Coexistence of Rapeseed Varieties in Time and Space: Using GENESYS Model to Adapt Cropping Systems

Frédérique Angevin[1*], Nathalie Colbach[2], J.M. Meynard[3]
[1] INRA Génétique et Amélioration des plantes, BP 01, 78850 THIVERVAL-GRIGNON, France, angevin@jouy.inra.fr
[2] UMR Biologie et Gestion des Adventices, INRA, BP 86510, 17 rue Sully, 21065 DIJON Cedex, France, colbach@dijon.inra.fr
[3] UMR d'Agronomie, INRA INA P-G, BP 01, 78850 THIVERVAL-GRIGNON, France, meynard@grignon.inra.fr

ABSTRACT
Gene flow among and between cropped and/or volunteer rape plants is frequent. If GM and non-GM rape varieties co-exist, the adventitious presence of GM seeds in non-GM harvests cannot be avoided. To study this phenomenon, the GENESYS model was developed which quantifies the effects of cropping systems (field patterns, crop rotation, cultivation techniques, rape varieties management of road margins) on gene escape from rape varieties to rape volunteers, in time and in space. This model was used in a prospective study to evaluate the consequences of the introduction of GM crops in European production systems. Presence of GM seeds in hybrid seed production and in non-GM rape harvest was simulated for intensive and organic farms. Changes in agricultural practices were simulated to identify those limiting gene flow and making the co-existence of different varieties feasible.

Key words: GM crops – model – gene flow – farming systems – agricultural practices

INTRODUCTION
Gene flow within and between oilseed rape populations located in cultivated fields and/or uncultivated road- and field margins is a common phenomenon. Pollen dispersal between rape fields cultivated with different varieties results in adventitious presence of unwanted genes in rape harvests. Seed loss before or during rape harvests leads to rape volunteers emerging in subsequent crops where they cause yield loss (winter cereals) or decrease harvest quality (rape). These processes are crucial when different rape varieties co-exist in a region and their harvests must meet high quality standards (e.g. fatty acid content). The same will be true if genetically modified and conventional varieties are to co-exist and the conventional harvests contain less than 0.9% of GM seeds.

As gene flow occurs over several years and large distances, it cannot be solely evaluated by field trials. Consequently, we developed a model quantifying the effects of cropping systems on gene flow from rape crops to rape volunteers, in time and in space (Colbach *et al.*, 2001). This model was used to in a prospective study to evaluate the consequences of the introduction of GM crops in European production systems and to assess whether changes in cultural practices could make the co-existence of different varieties feasible (Angevin *et al.*, 2001).

MATERIALS AND METHODS
The GENESYS model. Its aim is to evaluate the effect of cropping system and rapeseed varieties on gene escape from rapeseed crops to rapeseed volunteers in neighbour plots and in subsequent crops. The input variables of the model are (1) the regional field pattern comprising waysides, field edges and fields; (2) the crop succession of each field; (3) the agricultural practices used to manage each crop (stubble breaking, tillage, sowing date and density, herbicides, harvest conditions) and (4) rapeseed variety characteristics (genotype, self-pollination rates, differences between GM and non-GM varieties in pollen emission and yield). The main output variables are, for each year, adult rapeseed plants, newly produced seeds and seed bank. For each of these variables, the density of individuals and their genotypic proportions are given. The model describes the annual life-cycle of volunteer or cropped rapeseed plants, which is simulated for each plot and year. It comprises seed banks, seedlings,

adult plants, flowers, pollen dispersal, newly produced seeds and seed dispersal. These stages depend on crop type and management. Pollen and seed exchanges between plots depend on plot areas, forms and distances as well as on flowering dates. The model is presently being evaluated. The first results show that it correctly ranks cropping systems according to their rapeseed volunteer infestation. However, pollen and seed dispersal is frequently underestimated and this must be kept in mind when analysing the results.

The simulated farms. An expert panel designed farms representative of the chosen production areas. Each farm was defined as a combination of a typical field pattern (Fig. 1), agricultural practices and farm equipment and several levels of intensification were studied. Table 1 describes the farming practices of the intensive farms 1 and 3. The remaining farms (2, 2a and 4) were organic farms. Their practices differed in three points: the second winter wheat of the rotation is replaced by a spring barley, fields were tilled with a mouldboard plough and herbicides were replaced by mechanical interventions killing 40% of the volunteers, regardless of genotype. Farms 3 and 4 used farm-saved seeds for rape crops, the other farms certified seeds. No GM crops were cultivated on the farms; 50% of the off-farm rape was GM.

These farms and cropping systems were simulated for 13 years with the model and the resulting proportion of GM seeds (hence "harvest pollution") in hybrid seed production and in non-GM rape harvests analysed. In a second step, changes in the farming systems were simulated and their effect on harvest pollution analysed.

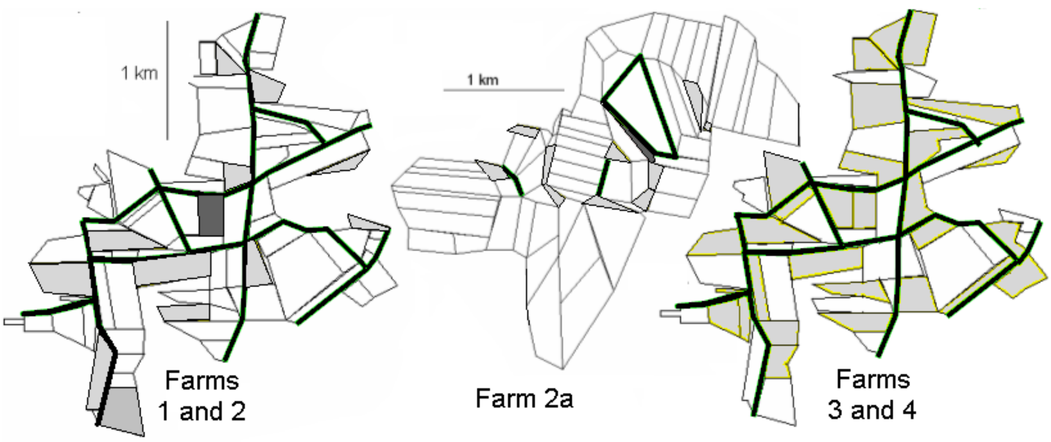

Fig.1. Field patterns of the simulated farms. Fields in grey belong to the analysed farms, dark-grey ones are used for hybrid seed production every 7 years, thick lines are roads with borders.

Table 1. Cultivation techniques used to manage crops and borders on intensive farms using a rape/winter wheat/winter wheat/set-aside/rape/winter wheat/spring barley rotation.

Crop	Stubble breaking	Soil tillage	Sowing date	Sowing density (seeds /m²)	Cutting	Herbicides kills	Herbicides mortality	Harvest loss
Border					none			
GM rape	yes	chisel	30 Aug.	70		GM plants	95%	5%
NGM rape	yes	chisel	30 Aug.	70				5%
seed rape	yes	chisel	30 Aug.	70				5%
winter wheat	yes	chisel	3 Oct..	350		all plants	95%	
spring barley	yes	chisel	1 March	350		all plants	95%	
set-aside					mid-April			

RESULTS

When analysing harvest pollution on the various farms, field size was revealed as the dominant factor. Small fields as on farm 2a were very sensitive to GM pollen inflow whereas the large fields of farms 3 and 4 were only slightly polluted, despite their using farm-save instead of certified seeds. The lower efficiency of mechanical volunteer control of the organic farms led to a slight increase in harvest pollution compared to the intensive farms 1 and 3. Risks of adventitious contamination highly depended on the rapeseed varietal type. Whatever the farm, the pollution rate of hybrid seed production exceeded the 0.3% threshold proposed by the EU for conventional seeds. Therefore, coexistence rules should be more drastic than for conventional varieties. Among the large range of simulated changes in the cropping system, only a few led to a sufficient decrease in harvest pollution of hybrid seed production (Table 2). These comprised aspects as diverse as ploughing before rape crops, systematic cutting of borders or adding spring crops to farm rotations.

Table 2. Simulated effect of changes in cropping system on rate of varietal impurities in hybrid seed production for intensive farm 1 (relative values).

Simulation	Relative rates
Basic system (Table 1)	1
Harvest loss in rape crops: 10% vs 5%	1.15
Farm seeds vs. certified seeds	4.025
Tillage before rape: *plough vs. chisel*	0.725
before other crops: plough vs. chisel	1.975
Rape sowing: early non-GM + late GM vs. simultaneous	3
late non-GM + early GM vs. simultaneous	0.275
Border cutting: mid-April vs. uncut	0.625
Border herbicides: glyphosate vs. none	14.9
Set-aside: spring sown vs. unsown	**0.025**
Rotation: spring barley added	0.425
Crop location: fields with past rape >200m vs.0 m	**0.015**
Farm field location: clustered vs. dispersed	**0.025**

DISCUSSION

This study showed the difficulty to extrapolate results to other agricultural contexts and consequently, the importance of adapting co-existence guidelines to production region. It led to the creation of a multi-disciplinary project funded by the French Research Ministry, of which the aim is to design a methodology to describe generic landscapes representative of agricultural regions to be used as input data for gene flow models. This study also underlined the need of cooperation among neighbour farmers in order to make recommended practices efficient. Co-existence implies a change in decision rules: guidelines should be designed not only at field scale but also at the farm and production basin scales.

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REFERENCES

Angevin F., Colbach N., Meynard J.M., Roturier C., 2001. Analysis of necessary adjustments of farming practices. Study for the ESTO Project “Scenarios for co-existence of genetically modified, conventional and organic crops in European agriculture”, Final report, 117 p.

Colbach, N., C. Clermont-Dauphin, and J.M. Meynard, 2001a: GENESYS: A model of the influence of cropping system on gene escape from herbicide tolerant rapeseed crops to rape volunteers. I. Temporal evolution of a population of rapeseed volunteers in a field. Agric. Ecosyst. Environ. 83, 235-253.

Colbach, N., C. Clermont-Dauphin, and J.M. Meynard, 2001b: GENESYS: A model of the influence of cropping system on gene escape from herbicide tolerant rapeseed crops to rape volunteers. II. Genetic exchanges among volunteer and cropped populations in a small region. Agric. Ecosyst. Environ. 83, 255-270.