

EFFECT OF INTRODUCING GLYPHOSATE-TOLERANT SUGAR BEET ON PESTICIDE USAGE IN EUROPE

Brigitte Coyette, Francesca Tencalla, Ivo Brants and Yann Fichet from Monsanto Europe in Brussels, Belgium, and Denis Rouchouze from the Ecole Nationale Supérieure d'Agronomie et des Industries Alimentaires (ENSAIA), Nancy, France, analyse the impact of introducing glyphosate-tolerant sugar beet on pesticide usage in 6 selected countries in Europe

Introduction

Sugar beet is an important crop for Europe. As the result of a growing demand for sugar, the global trend in Western Europe over the last ten years has been for an increase in the production of sugar from beets, from around 17 million metric tonnes in 1989–1990 to more than 19 million tonnes in 1999–2000. This increase has been achieved by improvements in yield rather than an extension of the land area cultivated.

European countries have made continuous efforts in selective breeding of sugar beet and production refinements in order to keep beet sugar supplies competitive with those from cane. Sugar beet growth is sensitive to climatic conditions, weed infestation and pest presence (Schweizer and May, 1993). Competition from uncontrolled annual weeds can result in yield reductions up to 100% (Schweizer and Dexter, 1987; May, 1996), therefore an efficient weed management programme is necessary to achieve a successful crop.

Since the 1960s, selective herbicides have been used to tackle this problem. Today, a wide range of products is available, however no universal solution exists and weed management strategies to achieve optimal sugar beet production are expensive, labour intensive and in many cases complicated (Schweizer and May, 1993).

Recently, the application of biotechnology methods to agriculture has led to the development of sugar beet varieties tolerant to broad-spectrum herbicides such as glyphosate or glufosinate-ammonium (Mannelöf *et al.*, 1997). These crops allow for simple and flexible weed control strategies, where only one herbicide may be used rather than tank mixes and farmers have more freedom in their choice of application timing. The efficiency of weed control in herbicide tolerant sugar beets, particularly against tough weeds such as weed beets or volunteer potatoes, has been demonstrated in a number of field trials (Brants and Harms, 1998; Dewar *et al.*, 2000 a and b; Fichet, 1998; Jensen, 1998; Madsen *et al.*, 1996; Messéan, 2000). Several years of experience with these crops reveal that their positive impacts are wide-ranging, including benefits for farmers (Dewar *et al.*, 2000a), the sugar industry in general (Brants and Harms, 1998) and for the environment (Wevers, 1998a). One of the most important environmental benefits of herbicide-tolerant sugar beet systems is linked to the potential for reducing the number and amount of pesticides applied for weed control compared to conventional cultivation systems (Buckmann

and Petersen, 2000; Moll, 1997; Pedersen, 1997; Tenning, 1998; Wevers, 1997; Wevers, 1998a and b).

The present paper analyzes the effect of introducing glyphosate tolerant sugar beets on pesticide use patterns, with a particular focus on Europe. The countries selected for this study were France, Germany, Spain, Belgium, the UK and the Netherlands. The selection was based on the total volume of sugar beet grown in each country and the possibility to collaborate with experts from national sugar beet research institutes.

Current status of weed control in the selected countries

Data on weed control in sugar beet were obtained from discussions and workshops with experts from sugar beet institutes in the various countries: Institut Technique de la Betterave (ITB) in France, Institut für Zuckerrübenforschung (IfZ) in Germany, Asociación de Investigación para la Mejora del Cultivo de la Remolacha Azucarera (AIMCRA) in Spain, Institut Royal Belge pour l'Amélioration de la Betterave (IRBAB) in Belgium, IACR-Broom's Barn in the UK and Institute for Sugar Beet Research (IRS) in the Netherlands.

The information gathered on cultivated surfaces and weed control programmes is summarized in Table 1. In 2000, the largest producers of sugar beet were Germany and France, each with cultivated surfaces well above 400,000 ha. The UK, Spain and the Netherlands all cultivated between 100,000 and 200,000 ha, whereas Belgium produced less than 95,000 ha. Across the six countries selected for the study, we limited ourselves to 17 herbicidal active ingredients (a.i.) most used for weed control in sugar beet. In any one country, the number of herbicidal active ingredients applied ranged from 8 to 11, at a mean use rate of 3.2 kg a.i. ha⁻¹ (range from 2.4 kg a.i. ha⁻¹ in the Netherlands to 4.1 kg a.i. ha⁻¹ in Belgium).

Metamitron is by far the largest product used (46% of market share), followed in decreasing order by chloridazon, ethofumesate, phenmedipham, glyphosate, lenacil, quinmerac, desmedipham and clopyralid. Minor products (less than 2% of the total market share) include triflusal-furon-methyl, dimethenamid, s-metolachlor, cycloxydim, fluzifop-P-butyl, propaquizafop, quizalofop-P, haloxyfop. These active ingredients are often used at very low doses, are not registered in every country (*e.g.* dimethenamid is only

Table 1. Cultivated area and weed control in sugar beet (2000)

Country	Area of sugar beet cultivated ('000 ha)	% of total arable land	Number of active ingredients studied *	Total dose of active ingredients (tonnes a.i.year ⁻¹)	Average use rate (kg a.i.ha ⁻¹)
Germany	470	4	11	1,753	3.7
France	427	3	8	1,140	2.7
UK	175	3	11	557	3.2
Netherlands	120	14	8	289	2.4
Spain	112	1	9	350	3.1
Belgium	94	13	9	393	4.1
TOTAL	1,398	38	17	4,482	-
MEAN	-	-	-	-	3.2

* More active ingredients are applied in the various countries but this study limited itself to the most used products

registered in Belgium) and are often expensive.

Weed control programmes in sugar beet include both pre- and post-emergence herbicide treatments. The most important products in terms of volume are those used pre-emergence. For cost and efficacy reasons, usually only one active ingredient is applied in this case, therefore higher rates are required to ensure sufficient weed control. In post-emergence, tank mixes are used in most countries, usually in several split applications at lower dose rates than in pre-emergence. The latest trend in several countries (Belgium, The Netherlands, France) is to use a balanced (to maintain the correct weed control spectrum) but very low use rate of the different active ingredients in the tank mixes in post-emergence. The number of post-emergence applications with these programmes therefore increases and the interval between the different application dates follows a rather strict regime in function of weed stage developments. This makes these programmes more vulnerable to timing of the sequential applications. Delays of a few days between scheduled sprayings (for example due to adverse weather conditions) will lead to the need to increase the rates of the tank mix components so as to control efficiently the more developed weeds.

Table 2 presents the herbicide application data for each of the selected countries for the year 2000. Based on the area of sugar beet cultivated (Table 1), it can be calculated that the dose applied in 2000 was almost always greater than 1 kg a.i. ha⁻¹ for metamitron whereas use rates of the other products were under 0.5 kg a.i. ha⁻¹.

In many cases, the broad-spectrum herbicide glyphosate is sprayed pre-planting. A second application of glyphosate in the crop may be used to control specific weeds like weed beet and volunteer potatoes with special equipment. The importance of the pre-sowing treatment varies by country. It is important in Belgium and in the UK (37% and 44% of the cultivated area, respectively), moderately important in Germany, France, and the Netherlands (20%, 23% and 25%, respectively) and represents a very small market in Spain (10%).

Estimation of the potential penetration of glyphosate-tolerant sugar beets in each country

Together with the experts of the national sugar beet institutes, potential market penetration scenarios for glyphosate tolerant sugar beet in the six selected countries were established based on various types of weed infestation profiles.

The first was a “technical market” scenario where adoption would be exclusively linked to benefits at a technical level. Farmers taking up the technology would be those experiencing major problems of weed control (e.g. with weed beet and volunteer potatoes), phytotoxicity with the currently used active ingredients and/or soil erosion. The glyphosate-tolerant crops would allow these farmers to better control weeds while reducing crop damage. Furthermore, because the herbicide can be applied later than in standard weed treatment programs, fields maintain a vegetation cover longer, thereby contributing to the control of soil erosion and water loss. Also, herbicide tolerant systems provide a good opportunity to use integrated cover crops which reduce erosion significantly and can easily be managed with glyphosate.

The second scenario takes into account more subjective factors potentially influencing farmers to switch to glyphosate tolerant crop technology: ease of use, reduced number of products to apply and higher flexibility in application timing. This is referred to as the “potential market” scenario.

The third scenario assumes that all the cultivated sugar beet areas are converted to glyphosate-tolerant crops and is referred to as the “100% market” scenario.

Table 3 presents the results of the estimated market penetration for glyphosate-tolerant sugar beet under the three scenarios presented above. The size of the “technical market” varies from one country to the next: the mean over the six countries for 2000 corresponded to 56%, ranging from 31% in Belgium to 71% in the Netherlands. These estimations may change year by year, depending on the

Table 2. Main herbicides used in sugar beet cultivation in 2000 (tonnes active ingredient year⁻¹)

	Germany	France	UK	Netherlands	Spain	Belgium
Metamitron	984	544	158	164	142	79
Chloridazon*	254	169	142	–	39	155
Ethofumesate	207	114	53	56	87	37
Phenmedipham	104	113	80	25	19	31
Glyphosate	103	106	55	25	8	38
Lenacil	–	26	41	–	37	30
Quinmerac	42	49	–	–	–	2
Desmedipham**	35	–	6	4	15	–
Clopyralid	10	0.2	12	7	2	0.6
Others	14	19	10	8	0.8	20
TOTAL	1,753	1,140	557	289	350	393

* Chloridazon regained its registration in The Netherlands in 2002,

** Desmedipham is also used in Belgium as the formulation B Progress but only in very small quantities

intensity of the weed infestation problem. In 2000, the surfaces affected by hard to control weeds such as weed beet or volunteer potatoes were already large, *i.e.* approximately 27% of the cultivated area in France and more than 49 % in the UK and the Netherlands. This constitutes an important potential market for the glyphosate tolerant crop technology.

The mean “potential market” penetration over the six countries was 84% of the cultivated area, ranging from 71% in Germany to 100% in Spain. Since there are practically no technical limitations for the use of glyphosate tolerant technology in sugar beet cultivation (it can be used everywhere, whatever the type of soil or the climatic conditions), 100% adoption is not impossible. Nevertheless, the present evaluation tried to distinguish the areas where weeds were easy to manage (therefore not requiring the use of herbicide tolerant crops) and considered that farmers would not adopt the technology in the first years after its commercialization. Taking this into account, the “potential market” was higher than 80% in almost all the countries, except Belgium and Germany where weed infestations composed by *Chenopodium* sp., *Polygonum* sp. and *Galium aparine* occurred at low densities on 282,000 ha (around 60% of the cultivated area) and did not cause problems for weed control.

Herbicide quantity reduction

When translating the introduction of glyphosate-tolerant sugar beets into benefits for the environment relative to conventional beet cultivation, only the quantity of herbicide applied was taken into consideration. The obvious limitation of this approach is that no actual assessment of the environmental impact (dose *versus* effect) for the different products was made, but this was considered to be

beyond the scope of the present paper.

As described above, representative herbicide treatment programmes were established for conventional and glyphosate tolerant crop in each of the six countries studied based on various weed infestation profiles. By comparing the two types of programmes, it was possible to calculate the quantity of conventional herbicides that would be substituted by glyphosate in a herbicide tolerant system. This calculation was performed for the various scenarios: initial situation and technical, potential and 100% markets. Results are shown in Table 3.

A potential reduction of herbicide quantity was observed in each country for all scenarios. At a mean market penetration of 56% in the “technical market” scenario, the estimated total savings compared to conventional sugar beet treatments corresponded to 1.2 million kg a.i. for the year 2000. In the “potential market” scenario, with a mean market penetration of 84%, this value increased to 1.6 million kg a.i. per year. Finally, a complete switch to glyphosate tolerant technology (“total market” scenario) would potentially bring about an annual total saving of 1.9 million kg a.i.

The most important reductions would occur in Belgium and Germany, regardless of the scenario considered. The UK would follow more or less the German model for the first two scenarios but not for the “100% market” penetration scenario (UK maximum reduction 41% compared to 56% in Germany). The reduction in herbicide use for the other countries ranged from *circa* 20–30% for all scenarios considered.

Interestingly, herbicide quantity reductions were not always directly related to the surfaces planted with glyphosate tolerant sugar beet. The Netherlands (average a.i. 2.4 kg ha⁻¹) for example presented the largest potential market for glyphosate tolerant crops (between 70 and 90%)

GM CROPS

Table 3. Estimated market penetration for glyphosate tolerant sugar beet in the countries studied and volume of herbicide used for the different scenarios

Market scenario/ Country	Market penetration (% cult. area)	Herbicide use (tonnes a.i. year ⁻¹)			Reduction of total use compared to initial	
		Glyphosate	Other	Total	(tonnes a.i. year ⁻¹)	(%)
Initial						
Germany	–	103	1,650	1,753	–	–
France	–	106	1,034	1,140	–	–
UK	–	55	502	557	–	–
Netherlands	–	25	264	289	–	–
Spain	–	8	342	350	–	–
Belgium	–	38	355	393	–	–
Total	–	335	4,147	4,482	–	–
Mean	–	–	–	–	–	–
Technical						
Germany	45	376	862	1,238	515	29
France	66	541	344	885	255	22
UK	58	199	180	379	178	32
Netherlands	71	156	63	219	70	24
Spain	67	149	106	255	95	27
Belgium	31	47	227	274	119	30
Total	–	1,468	1,782	3,250	1,232	–
Mean	56	–	–	–	–	28
Potential						
Germany	71	575	433	1,008	745	42
France	90	734	126	860	280	25
UK	89	297	45	342	215	39
Netherlands	93	203	17	220	69	24
Spain	100	247	0	247	103	29
Belgium	75	110	75	185	208	53
Total	–	2,166	696	2,862	1,620	–
Mean	84	–	–	–	–	35
100%						
Germany	100	778	0	778	975	56
France	100	822	0	822	318	28
UK	100	330	0	330	227	41
Netherlands	100	216	0	216	73	25
Spain	100	247	0	247	103	29
Belgium	100	145	0	145	248	63
Total	–	2,538	0	2,538	1,944	–
Mean	100	–	–	–	–	43

but potential herbicide reduction was the lowest (20–25%). Belgium (average a.i. 4.1 kg ha⁻¹) had a low market penetration of the technology (31% in the “technical market”) but presented the highest herbicide reduction values in all scenarios. The most important reduction in herbicide use with glyphosate tolerant sugar beet occurred in the countries where the current average dose of herbicide was the highest.

Conclusions

According to the estimations made in this study, the introduction of glyphosate tolerance technology in sugar beet cultivation would lead to a reduction in herbicide use, since the mean was calculated to reach 28% for the “technical market” scenario, 36% for the total “potential market” scenario and could be as high as 43% for a “100% market” penetration. Even in the situations where reduction was the lowest, represented by France and the Netherlands, the herbicide consumption should be reduced by at least 20%. We have only taken into account the amount of active ingredients and not the reductions in mineral oil and adjuvant use, which can represent high values as well (Wevers, 1998b).

Acknowledgement

The authors would like to thank the experts from the sugar beet institutes in the selected countries for their active participation to this project. Mr. Muchembled from ITB, Dr. Petersen from IfZ, Dr. Ayala from AIMCRA, Mr. Hermann from IRBAB, Mr. May from IACR-Broom's Barn and Mr. Wevers from IRS. They provided valuable information and data on weed control in sugar beet and actively participated in the estimation of the various market penetration scenarios for glyphosate tolerant sugar beet.

References

- Brants, I.; Harms, H. (1998) Herbicide tolerant sugar beet. Proceedings of the 61st IIRB (Institut International de Recherches Betteravières) Congress, 11–12 February 1998, Brussels, 195–204.
- Buckmann, H.; Petersen, J. (2000) Weed control in genetically modified sugar beet - two year experiences of a field trial series in Germany. *Z. PflKrankh. PflSchutz. Sonderh. XVII*, 353–362.
- Dewar, A.; May, M.; Pidgeon, J. (2000a) GM sugar beet – The present situation. *British Sugar Beet Review*, Summer 2000, 68(2), 22–27.
- Dewar, A. M.; Haylock, L. A.; May, M. J.; Beane, J.; Perry, R. N. (2000b) Glyphosate applied to genetically modified herbicide-tolerant sugar beet and ‘volunteer’ potatoes reduces populations of potato cyst nematodes and the number and size of daughter tubers. *Annals of Applied Biology*, 136, 179–187.
- Fichet, Y. (1998) Cultures tolérantes au glyphosate: des bénéfices confirmés après plusieurs années de développement technique et commercial. 17^e Conférence de COLUMA, Journées Internationales de la lutte contre les mauvaises herbes, Dijon 9–11 December 1998, 203–211.

- Jensen, P. E. (1998) Dose requirements at chemical weed control in ordinary and glyphosate resistant beetroots. 15th Danish Plant Protection conference, Ministeriet for Fodervaren, Landbrug og Fiskeri, DLF report n°2, 115–123.
- Madsen, K. H.; Blacklow, W. M.; Jensen, J. E. (1996) Simulation of herbicide-use in a crop rotation with transgenic herbicide resistant sugar beet. Second International Weed Control Congress Copenhagen, 1996, 1387–1391.
- Mannelöf, M.; Tuveesson S.; Tenning P. (1997) Transgenic sugar beet tolerant to glyphosate, *Euphytica* 94, 83–91.
- May, M. J. (1996) Weed control in sugar beet. *The Agronomist*, Spring 1996, 4–5.
- Messéan, A. (2000) Les OGM : Avantage aux herbicides. *Cultivar le mensuel*, supplément au n°482 du 29 février 2000.
- Moll, S. (1997) Commercial experience and benefits from glyphosate tolerant crops. *The 1997 Brighton Crop Protection Conference – Weeds*, 931–940.
- Pedersen C.A. (1997) *Oversigt over Landsforsodene*, 237–238
- Schweizer, E. E.; Dexter, A.G. (1987) Weed control in sugar beets (*Beta vulgaris*) in North America, *Reviews of Weed Science* 3, 113–133.
- Schweizer, E. E.; May, M. J. (1993) Weeds and Weed control. In *The Sugar Beet Crop: Science into practice*. Eds Q.A. Cooke and R. K. Scott, London: Chapman and Hall, pp. 484–519.
- Tenning, P. (1998) Transgenic herbicide tolerant sugar beet – Present status and future developments. *Aspects of Applied Biology*, 52, 273–278.
- Wevers, J. D. A. (1997) Reduced environmental contamination by new herbicide formulations. Institute of Sugar Beet Research (IRS), The Netherlands.
- Wevers, J. D. A. (1998a) Agronomic and environmental aspects of herbicide-resistant sugar beet in Netherlands. *Aspects of Applied Biology* 52, 393–400.
- Wevers, J. D. A. (1998b) The environmental contamination of weed control in transgenic herbicide resistant sugar beet. *Proceedings of the 61st IIRB (Institut International de Recherches Betteravières) Congress*, 11–12 February 1998, Brussels, 365–367.

Brigitte Coyette, scientific coordinator, leading the Benefit and Stewardship team for Europe and working in the European environmental stewardship team, at Monsanto. Her background is a PhD in organic chemistry from the Catholic university of Louvain-la-Neuve in Belgium.

Francesca Tencalla is Environmental Specialist for the group of Scientific Affairs in Monsanto Brussels. Her background is a PhD in ecotoxicology from the Swiss Federal Institute of Technology (ETHZ) in Zürich, Switzerland.

Ir Ivo Brants. Agronomist from University of Leuven, Belgium (1980). Working at Monsanto (Belgium) with responsibilities in technical developments. Technical project leader for glyphosate tolerant sugar beet.

Yann Fichet, Agronomist from the Institut National Agronomique in Paris. Has been working in seeds, pesticides and GM crops in various aspects, including breeding, technical development, and regulatory affairs. Currently Product Development and Regulatory Affairs Director for Monsanto France.

Denis Rouchouze is a student in the agronomy school ENSAIA in Nancy, France.