass release of sterile males** to inundate the population with males which copulate with the females without producing any offspring in the next generation (seems to be unfeasible to control WCR due to the high mobility of this species and due to multiple mating by females).

- Inducing **host resistance** against the pest. This approach is particularly relevant to agriculture where plant breeders select (or create) varieties resistant to diseases and insects.

- **Biological chemicals**, i.e. chemicals synthesized by living organisms. This category overlaps with chemical control and whether it should be listed under one particular control method or the other is a question of definition, e.g. while applying living *Bacillus thuringiensis* (BT) is without doubt a biological control option, to which group the use of the toxins stored in BT belong could be debatable.

- **Inundative biological control** using pathogens, parasitoids or predators that is unlikely to reproduce and establish in the ecosystem. Large-scale or mass releases of natural enemies are made to quickly reach adequate control levels of a pest population.

Self-sustaining biological control includes:

- **Classical biological control** which introduces specific natural enemies from the original range of the target species into new areas where the pest is invasive.

- **Augmentation** of enemies under pest outbreak conditions for immediate control when the natural enemy is capable of reproduce in the new environment. The control agent is reared or cultured in large numbers and released.

- **Habitat management enhances** populations of **native predators and parasitoids**, e.g. release/replant of native alternate hosts and food resources.

Rise in public concerns about pesticides uses on crops as well as the development of increasing levels of pesticide resistance and promotion of sustainable agricultural practices, resulted in the demand for alternatives to pesticides. This lead to the greater importance attributed to biological control as better alternative to pesticides in agriculture. Moreover biological control researchers had given in the past strong positive statement on the safety of biological control as quoted by Ehler (1990):

"*...no adverse effects on the ecosystem occur from biological control*." (DeBach, 1974);

"*...research in this sphere [biological control] results in prodigious economic benefits - without any environmental hazards...*" (Simmonds and Bennett, 1977);

"*The use of predators and parasites for pest control, when it is the result of a well thought out, carefully executed program, is in our opinion, risk-free*." (Caltagirone and Huffaker, 1980).

However, biological control is irreversible, self-perpetuating and self-dispersing (BIREA, 2007). These attributes although positive for a sustainable pest management programs are also factors which have alerted researchers to the potential environmental implications of such introductions.

The environmental safety of biological control has been questioned by several authors among which Howarth (1983, 1991), Samways (1994), Simberloff and Stiling (1996). Among the possible effects of biological control, the effects on non-target organisms, possibly leading to species extinction and the high failure rate of biological control programs are one of the most important. In many case, biological control simply fails to control the pest sufficiently. For instance, in classical biological control of insects, only about one third of the introduced agents have been able to establish, from which again about one third is able to suppress pest populations (Babendreier, 2007).

The introduction of a new species to an ecosystem has always an impact on the ecosystem and often not immediately understood. Complete prediction of the effects of such introduction is precluded by the complexity of species interaction in the nature. The potential risks from biological control introductions come from either direct effects on non-target species or indirect effects on the community into which the new species arrives. The most serious negative aspect of biological control would be the displacement of non-target species on a large, geographical scale or even globally, and the change of complete ecosystems.

Success of introduction of biological control are somewhat higher for weed control and generally agents released for weed control have better safety than for arthropods, even though cases of effects on non-target organisms have been documented (Louda, 2000; Louda et al., 2003).

In contrast to weed biological control, the potential risks for non-target organisms of arthropod biological control have only recently received attention. Babendreier (2007) reviewed the literature on negative effects of biological control introductions and outlined the study of Lynch et al. (2001) who examined the BIOCAT database to try to quantify the number of cases where non-target effects have occurred and also the relevance of these effects. They recorded 80 cases of classical introductions of insects listed in BIOCAT over 5,279 where one or more non-target effect has been reported. However, this includes all kinds of smaller effects such as low parasitism of a non-target species at a single location – indeed; these cases constitute the great majority. By contrast, the evidence for population reduction or extinction is fairly weak in many cases. Those cases where more serious effects were observed have virtually always happened on islands (Babendreier, 2007). The most cited case is, for instance, the introduction of predatory land snails (especially *Euglandina rosea*) for control of the alien giant African snail into Hawaiian Islands in the 1950s – and later even into other countries – had disastrous consequences for the non-target mollusk fauna (Howarth 1991). There is good evidence that the extirpation of endemic tree snails is caused by this introduced predator (Babendreier, 2007). In Howarth (1991) more cases of non-target effects have been documented. A common feature of these cases is that polyphagous predators are largely responsible for the observed effects, as demonstrated in several projects conducted early in the 20th century (Babendreier, 2007). The most well documented examples of adverse impacts from biological control programs have involved the introduction of vertebrates (e.g. the Indian mongoose against rats in West Indies and Hawaii; the other classical example is the introduction of the cane toad (*Bufo marinus*) from Central and South America in to Queensland to control two pests of sugar cane, the grey backed cane beetle and French's beetle).

One of the critical point for Howarth (1991) is that the lack of evidence for negative environmental impacts of biological control introductions is a result more of the lack of study of effects than the absence of these impacts. As he noted: "the *absence of evidence of negative environmental impacts is not evidence of absence of these impacts*".

Some studies have been conducted to address this concern. Barron et al. (2003) evaluated the non target effects of the introduction of the biological control agent *Pteromalus puparum* on the New Zealand red admiral butterfly *Bassaris gonerilla*. They concluded that the level of mortality caused by *P. puparum* is low relative to egg parasitism by *Telenomus* sp. and also low in comparison to larval disappearance and pupal parasitism caused by the accidentally introduced ichneumonid *Echthromorpha intricatoria* (Babendreier, 2007).

The polyphagous egg parasitoid *Trichogramma brassicae* has been mass released against the European corn borer in many countries in Europe. *T. brassicae* parasitize various butterfly species (including rare ones) under field cage conditions (Babendreier et al. 2003a).

Babendreier et al. (2003a, 2003b) have demonstrated that parasitism of non-target species under field conditions is zero or restricted to a few meters from the release field for *T. brassicae*. All these studies concluded that non-target effects of the biological control agent have been negligible. Practitioner of biological control argue in some instance that although comprehensive answer is not yet possible on whether many non-target effects have been missed, evidence is increasing that at least the more serious effects would have been detected.

4.2 Environmental risks of transgenic control

The Federal Department of Economic Affairs of Switzerland conducts a report on "Ecological impacts of genetically modified crops: Experiences from ten years of experimental field research and commercial cultivation" in 2006 which summarizes the up to date knowledge about the environmental risks of GM crops cultivations. Based on this report which reviews the main environmental risk studies on GM crops, we will present the currently accepted knowledge on GM risk safety. It is acknowledged that the safety of GM crops is generally assessed more intensely than that of conventionally bred crops. Indeed, to obtain the permission to release any new GM crop variety a thorough pre-market risk assessment of potential unwanted effects of the GM crop on the environment is requested. The risks of GM crops for the environment, and especially for biodiversity, have been extensively assessed worldwide during the past ten years. Substantial scientific data on environmental effects of the currently commercialized GM crops derived from these studies show that no scientific evidence exist that the commercial cultivation of GM crops has caused environmental harm (Sanvido, Stark, Romeis and Bigler, 2006).

The potential effects of transgenic Dvv. resistant maize varieties on the environment are discussed considering the impacts caused by cultivation practices of modern agricultural systems by Sanvido et al. (2006). Independent from the use of GM crops, modern agricultural systems have profound impacts on all environmental resources, including negative impacts on biodiversity.

Impacts on non-target organisms

The insect-resistant GM crops expressing Cry-proteins from *Bacillus thuringiensis* (*Bt*) could have negative impacts on organisms other than the pest targeted by the toxin. The main conclusions of the review of GM crop effects on non-target organisms made by Sanvido et al (2006) are:

"• The results of the various experimental field studies that have been performed during the last years provide evidence that Bt-maize expressing the insecticidal protein Cry1Ab is more specific and has fewer side effects on non-target arthropods when compared to currently used insecticides.

• No adverse effects on non-target natural enemies resulting from direct toxicity of Bt-crops have so far been observed in the field. Experimental field studies have only revealed minor transient or inconsistent effects of Bt-crops when compared to a non-Bt-control.

• Indirect prey-quality mediated effects due to Bt-maize may occur, but they can be considered being subtle shifts in the arthropod community caused by the effective control of the target pest.

• Extensive studies showed that risks from Bt-maize for the monarch butterfly were negligible, and that reports of toxicity of high doses of Cry1Ab protein to monarch butterflies in the laboratory did not necessarily mean that there would be a risk for monarch butterfly populations in the field."

Effects on soil-organisms

Bt-crops can have effects on soil organisms. *Bt*-toxins enter the soil system primarily via root exudation and via plant remains after harvest. Both degradation and inactivation of the *Bt*-toxin vary, depending on parameters such as temperature and soil type. Neither laboratory nor field studies have shown lethal nor sub-lethal effects of *Bt*-toxins on non-target soil organisms such as earthworms, collembola, mites, woodlice or nematodes as reported by the EU-ECOGEN project (Griffith, 2007). In particular, economic impacts of possible changes in soil systems have not been observed (Wesseler, et al., 2007).

Gene flow from GM crops to wild relatives

There is general scientific agreement that gene flow from GM crops to sexually compatible wild relatives can occur. Experimental studies have shown that GM crops are capable of spontaneously mating with wild relatives, however at rates in the order of what would be expected for non-transgenic crops.

Invasiveness of GM crops into natural habitats

In natural habitats, no long-term introgression of transgenes into wild plant populations leading to the extinction of any wild plant has been observed to date. Transgenes conferring herbicide tolerance are unlikely to confer a benefit in natural habitats because these genes are selectively neutral in natural environments, whereas insect resistance genes could increase fitness if pests contribute to the control of natural plant populations. The potential invasiveness is highly stochastic and would require landscape models (Gilligan et al., 2005).

Despite the concern of GM crops invading natural habitats was brought up early in the discussion on potential environmental risk related to the release of GM crops, it seems that modern crop varieties generally stay domesticated (Sanvido et al., 2006).

It is worthwhile to mention the results of the studies conduced in USA about the Bt maize expressing a *Bacillus thuringiensis* protein for resistance against the Western corn rootworm (Rice, 2004), i.e. Monsanto's "Mon 863" Bt maize variety, first commercialized in 2003. MON 863 was selected from hundreds of transformation events and produced and developed for commercialization as YieldGard® Rootworm maize. The environmental risk posed by YieldGard® Rootworm maize has proven to be not greater than the environmental risk posed by conventional maize varieties (Ward et al., 2005). YieldGard® Rootworm maize has shown efficacy in controlling corn rootworm larvae and seems to be more than or at least as efficacious as soil and seed insecticides in protecting roots from larval feeding damage.

5. Socio-economic analysis of controlling Diabrotica

5.1 Socio-Economic impacts of chemical control program

Insecticides can be used to decrease population levels of WCR and thus protect the crop against damage. Insecticides used as seed and soil treatments are the common chemicals applied to control WCR in Europe. However, the chemical control system can vary within the EU due to differences in insecticide application rules and agro-ecological conditions. In Italy, seed treatments are often used to control pests that attack maize roots, i.e. for WCR larvae, soil insecticides are not recommended because of potential negative environmental impact and economic costs of these plant protection products. The efficacy of seed treatments depends on the product, soil conditions, insecticide rate on the kernel, planting time and density of larval population level (Boriani et al., 2006). Nevertheless, seed treatments are generally not so effective for protecting maize root systems in areas with high populations of larvae. However, if seed treatments are a viable choice, their use can reduce the amount of active ingredients applied up to about 90%. In Hungary, fungicide seed treatments and herbicides were routinely applied to control diseases and weeds prior to the arrival of economic populations of WCR. To control WCR larvae, seed treatments also including insecticides, as well as soil application of insecticides at planting; have been added to the pest control scheme. Also, adult control through the application of insecticides at full and reduced rates (in combination with a feeding stimulant) by aerial and high-clearance sprayer application has been used (Boriani et al., 2006).

In many countries, soil insecticides are applied to manage the larvae in continuous maize production. Differences in insecticide formulation, level of insecticide solubility, insecticide placement, climate, date of planting, date of rootworm hatch, compaction, etc., can alter insecticide performance and subsequent level of rootworm larval damage. Rootworm soil insecticides can, depending on the product, be applied in a band over the seed row, as an in-furrow application or as a broadcast spray on the soil surface followed with a direct incorporation activity. A seed treatment involves the application of an insecticide directly on the seeds prior to planting. The insecticide may be absorbed by the plant as a systemic insecticide during seed development or be dispersed into the soil protecting the roots against rootworms. Recent research has shown that most soil insecticides work better than insecticide seed treatments, but the amount of insecticide per ha is considerably higher compared to the seed application.

Use of insecticides result in benefits to farmers due to their effectiveness in controlling WCR and eliminating the need to rotate to another crop. But these products can lead to environmental and health risks and these factors can results in difficulties in getting regulatory approval for their use. If not handled and used properly, there can be irreversible extra costs associated with food safety, farmer health, avoiding resistance and environmental quality.

The socio-economic impacts of chemical control program against Diabrotica are analyzed through the economic, environmental and health impacts for the main actors identified in that process.

5.1.1 Impacts for farmers

Economic Impacts

Use of insecticides result in benefits to farmers due to their effectiveness in controlling WCR and eliminating the need to rotate to another crop. Compared to a base case of no control of Diabrotica spreading, chemical treatments as an effective control technique increase the yields of maize production for farmers and result to be more competitive than rotating for many crops (barley, wheat, rape) for many EU member countries with higher farmer incremental benefits (Fall and Wesseler, 2007). Chemicals products present reversible private benefits due to their easiness to handle.

Insecticides are a solution that can be applied to all commercial uses other than organic farming with advantageous cost prices compared to bio-control products and transgenic if they are applied at sowing. But they can generate extra-costs to maintain soil health and seems to present growing difficulties for registration and regulation rules.

Environmental Impacts

Chemical treatment is associated with higher environmental costs in comparison to biological control agents. Impacts on non-target organisms such as honey bees must be considered as well as reduction of organic matter contents. Increasing pesticide use implies irreversible environmental impacts which can lead to growing pressure for environmental taxes for the use of pesticides.

Health Impacts

Chemicals present high potential damage to farmer health and food safety. Health impacts and potential lawsuits should be taken into consideration.

5.1.2 Impacts for industries

Economic impacts

Chemical control management program against Diabrotica is a market opportunity for the chemical industry in Europe. Due to the importance of maize production in Europe, 15 million hectares sown for grain and silage maize, the control of Diabrotica spreading with chemical treatments will entail a huge amount of pesticides applications. For the importance of maize production in Europe, one can refer to the report on market potential for biological control made under the Diabr-Act project (Fall and Wesseler, D0215, 2007).

Nevertheless, the recent development of resistance to several insecticides may involve additional costs for the development of new insecticides. Diabrotica virgifera resistance has been reported against aldrin, bufencarb, carbofuran, chlordane, diazinon, dieldrin, endrin, fonofos, heptachlor, lindane/BHC and parathion-methyl (Ester and van Rozen, 2006, D0102). In general the development and the homologation of a chemical pesticide can take 8 to 10 years and the costs can reach 80 million $. Thus, the development of resistance to pesticides can be challenging for the chemical industry with the development of cost-effective alternative control techniques (for example transgenic and biological).

The impacts for the processor industries will depend on the market effects of changes in prices and quantities due to the effects of the efficacy of the control program. One can expect that effectiveness of the control program will increase the volume of production of maize in Europe which can lead to decrease in prices ceteris paribus.

In general, there could be some changes on the distribution of the benefits among the chemical industry, the processor and the farmers from the efficacy of the control program depending on the underlying market supply and demand conditions, on the pricing system that will govern the pricing of the chemical products and on the competitiveness of alternative control techniques.

5.1.3 Impacts for consumers

Economic impacts

Consumers may benefit to the cost-effectiveness of chemical control program. The benefits from any resulting yield gains could have positive distributional effects for consumers. Increase in yields may result in a decrease in maize products prices at the end for the consumers.

Health impacts

Increase in uses of chemical products for controlling Diabrotica can be a threat to food safety and hence consumer health. Table 1 derived from Ester and Rozen (2006) gives useful environmental factors that are useful to assess health impacts of pesticides uses. Acute dermal toxicity and chronic toxicity can for example result from the increase in the use of chemicals for Diabrotica control. It is based on the environment impact quotient (EIQ) approach to assess the environmental impacts of pesticide uses. The EIQ was initially designed by IPM specialists to help farmers in their choice for pest-control options. The underlying premise of the EIQ is that impacts result from the interaction of toxicity and exposure; hence most effects are evaluated by multiplying ratings for indicators of exposure by indicators for toxicity. The EIQ incorporates the impacts on farm worker (application and harvest worker), the consumer and ecology (non-target organisms: fish, birds, honeybees, and other beneficial insects) (Kovach et al., 1992). The separate impacts are calculated based on inherent properties of a certain pesticide for example toxicity towards certain organisms and exposure of these organisms due to environmental behavior (Kleter and Kuiper, 2005). The inherent properties are assigned ratings ranging from 1-3 or 1-5, where 1 denotes the lowest toxicity or harmfulness and 3 or 5 the highest, based on predefined boundary values (Kleter and Kuiper, 2005).

5.1.4 Impacts for Public Authority

Economic impacts

For the public benefit, there is no need to subsidize for the development and use of chemicals compared to biological products. But in terms of costs, chemicals present more problems to food safety, environmental quality and resistance management. These problems that can result from chemical control program have some costs for the public authority that are costs for regulating, monitoring and treating the damage caused by increase in use of chemicals for controlling Diabrotica. These costs may not be negligible.

5.2 Socio-Economic impacts of biological control program

To prevent intensive use of insecticides and to protect existing biological control techniques that can be threatened by the use of insecticides, biological control program may be a good alternative for controlling Diabrotica. In Europe, the following biological control techniques against Diabrotica are under development:

- Classical biological control using specific and effective natural enemies of Diabrotica pests from their area of origin in the Americas;
- Repeated inundative releases e.g. using European mass-produced and already commercially available entomopathogenic fungi or nematodes.

Table 1 : Environmental impact quotient equation factors.

Key to EIQ categories		Score
Acute dermal toxicity	> 2000	1
LD_{50} (mg kg^{-1})	200-2000	3
	0-199	5
Chronic toxicity	None	1
reproductive, teratogenic,	Little	1
mutagenic, carcinogenic	Possible	3
	Definite	5
Bee toxicity	Relatively non-toxic	1
	Moderately toxic	3
	Highly toxic	5
Fish toxicity	> 10	1
96 h LC_{50} (ppm)	1-10	3
	< 1	5
Bird toxicity	> 1000	1
8 day LC_{50} (ppm)	101-1000	3
	1-100	5
Beneficial toxicity	Low impact	1
	Moderate impact	3
	Severe impact	5
	Post-emergent herbicide	3
Plant surface half-life (days)	0-14	1
	15-28	3
	> 28	5
	Pre-emergent herbicide	1
	Post-emergent herbicide	3
Leaching and run-off	Small	1
Potential	Medium	3
	Large	5
Systemicity	Non-systemic	1
	Systemic	3
	Herbicide	1

Source: derived from Ester and van Rozen (2006)

As mentioned by Toepfer, Haye and Kuhlmann (2007): a classical biological control approach against D. v. virgifera is not subject to conflict between different non-native parasitoids if they are host specific, for example the use of Celatoria flies (Tachinidae) or Centistes wasps (Braconidae) from Central America against D. v. virgifera, and the use of Trichogramma wasps (Trichogrammatidae) against Lepidopteran pests. Conflicts are unlikely because the first two are specific to adult Diabrotica beetles and the latter is an egg parasitoid of Lepidoptera. Also the polyhydrosis viruses and Bacillus thuringensis strains are probably specific enough to not attack the parasitoid groups. Fungi and nematodes are applied against D. v. virgifera larvae in the soil and thus would not interfere with above ground adult or egg parasitoids. The potential classical biological control agents, like parasitoids, could be combined with crop rotation as long as Diabrotica is present in a certain region each year.

The use of entomopathogenic fungi against other soil dwelling pests may have synergistic effects with fungi used against Diabrotica larvae.

The expected high efficacy of biological products and the large range of technologies that can be combined with bio-control strategy are incentive factors for the adoption of such technology notwithstanding his relative expensiveness in comparison with chemical or transgenic control techniques.

The socio-economic impacts of biological control program in some sense are not easy to assess due to the prospective aspect of this control program. Nevertheless, impacts on different stakeholders can be analyzed throughout information gathered from experts view at Wageningen workshops and from literature review.

5.2.1 Impacts for farmers

Economic impacts

Biological control may result in positive incremental benefits for farmers compared to a base case of no control action against Diabrotica (See Fall and Wesseler, 2007, D0216). The incremental benefits result from the yield gains effects of bio-control agents. However, natural enemies imply in general higher costs for farmers and are not a proper solution for all types of maize production (e.g. seed producer). The potential benefits of biological control for farmer depend on the situation or farming conditions:

- Farmers specialized on monoculture maize production and who would face high costs to convert to rotated maize are for example highly beneficial to adopt biological control technique. There is no need to use crop rotation systems which can lead to shift to a crop with less market value (price) for some regions due to climate, soil, and other conditions.

- The farmers who have difficulty to grow alternative crops, like wheat, are also potential users for bio-control products.

- High value maize systems such as seed, sweet and organic maize. Biological products would be the main technology to use against Diabrotica in organic maize system since organic production does not use chemicals or transgenic plants. In sweet maize production, concerns about pesticides residues and consumer attitude toward transgenic plant in Europe (even if transgenic maize was allowed for production in EU) are strong drivers towards the needs of biological products against Diabrotica. Moreover, these maize productions have enough high values to afford the expected relative expensiveness of potential biological products in comparison with chemical insecticides.

Benefits from bio-control products may come from their safeness to handle and their good public acceptance. Farmers that use biological control agents like *Trichogramma* already have a capacity for such applications. This would increase their acceptance for new bio-control products as well as reduce efforts for farmer trainings.

However, biological control products may increase production costs for farmers. They are in general more expensive than chemicals or transgenic seed premium. Also, farmers may incur some adaptation costs to shift to bio-control technique.

The main disadvantages are the lack of certainty about the levels of control that will be achieved, the delays until the established agents achieve their full impact and the relatively high costs in the beginning of screening potential biological control agents.

The main advantage of biological control program is his potential great environmental benefits by reducing pesticides uses. The reduction of pesticide uses benefits to farmers by increasing soil health, organic matter contents and avoiding resistance management problems. A clear advantage of a successful biological control program is the saving of sometimes huge amounts of pesticides, of which many are known to be harmful for numerous non-target insects, vertebrates and even humans. For example, the biological control program against alfalfa weevil conducted in the US reduced pesticide use by 95 % from 1968 to 1983, and is saving farmers more than $ 100 million each year in insecticide and application costs (Babendreier, 2007).

Resistance seems to be very unlikely for bio-control products, which leads to higher irreversible benefits due to future expenses avoided to control Diabrotica. One of the most striking advantages is that, if biological control works, then it virtually works forever. This means that it can be an extremely cost-effective pest control method, and the benefits may exceed the initial costs of the projects by several orders of magnitude (Hoddle, 2004).

Liability risks are also lower for farmers in case of environmental pollution compared to transgenic gene flows or chemical pollution.

Health impacts

Biological control safety standards require (e.g. IPPC Code of Conduct) that the specificity of all agents proposed for introduction be assessed. This involves extensive laboratory and field screening tests. This process for the introduction of an exotic species guaranties health safety of introduced agents for farmers.

Entomopathogenic nematodes are exceptionally safe biological control agents (Ehlers, 2007). The use of entomopathogenic nematodes is safe for the user and their associated bacteria cause no detrimental effect to mammals or plants (Ehlers, 2007). As noted by Ehlers and Hokkanen (1996) entomopathogenic nematodes are safe to production and application personnel and the consumers of agriculture products treated with entomopathogenic nematodes. An expert group meeting under a joint workshop supported by the EU COST Action 819 "Entomopathogenic Nematodes" and the Organization for Economic Co-operation and Development Research Programme "Biological Resource Management for Sustainable Agriculture Systems" in 1995 to discuss potential risks related with the use of entomopathogenic nematodes in biological control could not identify any risk for the general public related to the use of entomopathogenic nematodes.

5.2.2 Impacts for industries

Economic impacts

Biological control program against Diabrotica will be a market opportunity for the biological industry in Europe. Taking only high value maize production such as seed maize, sweet maize and organic maize the market size of those productions is 10 to 20 times higher than the current production capacity of bio-control agents by the bio-control industry (see Fall and Wesseler, 2007, D0215). Indeed, the industry for bio-control products is small in Europe and only a few companies develop bio-control agents (4-5 nematode companies and 3 to 7 fungi companies). This feature of the supply side of bio-control market leads to a low capacity to produce sufficient bio-control agents for large-scale maize production. The capacity of production of bio-control agents on a larger scale is estimated currently to be able to supply 10,000 to 20,000 hectares at most (Fall and Wesseler, 2006, D0202). There is a need to expand production capacity in case biological control would be implemented for high value maize systems. The development of biological products against Diabrotica can be an interesting control strategy for grain and fodder maize production in several EU countries for several reasons. Given the rise in the environmental awareness of the use of pesticides, some insecticides are banned in certain country. In Italy, soil insecticides are not recommended because of the potential environmental impact and economic costs of these plant protection products (Boriani et al., 2006). Moreover no WCR-resistant Bt maize variety has been approved for import and cultivation in the EU

(AGBIOS, 2006). These factors can make the biological option the only control option available for some farmers to reduce or suppress Diabrotica population in maize production. Moreover the potential classical biological control agents, like parasitoids, could be combined with crop rotation as long as Diabrotica is present in a certain region each year. Knowing that in some countries (like Slovenia, Croatia, United Kingdom, France, Hungary) the percentage of area growing maize rotationally is very high ranging from 60 to 80% that means that 9 million ha to 12 million ha can be potentially concerned by a combination of biological products and crop rotation to control Diabrotica. Then the volume of the market for bio-control products can potentially go up to 560 million €.

Moreover in the regions where larger subsidies are allocated to maize production they should be interested by bio-control products since it will help them to avoid rotation.

The industry specialized in dairy production and in bio-gas production could gain in biological control program as an alternative control mechanism to avoid crop rotation. That will be the case for grain buyers/collectors that have invested in dryers, storage bins that would become under-utilized in case of shift to crop rotational production.

5.2.3 Impacts for consumers

Economic impacts

Consumers would gain from the effects of the yields benefits of bio-control on market prices. The benefits from any resulting yield gains could have positive distributional effects for consumers. Increase in yields may result in a decrease in maize products prices at the end for the consumers.

By reducing insecticides applications, the degradation of soil with chemicals or ground water the use of biological control program would have positive impacts on the environment that may benefit to consumers. Moreover, biological control can be a vehicle for improving biodiversity which may increase consumer's non-pecuniary value to environment.

Health impacts

Agricultural products treated with biological control agents have not been recorded to have harmful effects for consumers (Ehlers, 2007). As noted above the safety standards required for the introduction of biological agents guaranty the safety for food made from biological production system.

5.2.4 Impacts for Public Authority

Economic Impacts

The adoption of biological products could need some financial support from public authority to compensate the costs for farmers compared to chemical treatments costs. This support means an increase in farmer's subsidies for maize production.
The regulation of biological control method would imply some additional costs for public authority.

Environmental Impacts

There is now general agreement that the potential for non-target effects has to be evaluated before releasing biological control agents. Now the question is how to reduce environmental risks for non-target organisms without setting stringent rules for biological control production.
The assessment of non-target effects and the regulation of arthropod biological control agents have lead to several international activities these last ten years. The FAO Code of Conduct for the Import and Release of Exotic Biological Control adopted in 1995 by the FAO Conference and published in 1996 as the International Standard for Phytosanitary Measures No. 3 (IPPC 1996) marks a starting point towards international regulation. The revised version of this Code of Conduct has extended its range from classical biological control to inundative biological control, native natural enemies, microorganisms and other beneficial organisms, and it also includes evaluation of environmental impacts (IPPC 2005). This standard will certainly continue to provide guidance for countries which are developing their own legislative systems for biological control regulation. The FAO Code has been endorsed by the European and Mediterranean Plant Protection Organization (EPPO) but recommended that regulation should not slow the importation of biological control agents.

EPPO has produced two guidance documents and a 'positive list' of organisms for safe use in EPPO countries (EPPO 1999, 2001, 2002). The documents concluded that a certification system should be put in place for Europe, rather than a registration procedure, to ensure a 'light' regulatory system with efficient and rapid mechanisms (Babendreier, 2007). The reasoning behind this decision was based on previous experience with the registration system for microbial biological control agents in Europe: the EU Directive and its implementation are so stringent that it is basically impossible to register a new microorganism in EU countries. For EPPO "*there is extensive previous knowledge and experience of the use of introduced biological control agents in a number of countries in the EPPO region, sufficient to indicate the absence of significant risks, or the availability of reliable risk management measures, for many individual organisms. This list accordingly specifies indigenous, introduced and established biological control agents which are recognized by the EPPO Panel on Safe Use of Biological Control to have been widely used in several EPPO countries. Other EPPO countries may therefore presume with some confidence that these agents can be introduced and used safely*".

An initiative of OECD (Organization for Economic Co-operation and Development) countries resulted in the development of a guidance document for biological control agents. The document (OECD 2003) proposes guidance to member countries on information requirements for (1) the characterization and identification of the organism, (2) the assessment of safety and effects on human health, (3) the assessment of environmental risks and (4) the assessment of efficacy of the organism. In Europe, the biological control industry expressed concern when the OECD guidance document was published, as the information requirements were considered to be too stringent. For Ehlers (2007) "*this document exaggerated the risks involved with the use of biocontrol organisms and therefore implementation of the requirements would result in severe negative impacts on the development and marketing of entomopathogenic nematodes based products. It is most unfortunate that the OECD steering committee spent much time in producing this recommendation instead of working on a consensus document including a positive list of invertebrate biocontrol agents, which have a history of safe use*."

Most recently, the European Commission released a call for project applications with the aim to develop a new, appropriate and balanced system for regulation of biological control agents (micro- and macro-organisms), semiochemicals and botanicals. It is expected that, in the foreseeable future, the EU members and other European countries may regulate invertebrate biological control agents under uniform principles (Babendreier, 2007).

All these activities on regulating biological control approach reveal that the potential for non-target effects of biological control agents has become an important issue recently and that important progress has been and have to be achieved.

In definitive, the regulation of the use of biological control program against Diabrotica should consider the tremendous benefits to the environment of this control mechanism, his safety for users and consumers that could outweigh possible risks to non-target organisms.

5.3 Socio-Economic impacts of transgenic control program

Advances in molecular biology have resulted in the development of genetically modified crops to resist damage caused by insects and diseases, as well as to tolerate herbicide applications.

Genes expressed by genetically modified cultivars to resist insect damage are derived from a common soil bacterium, *Bacillus thuringiensis* (Bt). Modern biotechnology has allowed for the isolation of genes coding for specific Bt toxins and these can be introduced into various plant types to provide insect protection. It is in the USA that a Bt maize expressing a *Bacillus thuringiensis* protein for resistance against the Western corn rootworm (Rice, 2004), i.e. Monsanto's "Mon 863" Bt maize variety, was first commercialized in 2003. MON 863 was selected from hundreds of transformation events and produced and developed for commercialization as YieldGard® Rootworm maize. YieldGard® Rootworm maize has shown efficacy in controlling corn rootworm larvae and seems to be more than or at least as efficacious as soil and seed insecticides in protecting roots from larval feeding damage. As it is incorporated within the roots, its performance is unlikely to be affected by severe environmental conditions (Ward et al., 2005). The insertion of the *Bt* genes into the maize plant potentially improves a farmer's abilities to manage serious insect pests (Pilcher *et al.*, 2002).

Good performance and consistency of control of YieldGard® Rootworm hybrids explain the rapid adoption patterns of WCR-resistant transgenic technology in the USA.

The introduction of these genetically modified crops has greatly enhanced agricultural productivity and economic returns for growers choosing to adopt this new technology. The Bt-technology is considered to be more consistent in its effectiveness than conventional or biological insecticides because it cannot be washed off or broken down by other environmental factors (Brookes, 2002). The success of using WCR transgenic varieties in the USA suggests this technology to be suitable strategy to control the WCR spreading in the EU. In Europe, Bt maize to control the European corn borer, Ostrinia nubialis (Hübner), has been planted each year in Spain since 1998. Small areas have been planted in France, Germany, Portugal and the Czech Republic (James, 2006). Currently no WCR-resistant Bt maize variety has been approved for import and cultivation in the EU (AGBIOS, 2006).

5.3.1 Impacts for farmers

Economic impacts

Studies on the adoption of transgenic crop in the United States confirm that on average the gross margin per area from transgenic crops is about as high as and sometimes higher than the gross margin from non-transgenic crops. The empirical studies also indicate that the amount of pesticides used may decrease for transgenic crops. The decrease in pesticide use not only reduces expenses of farmers but also provides additional benefits, as the application of pesticides has several negative impacts on the environment and human health (Antle and Pingali, 1994). Some of these external costs of pesticide application are irreversible. If the introduced transgenic crops result in less pesticide application, the introduction provides additional benefits (Wesseler, 2007).

The impact on average costs of production in the USA has been -$10/ha (based on an average cost of the technology of $42/ha and an insecticide cost saving of $32/ha). As a result the net impact on farm profitability has been +$12.7/ha in 2003 and +$13.1/ha in 2004 (Brookes and Barfoot, 2005).

Additional factors, both pecuniary and non-pecuniary in nature, will have positive benefits for farmers. The WCR-resistant transgenic technology is expected to provide a yield gain relative to conventional control, since its effectiveness does not depend on timing, weather, calibration of application equipment, or soil condition. This yield gain is estimated to range between 0 and 7 percent, depending on the insect pressure (Mitchell, 2002).

Farmers may gain greater benefits from planting transgenic crops due to reduction in variable production costs with reduced pest management and labor costs. Savings in fixed and variable planting costs may occur, since the insecticide application equipment attached to the planter will no longer be needed. Without the planter insecticide application equipment larger seed hoppers can be installed that will reduce refilling time in half and result in significant time saving and an additional net benefit. In addition, some "convenience" benefits are expected for farmers in terms of less time spent on crop walking and/or applying insecticides and also savings in energy use, machinery use, mainly associated with less spraying.

Gross revenues can increase due to an increase in yield from improved plant spacing. Additional benefits arise from improved risk management and insurance against pests and a reduction in equipment costs in zero-tillage production systems (Kalaitzandonakes 1999).

An implementation of an insect resistance management (IRM) program by EU would involve some direct costs (e.g., the expense of planning, planting, and managing a refuge for corn rootworm). In addition, adoption of an IRM program would imply that the per hectare benefits from adoption of the WCR-resistant transgenic technology would only apply to a fraction of the total area that would otherwise be counted as having adopted the technology, and these opportunity costs should be added to the direct costs associated with an IRM plan (Alston et al., 2002). Also, coexistence costs may exists for farmers depending on (and how) the coexistence rules if implemented by the EU. However, an IRM program would preserve the benefits from the transgenic technology over a longer time period. An effective IRM program will impose costs in the short run that will be over-weighted by the benefits in the longer run.

Environmental impacts

Environmental gains are expected from the adoption of WCR-resistant transgenic variety. WCR-resistant transgenic control program will reduce the amount of pesticides used in maize production. In the maize sector a 7.8% reduction in the environmental 'foot print' has occurred from a combination of reduced insecticide use and a switch to more environmentally benign herbicides (Brookes and Barfoot, 2005).

Environmental effects at farm level are also expected from the contribution of GM crops to lower levels of GHG emissions. With transgenic maize, the reduction of fuel use from less frequent herbicide or insecticide applications and the reduction in the energy use in soil cultivation would contribute to reduce GHG emissions for maize production. The fuel savings associated with making fewer spray runs (relative to conventional crops) and the switch to conservation, reduced and no-till farming systems, have resulted in permanent savings in carbon dioxide emissions. In 2004 this amounted to about 1,082 million kg arising from reduced fuel use of 400 million liters. Over the period 1996 to 2004 the cumulative permanent reduction in fuel use is estimated at 4,901 million kg of carbon dioxide arising from reduced fuel use of 1,815 million liters (Brookes and Barfoot, 2005).

Farmers who plant transgenic maize may cause negative external effects to non-transgenic or organic farmers by cross contamination through pollen drift or other forms of admixture. While strong supporters of the transgenic technology argue that the current legislation is sufficient to deal with this problem, others demand strict liability rules for GM-farmers and those who distribute GM-crops. In any case, the values of different production systems are highly affected by the allocation of liability rights (Beckmann and Wesseler, 2007). Depending on the institutional and regulatory setting defining liability rules in case of transgenic contamination farmers may face increasing costs for liability and insurance.

Health impacts

Transgenic technology is expected be safer for farmers than conventional chemical treatments and to improve food quality with lower levels of mycotoxins in transgenic maize.

The transgenic varieties would improve health and safety for farmers and farm workers from reduced handling and use of pesticides.

5.3.2 Impacts for industries

Economic impacts

Adoption of WCR-resistant transgenic control program would generate a huge profit for biotechnology industries in Europe. It will mark the opening of a market of about 15 million hectares of production of maize.

On the other hands, if the demand on strict liability rules for GM crop distributors and producers would have been adopted by European legislation, it will generate important costs in case of contamination for the biotechnology industry. In addition, the biotechnology industry may expect higher regulatory and registration costs for transgenic control program than conventional chemical treatments. The all production chain would bear market segregation costs if implemented.

5.3.3 Impacts for consumers

Economic impacts

The expected benefits resulting from yield gains and other on-farm benefits with the adoption of transgenic control program for Diabrotica could generate positive impact on maize made food prices for consumers. The distribution of the benefits from the transgenic technology among farmers, consumers, and suppliers of the transgenic control technologies (including seed, agricultural chemical, and biotechnology companies) will depend on the nature of competition and the underlying market supply and demand conditions.

Health impacts

On the debates about transgenic technology one of the uncertainties is attached to potential human and food safety effects. The scientific uncertainty or "ignorance" is one of the major consumers concerns about the genetically modified plants.

5.3.4 Impacts for Public Authority

Economic impacts

Transgenic control program for Diabrotica would be implemented with new regulations on genetically modified plants. On the public side, this would entails further elaborated monitoring systems, GM-crop cadastre and other measures should be established accompanying the release of transgenic plants in EU. At the public level, transgenic control program will generate costs implied by the new institutional arrangements involved by the changes in regulation for the governance of such policy.

Environmental impacts

Bt-corn releases the Bt toxin through its roots into the soil where it can bind with soil particles and accumulate over time, with unknown effects for soil communities. Other issues raised about possible irreversible effects of transgenic crops are that new viruses could develop from virus-containing transgenic crops (Kendall et al.1997) and that resistance of bacteria to antibiotics increases due to the use of marker genes. Once released in the environment, the genetic information of transgenic crops cannot be recollected and hence will produce irreversible costs (Wesseler, Scatasta and Nillesen, 2007).

6. Conclusion

The economic benefits of Dvv. control do outweigh the costs of control substantially. The most-likely scenario results in economic gains of Dvv. control of about 472 million Euro per year. The economic benefits of control and the control costs are unevenly distribute among EU member states. This uneven distribution may result in incentives undermining a successful control strategy. Indeed, some countries will benefit from the actions taken by others countries to avoid Diabrotica expanding throughout Europe. For example, Germany is now beneficiating form the actions taken by Austria to avoid Dvv. spreading. This externality effect should be valued at EU level to improve the implementation of EU wide management programs.

The environmental and socio-economic analysis of Diabrotica control programs undertaken in this report gives a global idea of what are the benefits and the inconvenient of each possible control strategy in terms of economic, environmental and health impacts for the different stakeholders involved in such management program. It has to be read in combination with the report on practical compatibility and competitiveness of these different control strategies (D0215). Then, a more complete assessment of the efficacy, competitiveness, and sustainability of each control strategy can be made for the European Union country members.

Nevertheless, notwithstanding the lack of data and studies on certain aspects (environmental, economic) of the different control programs, an optimal control management can be designed in regard of the decision variable considered (environmental, competitiveness, sustainability) at farm, national or EU level from the environmental and socio economic analyses, but also the competitiveness analysis.

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