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Gene flow of oilseed rape (*Brassica napus*) according to isolation distance and buffer zone

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Abstract

The introduction of genetically modified (GM) crops in the EU has raised questions concerning gene dispersal and co-existence with non-GM-farming. Quantitative estimates of the gene dispersal from fields with GM-crops to fields with conspecific non-GM-crops (conventional or organic) are therefore needed in order to suggest isolation distances and other management strategies to keep GM-pollination below acceptable threshold values. A meta-analysis of available gene-flow data for oilseed rape (*Brassica napus*) was performed. The probability distribution that seeds of non-GM-oilseed rape are fertilised by foreign pollen grains from a neighbouring field of GM-oilseed rape is modelled as functions of the width of the recipient (i.e. pollen receiving) field and the distance to the pollen donor fields. Furthermore, the significance of using a buffer zone (removal of a 1–5 m border of a recipient field parallel to the pollen donor field) to reduce GM-pollination of the crop, is quantified and discussed. The predicted median and 95% credibility level of the probability of foreign pollination is calculated as a function of the width of the recipient field and the buffer zone, as well as the distance between fields. Analysis of different management strategies shows that an increasing isolation distance is more effective to reduce GM-pollen dispersal than the use of a buffer zone, especially for small recipient fields. The analysis shows that increasing the width of a recipient oilseed rape field, relative to the pollen donor field, will have a large effect on reducing the average level of fertilisation by foreign pollen within the recipient field. The results indicate that a GM-pollination percentage $<0.1\%$ will be possible if the isolation distance exceeds 100 m and the width of the non-GM-field is larger than 200 m. If a threshold value of 0.3% is acceptable, an isolation distance of 50 m should be sufficient even for smaller fields. The use of a 5 m discarded buffer zone surrounding the non-GM-field is expected to reduce GM-pollination by about a third. The implications of the results for field management in conventional and organic farming are discussed.

Keywords: *Brassica napus*; Co-existence; Gene flow; Genetically modified organism (GMO); Farm management; Pollen dispersal

1. Introduction

A much-debated issue regarding the commercial growing of genetically modified (GM) plants is the possible transfer of transgene pollen into neighbouring

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fields with similar crops. If a non-GM-crop is fertilised by GM-pollen, a certain percentage of the harvested seed product will contain GM. This may be objectionable to consumers, and current regulation in the EU (EU, 2003) and elsewhere limits the allowed content. In organic farming, the regulations do not allow the use of genetic engineering in the grain production system partly in order to guarantee GM-free products to the consumers (Nijhoff and Andersson, 2001). Hence, the proportion of seeds containing GMO may not exceed a critical detection level, e.g. 0.1%, if the crop is to be classified and sold as an organic crop. This includes all sources of transgene contamination during production and distribution, which is generally low in organic crops because of the separate distribution lines. The main sources for GM contamination of non-GM-crops at the farm level are: seed impurities, pollen dispersal between fields, seed dispersal with machinery, dispersal of pollen and seeds from volunteer plants, and mixing of crops after harvest (Bock et al., 2002; Kjellsson and Boelt, 2002). For conventional crops, e.g. oilseed rape, the critical level of GM contamination by pollen is therefore in practice somewhat below 0.9%, which is the threshold value for labelling of GM in food and feed by the EU (EU, 2003). It has been realised for some time (e.g. Timmons et al., 1995) that commercial release of GM-oilseed rape is likely to result in movement of GM genes to non-GM-fields.

The current study is focused on providing management measures, i.e. isolation distances and buffer zones, to reduce the level of gene flow by pollen from GM-oilseed rape to conventional and organic rape to acceptable levels. This is done by a meta-analysis of existing data from field trials in EU, North America and Australia. Oilseed rape (*Brassica napus* L.) is a partially self-fertilising summer or winter annual crop where a number of GM varieties have been developed. These include herbicide tolerant varieties that are already in commercial production outside the EU and insect resistant varieties, which are being tested (JRC, 2003). While oilseed rape is a major crop in conventional farming in EU, it has a minor but increasing importance to organic farming (Tolstrup et al., 2003). The level of outcrossing from neighbouring plants in the field or from pollen dispersed by wind and insects varies between 12 and 47% (Becker et al., 1992). The relative importance of insects and wind for pollination seems to vary and no general conclusions can be made except that bees and wind can result in cross-pollination at distances of more than 5 km from the source (Eastham and Sweet, 2002; Ramsay et al., 2003). The concentration of oilseed rape pollen in the air normally decreases rapidly (exponentially) with the distance from the source (Metz et al., 1997). Cross-pollination may also show irregular patterns depending on prevailing wind directions (Eastham and Sweet, 2002), the topography and distribution of insect pollinator populations, including beehives (Ramsay et al., 2003).

2. Analysis of gene flow

Oilseed rape pollen are normally produced in an abundant amount (e.g. 9.3 ± 0.5 kg pollen per ha per day, Westcott and Nelson, 2001) over a period of approximately 4–5 weeks. The dispersal of the pollen is a stochastic process where the majority of the pollen grain are dispersed over a short distance (Lavigne et al., 1998). Due to the dispersal pattern of oilseed rape pollen and the large pollen production within an oilseed rape field, it is expected that the proportion of foreign pollen, i.e., pollen that are produced in a neighbouring field of oilseed rape, is reduced along a transect running from the border towards the centre of the field. This is caused by dilution of the foreign pollen from the massive pollen production in the receiving field. The dilution effect of foreign pollen from the same species may be used in the management for co-existence of organic and conventional crops with GM-crops. Hence, the proportion of successful GM-pollen in a non-GM-field with the same crop may be reduced by:

1. exclusion of a narrow, 2–5 m wide, strip of the non-GM-field, i.e., the buffer zone, opposite the GM-crop at the time of harvest,
2. increasing the width of the non-GM-field,
3. increasing the distance between the GM- and the non-GM-field, i.e., the isolation distance, or by using a combination of different methods.

The probability that a foreign oilseed rape pollen grain will result in a successful fertilisation in a neighbouring oilseed rape field will, in the following, be denoted as the probability of foreign pollination. (Note