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Review article

ENVIRONMENTAL AND AGRONOMIC IMPACT OF THE HERBICIDE TOLERANT GM RAPESEED

Gordana R. Zdjelar*, **Zorica T. Nikolić, Ana M. Marjanović Jeromela, Dušica D. Jovičić, Maja V. Ignjatov and Dragana N. Petrović**

Institute of Field and Vegetable Crops, Maksima Gorkog 30,
21000 Novi Sad, Serbia

Abstract: The introduction of genetically modified herbicide tolerant rapeseed has raised questions concerning the possible transfer of transgenes into wild relatives or neighbouring fields with similar crops. Pollen of rapeseed can be spread in the area and if a non-GM crop is fertilised by GM pollen, some percentage of the collected seed product will contain GM. Current regulation in the EU limits the allowed content. For conventional crops the critical level of GM contamination is in practice below 0.9%, which is the threshold value for labelling of GM in food and feed by the EU, although the limit for seeds is 0.1% in Serbia. In organic farming, the regulations do not allow the use of genetic engineering in the grain production system.

Key words: GMO, rapeseed, vertical gene flow, seed purity, organic farming.

Introduction

The commercial production of transgenic crops has raised a number of concerns among scientists, consumers and policy makers. The transgenic agriculture could have effects on the environment and agricultural production in general. Ervin et al. (2003) share the agricultural risk of the transgenic crops associated to the impact of the new agricultural practices on the farmed environment and on non-target species, the impact of gene flow from pollen dispersal and the impact of volunteer plants on gene flow and agricultural practices. Rapeseed (*Brassica napus* L.) is after soybean the second most important source of vegetable oil in the world (Marjanović-Jeromela et al., 2011a). The oil extracted from the seeds of rapeseed is used for human consumption (blended vegetable oil and margarine) and industrial applications (rubber additives, hydraulic oils, high-temperature lubricants, detergent and soap production and biodegradable plastic) (Senior and Dale, 2002; Marjanović-Jeromela et al., 2011b). The meal remaining after seed crushing is used as a protein-rich component in animal feed (Devos et al.,

*Corresponding author: e-mail: gordana.zdjelar@ifvcns.ns.ac.rs

2004; Marjanović-Jeromela et al., 2010). Considering that the rapeseed oil, beside its use for food, feed and industrial purposes, is also used for metilester, which is an important component for biodiesel production, it can be expected that the rapeseed production area will continue expanding in the next years, reducing the dependence on imported oil and thereby increasing south-eastern European competitiveness on the market (Marjanović-Jeromela et al., 2008; Jovičić et al., 2011).

In Serbia, as in many countries in the European Union, no commercial cultivation of GM rapeseed takes place. In the USA and particularly in Canada more than 80% of the area cultivated with rapeseed was planted with GM varieties (O'Donovan et al., 2011). All of the GM rapeseed grown throughout the world were herbicide tolerant (HT), which enables a more efficient and effective approach to weed control (Nikolić et al., 2010).

The environmental and agronomic concerns associated with the potential spread of herbicide tolerance traits to wild relatives and to other rapeseed cultivars (GM and non-GM) were extensively investigated (Snow, 2002; Ellstrand, 2003; Schiemann, 2003). One of the most mentioned concern regarding the commercial growing of genetically modified plants is the possible transfer of transgenic pollen into neighbouring fields with similar crops. If a non-GM crop is fertilised by GM pollen, some percentage of the collected seed product will contain GM. Because this may be objectionable to consumers, current regulation in the EU (EU, 2003) limits the allowed content of GM (Devos et al., 2004). 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). For conventional crops the critical level of GM contamination by pollen is therefore in practice below 0.9%, which is the threshold value for labelling of GM in food and feed by the EU (EU, 2003), although the limit for seeds is 0.1% in Serbia.

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. 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 transgenic contamination during production and distribution, which is generally low in organic crops because of the separate distribution lines (Damgaard and Kjellsson, 2005).

Vertical gene flow

Vertical gene flow is the movement of genes between two genetically different living plants or populations. In rapeseed, genes can be transferred between cultivars and from cultivars to certain wild relatives, volunteers and feral plants.

Volunteers are plants emerging within agricultural fields as a result of previous cropping, while feral plants are domesticated plants reverting to the wild type outside the cropped area (Devos et al., 2004). Important steps in vertical gene flow are the spread of the transgenes to other plants or populations, the formation of F_1 hybrids, and the stabilisation of the transgenes by introgression (Ellstrand, 2003; Chèvre et al., 2004). In rapeseed, the transgene can be spread in space through pollen and seeds, and through seeds in the seed bank (Devos et al., 2004).

Pollen dispersal in space

Rapeseed is a mainly self-fertile summer or winter annual crop. Rapeseed pollen is normally produced in an abundant amount e.g. 9.3±0.5 kg of pollen per ha per day (Westcott and Nelson, 2001), over a period of approximately 4-5 weeks. The majority of the pollen grain is dispersed over a short distance (Lavigne et al., 1998). 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 (Ramsay et al., 2003). In field studies differing in location, environmental conditions and experimental design, crossing between rapeseed plants has been detected at up to 4,000 m from the pollen source (Ramsay et al., 1999; Thompson et al., 1999; Rieger et al., 2002; Bartkowiak-Broda et al., 2011). Ramsay et al. (2003) even detected very low levels of fertilisations on male-sterile plants at 5 and 26 km from the nearest known pollen source (Devos et al., 2004). Pollen concentrations and consequently successful pollinations tend to drop quickly with distance from the source (Ramsay et al., 1999, 2003; Thompson et al., 1999; Ingram, 2000; Rieger et al., 2002; Beckie et al., 2003; Hall et al., 2003). Therefore, the cultivation of genetically modified rapeseed might lead to a distribution of new introduced genes in the environment (Dowideit et al., 2011).

Seed spreading in space and time

Rapeseed seeds can be spread over short distances to non-agricultural areas or neighbouring fields by wind, birds or machinery (Devos et al., 2004). Seed occasionally spills during transport from fields to final destination. Consequently rapeseed feral populations may arise in non-natural disturbed ecosystems, including roadsides, field margins, railway lines and wastelands (Pessel et al., 2001; Simard et al., 2002; Sausse et al., 2011).

Dormancy of the seed allows dispersal in time by maintaining genes year to year in the soil seed bank (Mallory-Smith and Zapiola, 2008; Gruber et al., 2011). Most of the dispersed seeds still germinate within two years and decline quickly (Beismann et al., 2003; Lutman et al., 2004). Some of the buried seeds can develop secondary dormancy and remain dormant for several years (Lutman et al., 2004; Weber et al., 2011), depending on environmental factors. The persistence of the secondarily dormant seeds has been confirmed to be up to 5 years, but may reach 10 years or more under field conditions (Schlink, 1998; Lutman et al., 2004).

Gene flow from GM rapeseed to wild relatives and non-GM rapeseed

A major concern about agricultural releases of GM rapeseed is the escape of transgenes in the environment through hybridization with their wild relatives or other rapeseed cultivars. Compared to the hybridization frequencies within cultivars (intra-specific), hybridization with wild relatives (inter-specific) will occur at a much lower level because most of the wild relatives are partially or fully isolated by breeding barriers. In addition, ecological barriers play an important role in limiting the process of inter-specific gene flow (Ellstrand, 2003; Chèvre et al., 2004; Devos et al., 2004; Van Tienderen, 2004). Therefore, the probability of inter-specific gene flow is very low, but some possibilities exist (Ellstrand et al., 1999; Ellstrand, 2003; Van Tienderen, 2004). Chèvre et al. (2004) describe several inter-specific hybrids between rapeseed and its wild relatives, but under field conditions, gene introgression has only been confirmed for *B. Napus*-*B. rapa* hybrids. It is important to note that in agricultural fields, the extent of vertical gene flow from rapeseed to certain weedy relatives will depend on the agricultural and weed control practices (Devos et al., 2004). The development of HT weedy relatives is expected to be slow in conventionally managed fields (Pertl et al., 2002; Hauser et al., 2003).

Multiple herbicide tolerance, which occurs in some HT rapeseed, is most likely the result of the pollen flow between different HT rapeseed (Beckie et al., 2003; Hall et al., 2003). The incorporation of the HT traits in recipient plants may increase the fitness of these plants, making them more abundant and persistent. Herbicide treatments are commonly used by farmers to control weeds, including rapeseed volunteers and certain wild relatives. The presence of the HT plants limits the effectiveness of the herbicides used for controlling weed infestation. Initially, the problem is expected to be less severe for HT wild relatives because of their significantly fewer numbers compared to volunteers. Multiple HT rapeseed volunteers and HT wild relatives could occur when cultivars tolerant to different herbicides are grown in proximity (Devos et al., 2004; Thöle et al., 2011). HT weeds may cause problems to farmers or seed producers if they switched to agricultural practices with low herbicide usage. It is well documented that when a single herbicide is used repeatedly on a crop, the chances of herbicide resistance developing in weed populations greatly increase (Holt et al., 1993). This increased herbicide resistance as a result may increase usage of selective broad-leaf herbicides or herbicide mixtures. As the herbicide is known to accumulate in fruits and tubers as it suffers little metabolic degradation in plant, questions about food safety also arise (Altieri, 2000). The use of long residual herbicides that are mobile in surface water or penetrate into groundwater could lead to additional water quality concerns.

Similarly, uncontrolled HT weeds can make it difficult to meet the requirements with the established labelling thresholds for the adventitious presence of GM material in non-GM produce or to achieve the seed purity standards (Jørgensen et al., 1998; Weber et al., 2011). Cross-pollinations between neighbouring fields with GM and non-GM rapeseed cultivars, the emergence of secondarily dormant GM rapeseed seeds from the seed bank in the next non-GM rapeseed grown in a 4-year rotation, and admixing of GM and non-GM seeds can introduce impurities (Devos et al., 2004). In Canada, impurities above the permitted threshold (0.25%) have already been found in commercial certified rapeseed seed lots (Friesen et al., 2003; Demeke et al., 2006).

Herbicide tolerant rapeseed in Serbia

The use of genetically modified organisms (GMO) as food and in food products is becoming more widespread (Taški-Ajduković et al., 2009; Matić et al., 2010; Nikolić et al., 2010; Zdjelar et al., 2011). Although the cultivation of GM plants has not yet been approved in Serbia, their import is expected to increase, and their unforeseen, intended or accidental cultivation may eventually occur as has been revealed for Roundup Ready soybean (Nikolić et al., 2009). In Serbia, there are neither wild relatives of *Brassicaceae* nor local populations, so the gene flow from HT rapeseed to wild relatives is not an issue. But contaminations in pedigreed rapeseed seed lots with herbicide resistance traits could occur. Appropriate monitoring is necessary to detect the possible dispersal of imported GM plant seeds in the transportation system (Nikolić et al., 2010).

Conclusion

In the context of GMOs, rapeseed is considered as a crop with a potential to cause environmental and economical problems because volunteers frequently occur and ferals allow persistence of herbicide tolerant genotypes in the wild. Extended herbicide resistance as a result may have increased usage of selective broad-leaf-herbicides or herbicide mixtures. Increased amount of herbicides can accumulate in fruits and tubers or penetrate into groundwater affecting invertebrates and humans who use them.

The other risk from GM rapeseed is that contaminations in pedigreed rapeseed seed lots with herbicide resistance traits could occur and cause seed impurities above permitted threshold. Adventitious presence of GM materials in non-GM seed is a concern to international grain trade, especially to organic farmers, and needs continuous monitoring by traditional and innovative techniques of investigation. The developed practical GMO detection method must verify that the system of GMO labelling is valid and that it can be used to monitor the status of the GMO trade.

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GM ULJANA REPICA TOLERANTNA NA HERBICIDE-UTICAJ NA ŽIVOTNU SREDINU I POLJOPRIVREDU

Gordana R. Zdjelar*, Zorica T. Nikolić, Ana M. Marjanović Jeromela, Dušica D. Jovičić, Maja V. Ignjatov i Dragana N. Petrović

Institut za ratarstvo i povrtarstvo, Maksima Gorkog 30,
21000 Novi Sad, Srbija

R e z i m e

Uvođenje genetski modifikovane uljane repice koja je otporna na herbicide nameće pitanja u vezi sa potencijalnim prenošenjem transgena sa genetski modifikovane uljane repice na njene divlje srodnike ili susedna polja sa sličnim kulturama. Polen uljane repice širi se u prostoru, te ukoliko je genetski nemodifikovan usev oplođen genetski modifikovanim polenom, određeni broj biljaka biće genetski modifikovan. Važeća zakonska regulativa u Evropskoj uniji ograničava dozvoljen sadržaj genetske modifikacije u usevima. Za konvencionalne useve najviši dozvoljen nivo kontaminacije u praksi je 0,9%, što je istovremeno i granična vrednost za obeležavanje GM hrane i hrane za životinje u Evropskoj uniji. U Srbiji kritična granica za semena iznosi 0,1%. U organskoj proizvodnji zakonska uredba ne dozvoljava upotrebu genetičkog inžinjeringa u sistemu proizvodnje semena.

Ključne reči: GMO, uljana repica, vertikalni protok gena, čistoća semena, organska proizvodnja.

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*Autor za kontakt: e-mail: gordana.zdjelar@ifvcns.ns.ac.rs