Crop Management of Transgenic Rapeseed : Risk Assessment of Gene Flow

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The development of transgenic rapeseed raises several questions, most of them being non specific of recombinant DNA techniques : ethical concerns, relationship between science and society and organization of collective expertise, marketing of transgenic plants with new rules, protection of biotechnology and patent policy, food and feed safety of these novel plants, environmental and agronomic concerns. With respect to these last concerns, the evaluation has to be performed on a case-by-case basis. The risk assessment of gene flow must take into account the specific trait introduced (e.g. herbicide resistance vs oil quality), the biology of the plant (open vs self pollination, seed dormancy) and the agricultural context (cropping systems, spatial organization of the crops, agricultural practices, ...).

Herbicide resistance is not only one of the first traits for which marketing clearance has been required but it is also an adequate model to carry out the risk assessment of crop management of transgenic plants. In the case of rapeseed, gene flow can occur through two different ways :

* the pollen, either towards rapeseed plants (intraspecific crosses) or towards wild relatives which are quite numerous (interspecific crosses) ;

* the seeds, through volunteers in subsequent crops or seed dissemination during transportation.

The long-term effect of such phenomena on farmers' crop management of transgenic plants and the design of adequate agricultural practices are assessed by carrying out several types of studies :

* Modeling the gene flow. Models of gene flow between two adjacent fields have been designed (Reboud, 1992 ; Lavigne, 1994) and are being improved by taking into account crop rotations, spatial patterns of crops and agricultural practices.

* Specific studies about outcrossing have been performed in order to estimate pollination distances (Chèvre and Renard, 1995) and interspecific crosses (Jorgensen and Andersen, 1996 ; Keran et al., 1992 ; Eber et al., 1994 ; Baranger et al., 1995). Pollination distances are quite large and outcrosses with wild relatives like wild radish or wild radish can occur under natural conditions.

A multi-crop and multi-year monitoring study

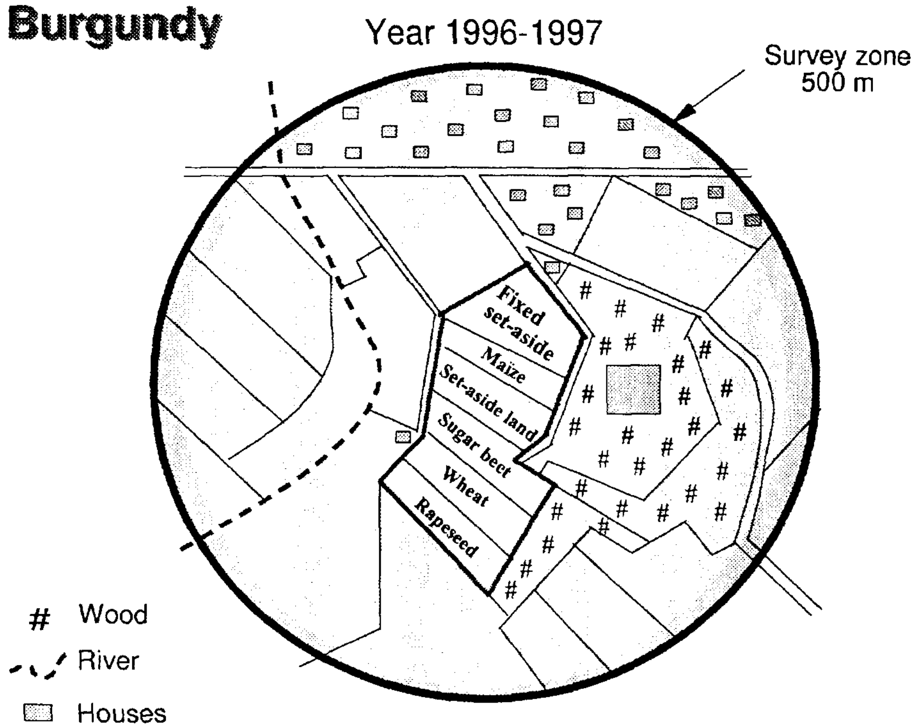
In order to assess the effect of such outcrossing under agricultural conditions, in 1995, we have designed and implemented a monitoring study for various transgenic crops on three platforms located in different regions of France : Champagne, Burgundy and South-West. Each platform consists of a 6 ha field where transgenic corn, rapeseed and sugar beet are cropped with the usual local cropping system (see figure 1). The transgenic traits are as follows :

* glufosinate and glyphosate resistance for corn, rapeseed and sugar beet ;

* bromoxynil resistance for rapeseed and corn borer tolerance (using the Bt system) for corn.

A 500 meter area around the field was defined and monitored in order to assess the spatial impact of transgenic crops.

Figure 1



Example of cropping system, Burgundy

Year 1995-1996	Set-aside land	Rapeseed	Wheat	Sugar-beet	Maïze	Fixed set-aside land (trefoil)
Year 1996-1997	Rapeseed	Wheat	Sugar-beet	Wheat	Maïze	Fixed set-aside land (trefoil)
Year 1997-1998	Set-aside land	Sugar-beet	Set-aside land	Rapeseed	Maïze	Fixed set-aside land (trefoil)

This three-year experiment aimed mainly at :

* assessing the impact of these transgenic crops when cultivated together in the same field area ;

* designing the weed control of volunteers in subsequent crops which are resistant to the same herbicide (e.g. glyphosate-resistant rapeseed volunteers in the subsequent sugar beet resistant to glyphosate) ;

* evaluating the multiple resistance rate when cropping two adjacent rapeseed fields with two different herbicide resistances ;

* estimating the interspecific outcrossing towards the wild relatives under real and local conditions and

* estimating the cost-benefit of herbicide resistance technology with respect to conventional techniques.

Outcrossing with wild relatives

Within the monitoring area, each wild relative plant of rapeseed was located and surveyed until seed maturity. The flowering period was observed and compared with the flowering periods of the transgenic rapeseed crops. Seeds were sampled for assessing the herbicide resistance which was checked by spraying herbicides after re-sowing. Table 1 gives the occurrence of wild relatives observed during the first year of the study (1996) : a plot represents one or several plant(-s) located at the same place.

IDENTIFICATION OF WILD RELATIVES IN 1996
Weed species and number of samples

	Rapeseed plot	Other crops and survey zone
Midi-Pyrénées	Sinapis arvensis - 1 Rapistrum rugosum - 35 Brassica nigra - 3	Sinapis arvensis - 4 Rapistrum rugosum - 1 Brassica nigra - 38 Sinapis alba - 21
Total	**39 samples**	**64 samples**
Burgundy	Sinapis arvensis - 12	Sinapis arvensis - 30 Rapeseed volunteers - 1 Arabidopsis thaliana - 1 Capsella bursa pastoris - 1
Total	**12 samples**	**33 samples**
Champagne-Ardennes	No compatible weed	Rapeseed volunteers - 20 Sinapis arvensis - 5 Sinapis alba - 4 Raphanus raphanistrum - 1
Total	**0**	**30 samples**
	51 samples	**127 samples**

Preliminary results indicated that no resistance with wild mustard and other mustard species occurred during this first year. Unfortunately, wild radish was not present in our situations and specific location sites should be looked for. The following years will allow us to increase the precision of the estimated frequency of outcrossing.

Multiple resistance

The three herbicide resistant rapeseed varieties were cropped in adjacent fields and double resistant plants were detected in two different ways :

* by applying the herbicides on volunteers whose emergence occurred after harvesting ;

* by sampling seeds and re-sowing using a specific design of experiments and direct application.

Both methods gave similar results with respect to the rate of double resistance. Although the results are depending on the variety, the average rate of double resistance can be estimated under our specific conditions : about 2 % at a one meter distance, 0.2 % at 20 meters and less than 0.01 % at 65 meters. Although further data are still required, these results seem to indicate that multiple resistance should probably be the major concern for farmers rather than interspecific crosses.

Conclusion

The preliminary results obtained during the first year of the project confirmed what was expected from previous studies. They have been obtained under current farmer practices and provided data which will be used to fit simulation models for gene flow. Further location sites will be necessary in order to enhance the range of agricultural conditions and observations of long-term effects will require several years. Practical recommendations for crop management by farmers are expected.

Bibliography

REBOUD X. Les risques associés aux manipulations génétiques : le cas de la résistance aux herbicides. Thèse INAPG, 1992 (62 p.)

KERLAN M.C., CHEVRE A.M., EBER F., BARANGER A. & RENARD M. 1992. Risk Assessment of outcrossing transgenic rapeseed to related species : I. Interspecific hybrid production under optimal conditions with emphasis on pollination and fertilization. in :*Euphytica* 62 : 145-153.

EBER F., CHEVRE A.M., BARANGER A., VALLEE P., TANGUY X., RENARD M. 1994. Spontaneous Hybridization between a male sterile oilseed rape and two weeds. in : *Theor. Appli. Genet.* 88 : 362-368

BARANGER A., CHEVRE A.M., EBER F. & RENARD M. 1995. Effect of Oilseed rape genotype on the spontaneous hybridization rate with a weedy species : an assessment of transgene dispersal. in : *Theor. Appli. Genet.* 91 : 956-963.

JORGENSEN R.B., ANDERSEN B. 1996. Spontaneous Hybridization between oilseed rape (*Brassica napus*) and weedy relatives. in : *Acta Horticulturae*. Vol. 407, pp.193-200.

LAVIGNE C., GODELLE B., REBOUD X. & GOUYON P.H. 1996. A Method to determine the mean pollen dispersal of individual plants growing within a large pollen source. in : *Theoretical and Applied Genetics*, Vol. 93, n° 8, pp.1319-1326.

MIKKELSEN T.R. & ANDERSEN B. The Risk of crop transgene spread. in : *Nature*, March 7, 1996, Vol. 380 (p.31).

TIMMONS A.M., CHARTERS Y.M. & CRAWFORD J.W. Risks from transgenic crops. in : *Nature*, April 11, 1996. (p. 487).