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My view

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Biotechnology has produced transgenic herbicide-tolerant (tHT) crops that are tolerant to broad-spectrum herbicides such as glyphosate and glufosinate-ammonium. In the U.S. and Canada, several tHT crops are already grown on a large scale, e.g., glyphosate-resistant soybean, glufosinate-resistant oilseed rape, and bromoxynil-resistant cotton. tHT crops might be marketed in Europe in 2000.

Transgenic herbicide tolerance has aroused much debate in Europe. Elements of this debate in the Netherlands were analyzed in a Technology Assessment Program funded by the Dutch Ministry for Agriculture (Bijman and Lotz 1996). The following concerns were identified during the technology assessment: (1) there is uncertainty about the long-term agronomic and ecological effect of tHT crops; (2) growing tHT crops means a continuation of weed management strongly dependent on chemical weed control and may actually result in increased herbicide dependence; (3) successful introduction of tHT crops may lead to a slowdown in the development of innovative nonchemical weed control methods; and (4) there is a difference of opinion on the environmental quality of the herbicides for which tHT crops are being developed. The starting point in this debate is a Dutch policy document, called the Multi-year Crop Protection Program, which urges stimulation of the development of novel systems for crop protection that are less reliant on pesticide use. The plan aims to achieve an average pesticide use reduction of approximately 60% by 2000 compared with the mean use from 1984 to 1988. For herbicides, the reduction target is 40%.

In our view, growing tHT crops offers both advantages and disadvantages for agricultural practice and the environment. tHT crops may hold benefits for sustainable agriculture such as the following: (1) currently used herbicides may be replaced by more environmentally benign compounds; (2) these may contribute to integrated weed management by increasing the options for weed control. Risks of poor results of mechanical weed control, due to unfavorable weather, may be reduced by using a broad-spectrum herbicide. tHT crops fit well with the goals of site-specific management because preemergence would be replaced by postemergence treatments; (3) they rnay promote systems for minimal tillage and mixed cropping; and (4) they might lower the cost of weed control.

tHT crops threaten sustainable agriculture because they may: (1) decrease the number of herbicides available; (2) provide fewer incentives for the development of nonchemical weed control methods; (3) increase development of resistance in weeds; (4) change weed species composition or increase weed problems from volunteer crops; (5) result in new weeds through introgression; and (6) increase the amount of herbicide used.

Because tHT crops will inevitably be a part of weed management, we must accept the challenge of reaping the benefits as we work to avoid the disadvantages. This can be done by monitoring programs and by stimulating integrated weed management. At present, experiments with tHT crops in Europe have been limited to small-plot studies. Because there are no published records where crop rotation systems have been evaluated to determine the agronomic, economic, and environmental effects of tHT crops, case studies are urgently needed to explore in detail any risks linked to wide-scale use of tHT crops and their associated herbicides. In this respect, farmer and consumer perspectives and attitudes should also be assessed when considering the effect of this technology.

As a first step in these assessments, representatives of the Dutch Farmers Organization (LTO) were asked to comment on the aforementioned advantages and disadvantages. These farmers agreed with the above-listed advantages, though they asked if systems involving minimal tillage and mixed cropping were relevant to their current farming practices (where tillage and monocropping are widely practiced). They also indicated they would carefully follow seed prices of tHT crops, stating that at this moment it cannot be concluded that the weed control in these new crops will be less expensive. The concrete advantage farmers mentioned was that volunteer potatoes would be much easier to control in sugar beet than at present.

The farmers' representatives also agreed with the disadvantages, especially concerning a possible decrease in the number of herbicides available and an increase in the risk of resistance development in weeds and changes in weed

TABLE 1. Comparison of weed control in tHT silage corn with other weed control systems in this crop.

	Liberty link	Current	Adjusted dose	Organic
Compound	Glufosinate	e.g., metalochlor, atrazine + bentazon/pyridate	Atrazine, pyridate, rimsulfuron, bromoxynil	None
# treatments	2 (–3?) spray	1–2 spray	2 harrow, 1 spray	3–4 harrow/hoeing
g ai ha^{-1}	900	1,300–4,900	400–800	0
Weak control	ELYRE URTUR VIOAR GALAP	ECHCR SOLNI ELYRE Vol. potato	*Digitaria* sp. ATRPA	
$ ha^{-1}	150–175[a]	80–230	80–170	130–200

[a] Technology fee for the seed not included (still unknown).

species composition. They expect that weed control systems based on a single broad-spectrum herbicide like glyphosate or glufosinate will become less effective as the population size of tolerant or resistant species increases. In our view, this anticipated outcome is in line with changes in weed flora observed where repeated glyphosate use has been practiced. Since 1990, weed control on Dutch railways has relied on regular applications of glyphosate. The frequency and abundance of field horsetail (*Equisetum arvense*) and some other weeds have increased.

Using the best available farmers and expert knowledge, the expected herbicide use and economic results of weed control systems being developed in tHT sugar beet and silage corn were compared with current integrated management and organic weed control methods in the Netherlands (Table 1). We project that the profitability of weed control in tHT crops will improve over current systems. However, this benefit is small or not realized if the comparison is made with recently developed weed control systems in which a mixture of herbicides at low dosages is combined with mechanical weed control. The prospect of meeting the herbicide reduction targets of the aforementioned Dutch crop protection policy may be more likely with greater integration of already existing technologies of the kind described above. In contrast, if glyphosate and glufosinate are more environmentally benign than the other compounds, the effect of their use would be lower than more persistent compounds or those that are more toxic to nontarget organisms. A reasonable question is, whether or not in the long term glyphosate and glufosinate need to be combined with other herbicides to achieve acceptable control of weed species that are less susceptible to them. In that case, the environmental benefit will be, at least partially, lost.

We are concerned that until now in Europe, relatively little in the way of an open presentation of the facts on the technology of tHT crops and recently developed integrated weed control systems has been openly discussed in the scientific and farming communities. The pros and cons of tHT crops should be assessed in an independent way, in real crop rotations as soon as possible. In these assessments, weed scientists should intensively cooperate with the companies, farmers, consultants, extension specialists, and farm managers to collect and disseminate the required objective information to ensure that tHT crops will contribute to a more sustainable and economically sound agriculture. We have to realize that the question about long-term effects of tHT crops must be answered, insofar as possible, before these new crops are introduced. Information is lacking on the effects on total herbicide use, changes in weed flora and volunteer problems, effects of incorporating multiple herbicide resistance into a single cultivar, and availability of specific herbicides, especially for smaller hectarage crops. This lack of information will become more urgent when tHT crops, resistant to just one or two herbicides, are grown shortly after introduction on a very large scale, i.e., on a large area and during several years of the crop rotation. In the Dutch debate concerning tHT, various possible environmental side effects have been mentioned. These side effects are linked to use on a very large scale (e.g., on food webs and plant–pathogen interactions) and are therefore difficult to predict. It is for this reason that the Dutch Board for the Authorization of Pesticides has suggested that scenario and case studies are needed to comprehensively define the risks associated with wide-scale adoption of tHT crops and their associated herbicides. Further, these risks should be weighed against each other in the registration of the broad-spectrum herbicides associated with tHT crops. In our view, studies should be undertaken immediately to determine whether this suggestion of the Dutch Board for the Authorization of Pesticides will be justified by scientific results.

Literature Cited

Bijman, W. J. and L.A.P. Lotz. 1996. Transgenic Herbicide Resistant Crops. Technology Assessment Program, Rep. 7. The Hague: Ministry for Agriculture, Nature Management, and Fishery. 69 p. [In Dutch]