Crop management for optimal low-linolenic rapeseed oil production Field experiments and modelling

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Abstract

Oil of conventional rapeseed varieties with 7-10 % linolenic acid content can be oxidized when heated, resulting in unpleasant odour. Varieties with low (around 3 %) linolenic acid content have been bred to provide industries with new raw material for frying media production.

However, the low-linolenic character can be compromised if the low-linolenic rapeseed field is polluted by conventional varieties through pollen flow or volunteers. Therefore, harvest quality can be compromised by i) nearby fields of conventional oilseed rape, ii) volunteers of conventional rapeseed growing in a low-linolenic field or in nearby fields. Crop management practices as crop rotation, weed control, soil tillage, varieties and field pattern might be decisive.

The Genesys model (Colbach *et al.,* 2001) was initially developed to quantify the effects of cropping systems on gene flow between Genetically Modified (GM) and non-GM crops. In this work, the model was used, after adequate improvements, to predict linolenic content of rapeseed harvests, particularly low-linolenic ones, in different situations.

Field experiments carried out at the experimental station in Changins (VD), Switzerland in 2004 and 2005 and observations made on farmers fields showed that beyond 50 meters of distance, a field of conventional rapeseed caused only a minor increase in C18:3 content of a neighbouring low-linolenic rapeseed field. After 20 meters, contamination estimated from linolenic acid increase was about 1%. According to simulations, the presence of volunteers of conventional rapeseed in the low-linolenic field had the most dramatic effect: in a short crop rotation an important amount of volunteers significantly increased the linolenic acid content. In Switzerland, oilseed rape is usually grown with a longer interval than every four years in normal crop rotations, which is usually enough to prevent major contamination by volunteers if the latter are correctly managed. It is however important to be very cautious not to mix seeds of low linolenic rapeseed with conventional rapeseed before sowing or during and after harvest.

Key words: alpha-linolenic acid content, model, gene flow, crop management practices

Introduction

Rapeseed oil, rich in polyunsaturated fats and especially alpha-linolenic acid (7 to 10%) is easily oxidized when heated and therefore not suitable for deep-frying. New varieties with reduced linolenic acid content (around 3%) have been bred to provide industry with a better raw material for the production of frying media. To avoid hydrogenation, industries need oil with linolenic acid content as low as possible.

As low-linolenic and conventional rapeseed varieties coexist in agricultural regions, both are submitted to contamination through seeds or pollen. The presence of conventional rapeseed seeds in low linolenic fields can considerably increase the linolenic acid content. Therefore, harvest quality can be compromised by i) pollen of nearby fields with conventional oilseed rape, ii) volunteers of conventional rapeseed growing in a low-linolenic field or in nearby fields. The GeneSys model (Colbach *et al.,* 2001) was initially developed to model the effects of crop rotation and management on gene flow and the consequences of an eventual coexistence between GM and non-GM crops. In our study, this model was used to predict the consequences of various cropping systems on the final linolenic acid content of the crop.

Materials and methods

Field experiments

Effects of cross-pollination

Field experiments were carried out at the Changins experimental station (VD, Switzerland) in 2004 and 2005. Each year, a conventional rapeseed field was deliberately sown next to a low-linolenic field to test the impact of cross-pollination on linolenic acid content. In 2004, the low-linolenic field was divided into small plots (4.5m X 15m) harvested and analysed separately. In 2005, samples were harvested at 0, 5, 10, 20, 30, 40 meters from the edge of the conventional field, with four replicates. The analysis of linolenic acid content of each plot/sample gave the gradient of linolenic acid content in the low-linolenic field.

Effects of volunteers

Fields were sown with a mixture of low-linolenic (Splendor) and conventional rapeseed variety (Express in 2005, Talent in 2006) in order to evaluate the consequences of volunteers in a field. The proportion of the 2 varieties ranged from 0 to 100% with 3 replicates of each treatment. Each plot (2.25*15m) was surrounded by pure low-linolenic (Splendor) plots to minimize pollen contamination.

After harvest, a sample of each plot was dried 24h at 60°C then fatty acid profile was determined by gas chromatography.

Contamination rate

The calculation of linolenic acid content contamination rate in rapeseed oil as well as linolenic acid content from simulated contamination was based on following assumptions: 1) In our study, gene flow was the only factor influencing linolenic acid content. 2) Reference values for linolenic acid content of low-linolenic and conventional varieties exist and are valid for the local conditions. We chose as reference for low-linolenic acid content, the value obtained for the best-isolated part of the same field (same climatic conditions, same crop management) and we assumed that the volunteers have no significant effect, compared to cross-pollination). 3) As was demonstrated by Jourdren *et al.* (1996) for the cultivar Stellar, we assumed that the inheritance of the low linolenic trait is controlled by at least two genes with additive effects.

The model

The details of the model are given by Colbach et *al*. (2001a, 2001b). For each field, the model estimates the pollution rate, i.e. the proportion of high- and low-linolenic genotypes. Input variables consist in the field pattern of the simulated area comprising both fields and uncultivated areas such as road margins, the crop rotation for each field, crop management practices and rapeseed varieties characteristics. The variables influence the annual life-cycle of both crop and volunteer plants. In addition to the number of individuals at each stage, the model calculates the genotype proportions resulting from the genes coding for linolenic acid. During flowering and seed production, the various life-cycles connect, leading to pollen and seed dispersal. In the past, the model had been evaluated in farmers' fields and on several experimental stations (Colbach et al., 2005). In the present paper, the model was tested by comparing its simulations of linolenic acid content to field trial results, and then used to run simulations.

Results and discussion

Contamination from neighbouring fields grown with conventional rapeseed

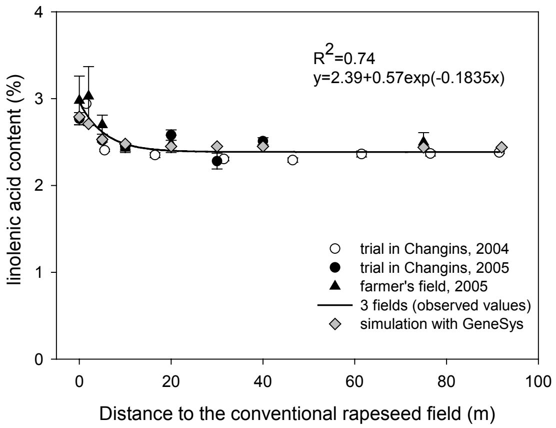

Fig1: Effect of the distance to a contaminating high-linolenic rapeseed field on linolenic acid content of a low-linolenic field. 3 locations + simulated values. Error bars = standard error (n=4)

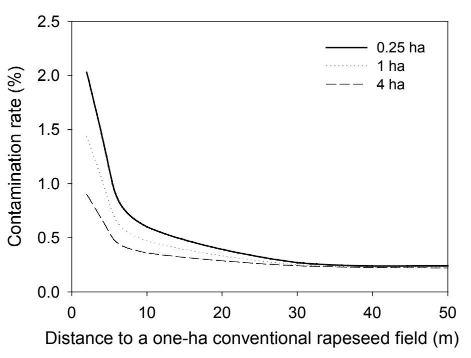

Fig2: Simulation of the contamination rate in a low-linolenic field according to its size and to the distance to a one-ha conventional rapeseed field. A- Schema of the simulated fields. B - Simulation by GeneSys.

Linolenic acid content was highest at the edge of low linolenic fields but decreased sharply with the distance, to reach the minimal value after about 30 meters. The model confirmed this trend (fig 1). The results of the model considerably depend on the values chosen for the lower and upper limits of linolenic acid contents, i.e. the value for uncontaminated low-linolenic and conventional varieties. We used in our simulations the value measured in Changins in 2005: 7.0% for conventional and 2.4% for low-linolenic rapeseed.

Numerous studies on gene flow in oilseed rape have shown harvest contamination to considerably depend on the distance between the fields as well as the areas of both gene-emitting and receiving fields (e.g. Bilsborrow *et al.* 1994, Bilsborrow *et al.* 1998, Colbach *et al.* 2005b, Devaux *et al.* 2005). This was confirmed in the present studies with simulations showing that harvest contamination decreased with the distance between the fields as well as with increasing area of the low-linolenic field (Fig 2). As only a few meters contain contaminated seeds, they are diluted in the whole field if it is large enough and thus contaminated seeds have a limited impact on the linolenic acid content of the whole field. Furthermore, even in the worse cases (small linolenic field next to a conventional one), the influence of the contamination on linolenic acid content was limited: 2% of contamination only induced an increase of about 0.05% C18:3, which does not alter oil quality. We can conclude that cross-pollination through conventional crop has only a minor effect on low-linolenic rapeseed production.

The impact of volunteers of conventional rapeseed on linolenic acid content

Crop management can have an impact on final linolenic acid content through its effect on the density of conventional rapeseed volunteers in the low-linolenic fields. As the trials were in a transitory period and the two types of rapeseed crop coexisted, most of the volunteers were still conventional double-low rapeseed, with high linolenic acid content. The two years of experiments carried out in Changins in 2005 and 2006 showed the impact of an increasing density of conventional rapeseed volunteers on final linolenic acid content (Fig 3).

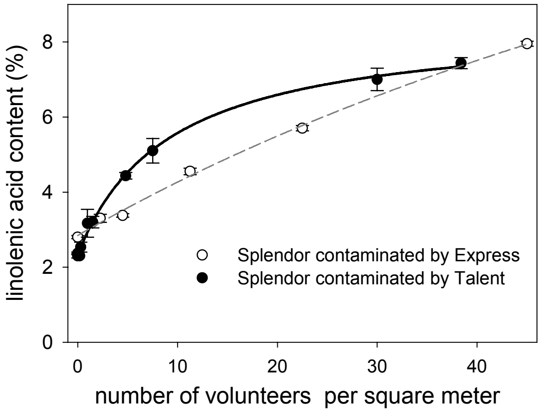

Fig 3: Impact of volunteers on linolenic acid content of a low-linolenic field. Differences observed between two contaminating varieties of conventional rapeseed.

Linolenic acid content increased progressively with increasing density of volunteers in the field. The lower and upper values for uncontaminated low-linolenic and conventional rapeseeds were lower in 2006 than in 2005, which could be explained by better climatic conditions in 2006 (Talent). However, in 2006 the contamination was much higher than was expected from the results obtained in 2005 with the variety Express. The impact of the volunteers depends on their nature: the variety Talent grown in combination with Splendor in 2006 had a more important effect on final linolenic acid content than Express. The difference in competitiveness between Splendor (low-linolenic variety) and the cultivar chosen to simulate the volunteer (either Express or Talent, hybrid cultivar) seemed to have a great importance on the final contamination rate. Whereas the vigour of Express can be compared to Splendor's, the variety Talent was taller and produced more seeds and pollen than Splendor. The final linolenic acid content was therefore higher than expected from the density of volunteers at emergence. Consequently, the competition between the crop and volunteers has a crucial effect on final harvest quality. Therefore, improved and more vigorous low-linolenic varieties would contribute to improving quality, reducing the impact of volunteers.

Modelling the effects of crop management on linolenic acid content

Tab1: Effect of crop rotation on linolenic acid content of a four-ha low-linolenic rapeseed field.

Tested strategy	Crop rotation	Rapeseed in neighbour fields	Contamination rate	Linolenic acid content
Control	6 years	No	0.3	2.4
Short rotation	2 years	No	7.0	2.7
Required rotation	4 years	No	0.6	2.4
Surrounded by rapeseed	6 years	Yes	0.3	2.4

Basis value for C18:3 content for uncontaminated low linolenic rapeseed=2.4%, for conventional rapeseed=7.0%

Crop management practices such as crop rotation, tillage and cultivar vigour etc. may have effects on gene flow from volunteers or neighbouring fields. The results of the simulations suggest that, in case of efficient volunteer management, only very short rotation generate enough volunteers to significantly affect C18:3 content. In Switzerland a crop rotation of 4 years is a common practice.

Conclusions

The GeneSys model was initially developed to simulate the coexistence between GM and non-GM crops. With the new low-linolenic rapeseed crop, controlling gene flow (and therefore quality) between non-GM crops became relevant from a "coexistence" point of view. Nevertheless, linolenic acid content is not very sensitive to pollen flow in low-linolenic varieties. C18:3 content is about 2.5% in low-linolenic varieties and 7 to 10 % in conventional varieties. It means that for a one-percent contamination, the increase in linolenic acid content is only 0.02 to 0.04%. To increase linolenic acid content of 0.1%, the contamination rate must vary between 3 and 5% according to the characteristic of the variety (lower or higher linolenic acid content). Very high and thus threatening contamination through pollen cannot happen in farmers' conditions. On the other hand, volunteers of conventional double-low varieties must be avoided by adequate rotation and tillage as they can increase contamination tremendously. Seed flow during sowing, harvest and storage represents the main other contamination factor and can be avoided by watchfulness during these operation. The specialisation of whole areas and collecting stations, with either low-linolenic, or conventional rapeseed may be required.

Acknowledgements

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