The co-existence between GM and non GM oilseed rape: identification of critical points in two European contrasted regions

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Abstract

The implementation of the European regulation on co-existence between GM (genetically modified) and non GM crops is critical in the case of oilseed rape. Admixture can occur in the field, due to cross pollination and volunteers, and after harvest, due to grain transport and storage. We started from the hypothesis that such problems depended on the local context, including farm types, landscape, cropping systems, and the infrastructure for storage and transport of seed. In that case, co-existence should require adapted solutions. The methodology to test this hypothesis included three steps: (1) two contrasted European regions were described via existing databases and surveys on farms; (2) for each region, a gene flow simulator predicted the admixture between GM and non GM oilseed rape in real landscapes, in the case of GM introduction: the simulator quantifies spatial and temporal gene flow via pollen dispersal and seed persistence as a function of cropping systems; (3) results were discussed by local actors (farmers, private contractors, cooperatives, grain merchants) in order to identify the critical points. This methodology allowed us to analyse how the constraints for the management of co-existence varied between each region but also within each of them. The results will be used in further studies on the elaboration of scenarios for co-existence.

Key words: oilseed rape, genetically modified, co-existence

Introduction

The European Regulation about cultivation of GM crops calls upon member states to implement co-existence rules in order to allow freedom of choice for both consumers and farmers [6, 7]. The rules should ensure that no economic damage would arise from admixture between GM and non GM products all along the food supply chain. Labelling and traceability are required to inform the consumer whether the final product contains GM ingredient above 0,9% or not [9, 10]. The case of oilseed rape (OSR) is critical as gene flow can occur in cropping systems via both cross pollination and the persistence of viable seeds in soil during several years [8]. Field patterns and characteristics of cropping systems could influence these events [2, 3], and we started from the hypothesis that the achievement of co-existence and efficient complementary measures would depend on the local context.

Material and methods

In order to test this hypothesis, we compared two regions offering contrasting characteristics influencing gene flow: the "Beauce Blésoise" in France, and "Fife county" in Scotland. The methodology was based on the use of the gene flow simulator GENESYS [1, 4, 5] to assess the feasibility of co-existence in realistic landscapes without specific measures like isolation distances. The simulator quantifies spatial and temporal gene flow via pollen dispersal and seed persistence as a function of cropping systems in agricultural regions of a few km². It uses the following inputs: the field pattern consisting of fields and uncultivated road verges; crop succession and agricultural practices (e.g. tillage, sowing date and density, herbicide treatments, cutting or grazing in pastures, seed loss at harvest for OSR…); the management of road verges; characteristics of the OSR varieties; daily temperatures and latitude.

The first step consisted of gathering data to describe whole regions and simulation areas within each of them. We extracted information from national databases to get land occupation, farm types and climate at the regional level. For each simulation area, we obtained field maps showing fields occupied by different crops in a single year. Surveys gave information about current crop rotations and agricultural practices for each farm of the simulation area. Two kinds of simulation were carried out: (1) co-existence during 20 years between cropping systems supporting GM or conventional non-GM OSR, focusing mainly on spatial aspects where a conventional OSR cannot be grown after a GM OSR. Cropping systems with GM OSR were randomly allocated to field aiming at introduction rates of 10, 50 and 75% of total OSR area (30 replications); (2) reconversion to conventional OSR after 20 years of GM OSR cultivation on three similar landscapes, focusing on temporal aspects. These simulations did not take into account any specific measures to avoid gene flow. Nevertheless, we made complementary simulations with the Beauce area in order to assess the weight of key variables in this specific context, by modifying the corresponding practices independently from each other (soil tillage, herbicide efficiency, seed purity, seed loss and field margin management). All simulations were carried out with pure seeds, and varieties were considered isogenic. Two output indicators were calculated for each simulation: the GM content of the total conventional OSR harvest (recorded at the "landscape level"); the percentage of conventional OSR area exceeding the 0,4% threshold ("field level"). This threshold, more severe than 0.9%, has been chosen in the calculation in order to take the underestimation of geneflow by GENESYS into account [1]. Results were used in a working group in Beauce including researchers and professional partners (farmers and country elevator managers) to identify critical points for the management of co-existence.

Results

The two regions differ by many characteristics (Table 1). Field patterns, densities of OSR and frequencies of OSR in the rotations indicate that Beauce cropping systems would be more sensitive to gene flow than Fife systems, confirming the choice of contrasted regions. The main characteristics of each simulation areas are summarized in Table 2. As the Beauce region shows a great variability, we chose a simulation area maximising the risk of gene flow (high OSR density and small fields belonging to scattered farms), in order to increase management difficulties to a maximum. In the same way, the OSR density on the Fife area would ensure higher risks than on the whole region.

Table 1: Main characteristics of each region (source: [11])

Name	Beauce Blésoise (France)	Fife county (Scotland)
Definition	intersection between Loir et Cher department and "Beauce" natural region (159 km²)	administrative unit (134 km²)
Coordinates	47°37' N 1°18' E	56°10' N 3°05' 0
Inhabitants / km²	32	264
Agricultural area / total	75%	74%
Arable crops / agricultural area	97%	49%
%OSR in agricultural area	13%	4%
Average farm area	95 ha	71 ha (93 ha for farms above 20 ha)
Field patterns	High diversity: scattered farms with small fields vs. aggregated farms with large fields	Large aggregated farms ("holdings") coexist with non professional small farms
Farm type	cash crops (cereal, seed production, protein and oil)	mixed (cash crops with livestock)
Main cropping systems	3-year rotation (OSR/wheat/wheat) and more diversified rotation with spring crops and/or seed production	diversified rotation based on wheat, possibly including potatoes or temporary grass
Grain collect	One cooperative dominates the local market. Little storage on farm	Storage on farm and sale to private companies

Table 2: main characteristics of the simulation areas

Area	Beauce	Fife
Area (ha)	243	768
Field area (ha)	1.97 ± 1.46	7.0 ± 6.0
Number of fields (for crop only)	125	105
OSR area / total area (20 years)	21%	11%
Cropping systems	OSR followed by 2 or 3 cereals; in some cases: spring crops; no set aside	diversified rotations possibly including set-aside, temporary grass (3 years), potatoes; permanent pastures
Delay for return of OSR in rotation	3 or 4 years	4 years or more
Soil tillage	4 to 6 tillage operations Occurrence of mouldboard ploughing depends on the farmer, the previous crop	Mouldboard plough + rotary harrow in all situations

Simulations show that risks depend on the indicator we consider (Figure 1). Risks are very low at the landscape level in both cases when the GM introduction rate is below 50%: without specific measures for reducing gene flow, quality standards could be reached for conventional OSR if harvests from the all different fields are mixed. In contrast, the risk of a given field being downgraded (i.e. presenting a harvest impurity rate exceeding the 0.4% threshold) is real in all situations. The Beauce area is far more sensitive to gene flow than the Fife area under these dissemination schemes. Yearly boxplots show that results from the first and the last years to be similar (not shown) which indicates that cumulative effects are negligible when considering the 0.4% threshold. Distance between GM and conventional OSR is the main factor explaining harvest admixture. All the conventional fields exceeding the impurity threshold are adjacent to GM fields.

At the field level, reconversion to conventional OSR after 20 years of GM varieties in cropping systems is risky during the first four years after the conversion in both cases (Figure 2). At the landscape level, periods when harvest could be above the threshold are two years for Beauce or four years for Fife. Additional simulations with the Beauce area show the contribution of various practices applied individually to be negligible in case of co-existence: the management of road verges, herbicide efficiency in cereals or OSR sowing dates have little impact on gene flow. In contrast, mouldboard ploughing after OSR, minimum tillage in summer, high seed loss before or during OSR harvests and seed impurity (use of farm-saved seed or impure certified seeds) increase risks of admixture.

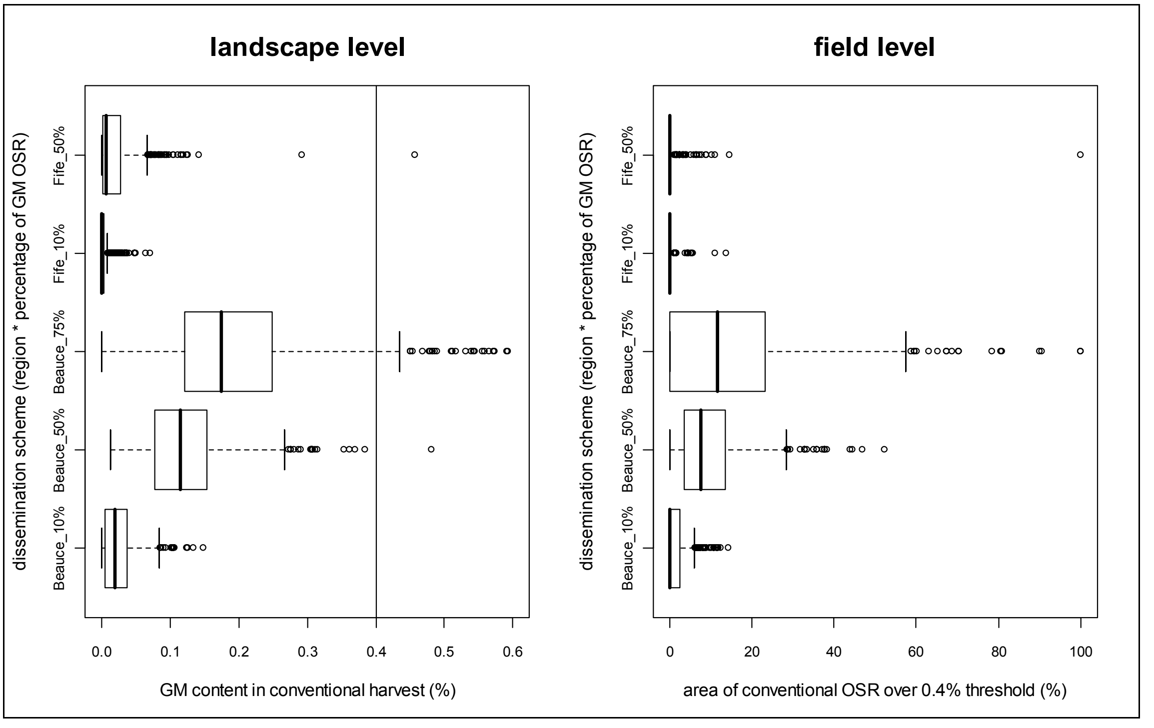

Figure 1: Above labelling threshold area and GM content in conventional OSR harvest in different dissemination schemes. Each boxplot summarize 600 points (30 simulations * 20 years, distributions inside boxplots do not depend on the year). For Beauce 75% and Fife 50%, the low number of field numbers with conventional OSR resulted in stretched distributions (Beauce 75% : 0 to 15 fields by year (median=6); Fife 50% : 0 to 11 fields (median=5)). The 0.4% threshold corresponds to the 0.9% labelling threshold after correction.

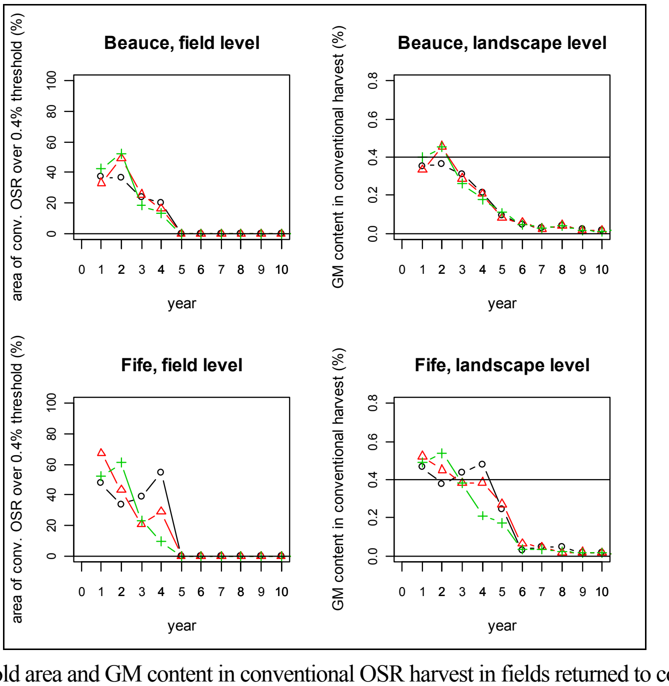

Figure 2: Above labelling threshold area and GM content in conventional OSR harvest in fields returned to conventional OSR after 20 years cultivation with GM OSR. Three similar landscapes were simulated for each case. The 0.4% threshold corresponds to the 0.9% labelling threshold after correction.

The working group in Beauce contributed to the identification of critical points. The participants already have their own experience with co-existence, because they deal with grain quality management in cereals (mycotoxins) or OSR (both “00” for food and high-erucic rape for industry are grown in the region). That is why their discussions were influenced by these concepts. The participants estimated that volunteer management was a major issue which was consistent with simulation results showing harvest impurity to be largest in reconversion scenarios. The participants also emphasized other issues not taken into account by GENESYS such as seed loss during transport from trucks or harvest combines. The question of silo versus field management was strongly discussed (i.e. is the labelling threshold a compulsory objective for all the fields or only for the silo?). For an introduction rate under 50%, management at the silo level would be easier, but this raises the question of lack of incentive for good management practices at the field level. One key factor was said to be the analytical ability to identify GM impurity at the field level (feasibility, delay and costs).

Discussion

Concerning the first set of simulations ("spatial" co-existence), the simulated practices may explain the low cumulative effects over the years. On both simulation areas, volunteers are well controlled in cropping systems. As part of this control, agronomic set-aside is well managed (Fife) or replaced by OSR as set-aside for industry (Beauce).

Simulations show that the feasibility of co-existence with a 0.9% impurity threshold would depend on (1) the management level (silo/field) (2) on the dissemination scheme (reconversion to conventional OSR allowed or segregated fields dedicated to GM varieties) (3) on the region. Co-existence without alternating GM and non-GM varieties on the same field could be achieved in both regions at the silo level without specific measures, even for GMO introduction rate below 50%. Above this rate, management measures at the field level would be necessary in Beauce. These measures could be preventive (e.g. distancing GM and non-GM varieties) or curative (e.g. discarding part of the non-GM field by harvesting polluted buffer strips separately). In case of reconversion to conventional OSR, the first conventional harvest would be susceptible to be downgraded. Measures like reducing harvest seed loss by adapted practices or machinery, adapted soil tillage or mechanical weeding in OSR could decrease this risk. Differences between regions appear at the field level where risks are higher in Beauce, mainly because of the larger OSR density in the landscape. However, the longer rotations in Fife did not make reconversion to conventional easier.

Simulation results need to be interpreted carefully. First of all, we assumed that sown OSR seeds were pure. Moreover, the present results concern small areas and thus raise the question of upscaling. As regions are not homogenous for cropping systems, gaining knowledge at this larger scale is necessary whether the simulation results can be extrapolated to whole regions. In the present study, we considered that extrapolating the simulation results from the sample areas to the whole regions would lead to overestimating the risks at the regional level. On the other hand, other dispersal processes were neglected in the GENESYS simulations, particularly on farm and during grain transport. Other extra agricultural criteria may also play a role, for example any difficulties in social acceptability of co-existence.

Acknowledgments

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