Impact of GMOs within cropping systems: towards a more systemic approach

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ABSTRACT

With the development of Genetically Modified Organisms in the field of agriculture, new concerns about environmental impact of novel plants and their crop management have been raised. It is determined that besides the typical case-by-case evaluation already implemented within the regulation process before marketing, a more systemic approach taking into account global, cumulative and long-term effects is required. Therefore, a French case report from a multi-year and multi-crop experimental study suggests that a challenge is open for science to design new methods and tools for assessing cost-benefit balances, providing adequate crop management guidelines and building new monitoring systems. These issues are presented and discussed through the herbicide tolerance trait.

Key words: GMO, landscape, gene flow, crop management

INTRODUCTION

Although gene flow is a common phenomenon for crop species, its implications for Genetically Modified Plants have raised new concerns. Gene flow for rapeseed occurs through pollen flow as well as through seed dispersal and GM rapeseed plants can persist over several years within and outside the fields where they are grown. Undesirable related effects result in **ecological** or **agronomic** considerations (persistence of resistant volunteers; creation of new weeds; multiple resistance) as well as **in commercial** considerations (unintended presence of GMOs in conventional rapeseed production affecting its competitiveness in the marketplace).

Although a large amount of knowledge is now available on the direct impacts of each GMO, it is necessary to address the interactions between GMOs within agricultural systems as well as their indirect and long-term effects. New methodological tools for assessing systemic effects within the diversity of environmental systems in which GMOs may be cultivated are thus needed.

Specific field experiments or studies have been carried out for addressing those concerns: pollen dispersion curves, ability for rapeseed to hybridize with wild relatives, etc. Nevertheless, they are not sufficient for taking into account the interactions between GMOs and some studies have been carried out in order to broaden the scope of the evaluation: the inter-institute platforms in France (Champolivier *et al.*, 1999) or the Farm Scale Evaluation programme in the UK (Firbank, 2003). Furthermore, for forecasting the spread and behaviour of transgenes and their impacts in a wide range of agro-ecosystems as well as for helping decision-makers to design scenarios, management rules and monitoring tools, modelling is a key element. For example, GENESYS®-rape aims at forecasting the effects, both in time and in space, of cropping systems and of rapeseed varieties on gene flow from rapeseed crops to rapeseed volunteers (Colbach *et al*, 2001).

A synthesis of results that came out from the multi-year and multi-crop experimental study in France is presented for the herbicide tolerant rapeseed case and is discussed in terms of rules for managing the introduction of GM rapeseed within agricultural systems.

MATERIALS AND METHODS

A monitoring study has been designed and implemented for various transgenic crops on three platforms located in different regions of France: Champagne, Burgundy and Midi-Pyrénées (South-West). Each platform has a 5 to 6 ha acreage and transgenic corn, rapeseed and sugar beet are cultivated under the current regional cropping system and practices. The transgenic traits considered are (i) Glufosinate and glyphosate resistance for corn, rapeseed and sugar beet and (ii) European Corn borer tolerance (using the Bt system) for corn.

The main observations carried out on rapeseed are (i) the persistence and fate of volunteers within the rotation; (ii) the detection of crop-to-wild hybrids by sampling wild relatives inside fields and within a 500-meter monitoring area; (iii) the short distance crop-to-crop pollen flow as well as (iv) the long distance pollen flow by surveying all commercial fields located at a distance between 400 m (isolation distance of the experiment) and 1,000 m.

This study has been carried out since 1995 through a wide co-operation including public research teams (INRA, University of Orsay), agricultural technical institutes (CETIOM, AGPM, ITB, ITCF) and competent authorities. A first report was issued at the end of 2000 within the framework of the French moratorium of herbicide tolerant traits for rapeseed and sugar beet (CETIOM, 2000).

RESULTS

Volunteers. Seed losses in the field (50 to 300 kg of seeds/ha, or 1100 to 6700 seeds/m² on average remaining on the plot at the time of harvest) is a well-known phenomenon that farmers already have to manage in conventional crops. However, herbicide tolerant volunteers can no longer be controlled by the herbicides to which they are tolerant even if conventional herbicides currently used would remain effective on these volunteers.

Seed dispersal outside fields. Seed dispersal outside fields through wind (short distances) and through machinery (over longer distances) results in a gene flow, particularly to non-cultivated areas located near the plots (edges of paths and roads). Genetic profiling of feral plants was carried out in a regional area (Center of France) and it was demonstrated that phenotypes corresponding to conventional varieties which had not been sold for at least 8 years could subsist there (Pessel et al., 2000). Even if these feral plants produce less pollen than cultivated fields, they do contribute to long distance dispersal of GMOs, particularly if selection pressure is favored by treating such areas with a broad-spectrum herbicide used alone.

Crop to crop gene flow between fields. Dispersion of pollen by wind and insects was mainly studied in continuous field conditions, both in specific experiments and in the platforms previously described. Results show that most of the pollen released remains within several meters of the emitting plant. At 30 m, less than 1 seed out of 100 bears this trait. At 120 m, less than 5 seeds out of 1,000 bear this trait. Observations of dispersal over long distances (between 400 m and 1,000 m) have been carried out. Results indicate that the dispersion of pollen becomes highly irregular but that tolerant seeds can be detected in most of the commercial fields that have been surveyed (from 0 to 1 seed out of 1,000 bearing this trait). Rates depend on the size of the emitting and receiving fields as well as the pattern of the landscape.

Crop to wild relatives gene flow. Under French conditions, it was established that rapeseed could hybridize with various species and, in particular, wild radish - *Raphanus raphanistr*um - and hoary mustard - *Hirschfeldia incana* –. At our platforms, we are surveying wild relatives and looking for crop to wild relatives gene flow. More than 75,000 seeds of wild mustard (*Sinapis arvensis*) have been collected, over a four-year period, from plants sampled inside the field where transgenic rapeseed is cultivated as well as in the monitoring area. None of them has become tolerant to the non-selective herbicides (CETIOM, 2000).

DISCUSSION

From the available results, it can be stressed that herbicide tolerant rapeseed cannot be cultivated without applying specific guidelines for crop management. However, and even if research is still required, specific crop management guidelines have been suggested in order to limit the undesirable effects by achieving two main objectives: (i) the development or extension of practices aiming at reducing, in time and space, the persistence of undesirable plants (volunteers and hybrids with wild relatives) and (ii) the avoidance of selection pressure on these undesirable plants.

Several mitigation measures have been defined for building crop management guidelines for herbicide tolerant rapeseed:

1) favor the immediate emergence of seeds remaining on the soil after harvesting in order to withdraw them from the seed bank: no tillage until the first rain then repeated minimum soil tillage avoiding seed dormancy;
2) increase control of rapeseed volunteers within the subsequent crops in order to reduce the seed bank;
3) avoid other crops resistant to the same herbicide within the rotation in order to make easier the control of tolerant volunteers in the subsequent crops;
4) organize the spatial location of crops through adequate isolation distances and/or through regional specialization;
5) and dedicate to tolerant crops the use of broad spectrum herbicides with their active matter used alone (glyphosate or glufosinate) and associate another active matter to these for their non-selective uses (pre-harvest applications, fallow land management).

These measures as well as other measures such as feral plants control within edges, set-aside management or cropping systems changes have been assessed, through simulations GENESYS®-rape, in terms of impacts on the co-existence between GMOs and non-GMOs (Angevin et al., 2002 and this IRC Conference). This effectiveness is highly dependent on the threshold level considered GMO adventitious presence in conventional products. Furthermore, the capability of the economic agents (farmers, co-operatives, agrochemical and seed companies) to carry out such measures and to co-operate has to be taken into account.

CONCLUSIONS

Results from various risk assessment studies suggest that, even there is no direct major ecological risk in the case of herbicide resistant oilseed rape, various agronomic and commercial concerns have been raised and specific crop management guidelines are required. Mitigation measures have been defined and are being evaluated in terms of efficacy to keep under control the unexpected or undesirable events as well as in terms of feasibility and acceptability. For such a perspective, specific fields experiments, modelling and large scale field surveys or monitoring are parts of a global approach. Indeed, models for forecasting the fate of transgenes at the landscape level by taking into account the various cropping systems and the agricultural practices are necessary for assessing the impact of introducing GM crops, for helping in the elaboration of co-existence rules as well as for assessing their feasibility and consequences or for setting up monitoring schemes.

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