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Hot Topic #9 - Co-existence of genetically modified and non-genetically modified crops

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Hot Topics have been conceived to bring New Zealand agricultural and horticultural issues that need debate to the fore in a style and timeliness that cannot be achieved through traditional scientific publication approaches.

The full paper on which this article is based was published online by Taylor & Francis in the New Zealand Journal of Agricultural Research on 31 March 2025 and can be accessed at https://doi.org/10.1080/00288233.2025.2479724. The full paper contains extensive referencing to support arguments, claims and conclusions about the opportunities and challenges of co-existence between genetically modified and non-genetically modified crops.

Introduction

Co-existence and containment of genetically modified (GM) plants has been a contentious issue since GM technologies were first commercially released in the mid-1990s (Azadi et al. 2017; Timpo 2019). The concept of co-existence ensures that 'different primary production systems can exist concurrently or in the vicinity of each other and can be managed in such a way that they affect each other as little as possible' (Hubbard and Hassanein 2013). The feasibility of co-existence and containment through managing gene flow via pollen transfer from GM crops/plants to non-GM plants, whether these be other sown crops or wild populations of the same species, and downstream segregation will be reviewed. It will largely focus on forage and pasture species which dominate New Zealand pastoral agricultural systems, but relevant learnings will be taken from co-existence principles used in overseas commercially grown GM crop species.

Managing the risk of gene flow

Degree of pollen transfer will depend on distances between crops of sexually compatible species, similarity of flowering times, outcrossing rate of the species concerned, and climate conditions. The positive and negative aspects of a range of measures that can be taken to stop or minimise gene flow from GM crops has been summarised by Rizwan et al. (2019). These fall into three groups:

1. Physical barriers to stop pollen dispersal and seed movement (Arriola 1997) include the use of physical distance and/or buffer strips between crops (Gray et al. 2011). The effective width of pollen barriers can be established through understanding '(i) the tolerance for GM adventitious presence which depends on market and labelling thresholds for GM adventitious presence; and (ii) the reliability level of satisfying the adventitious presence constraint which is equivalent to the confidence level of hypothesis testing' (Lichtenberg and Zilberman 1988; Gray et al. 2011). Most gene flow occurs over very short distances but with often a long-tailed distribution (Kareiva et al. 1994; Scheffler et al. 1995). Vegetative barriers of a trap crop are more effective than open gap distances in reducing pollen movement at distance (Morris et al. 1994; McPherson et al. 2009).

2. Temporal barriers such as the timing of the planting of the crops so that the pollination period of GM sown areas does not overlap with the pollination period of nearby farms that grow non-GM crops (Friedland 2005). However, this is largely only applicable to annual crops.
3. Biological/ molecular barriers through genetic manipulation to disrupt the pollination and fertilisation process (Moon et al. 2011) may include:

    - Removal of the transgene in pollen through site specific recombination systems (Daniell 2002; Mlynárová et al. 2006; Moon et al. 2009).
    - Targeting of the transgene to the chloroplast genome in species in which chloroplasts are generally maternally inherited (Bock and Khan 2004; Maliga 2004).
    - Targeted transgene removal after the desired protein has been produced (Clark and Maselko 2020).
    - Synthetic auxotrophy which requires genetically engineering a strain such that it depends on an externally supplied compound to execute crucial biological functions (Moe-Behrens et al. 2013).
    - Engineering genetic incompatibility (Clark and Maselko 2020).
    - Incorporation of cytoplasmic male sterility (Munsch et al. 2008).
    - Cleistogamy, which involves non-opening flowers and results in self-pollination and fertilisation taking place within the closed bud and so there is no release of pollen (Hüsken et al. 2010; Ohmori et al. 2012).
    - Genetic use restriction technologies that are linked to the transgene, so that when activated there is expression of a disrupter gene that drives cell death, e.g. Terminator (Zhang et al. 2012).

Learnings from GM and non-GM co-existence experiences

Genetically modified plants and crops have been grown in many countries for the last 30 years and in situations where co-existence with non-GM crops was required solutions have regularly been developed. It is a somewhat surprising observation that countries with the largest areas devoted to organic agriculture also have amongst the highest land area used for GM crops (Sánchez and Campos 2021).

USA

USDA regulations previously allowed farmers to keep their organic certification and continue to sell product as organic despite unintentional contamination due to pollen flow from GM crops (Friedland 2005; Cox 2008). Now the USDA expects organic farmers to be more proactive with buffer zones, staggered planting to reduce unintentional contamination. Protocols have been developed with the intention of supporting organic, conventional, and GM crop farmers and encouraging shared responsibility for identity preservation of non-GM crops. These protocols included:

1. Approving GM maize hybrids on a case-by-case basis.
2. Promoting communication among neighbouring farmers.
3. Providing for a 46 metre buffer zone to keep cross-pollination between adjacent fields below 1%.
4. Supporting measures to minimise the probability of insect resistance development.
5. Calling for monitoring and dispute resolution mechanisms.

It has been stressed that 'shared responsibility for co-existence is a practical and desirable strategy, if based upon an acceptably low level of cross-pollination rather than a 'zero-tolerance' level'.

South America

South America is now the dominant world producer of GM soybeans, a crop of no significance in the region before the middle of the twentieth century, with Brazil and Argentina producing 176 million tons which is over half of all world production and accounts for 57% of soybean exported in international trade (Klein and Luna 2021). Chile has also been a leader in the production of GM crops, primarily maize, soybean, and canola, all destined for export. To ensure genetic purity while minimising economic risk to growers, Chile has a voluntarily self-imposed co-existence strategy between GM and non-GM seed crops (Sánchez and Campos 2021). Seed companies use a Global Positioning System (GPS)-based software that is operated and supervised by the national seed trade association (ANPROS) (Sánchez and Campos 2021) which provides users with positioning, navigation, and timing (PNT) services (GPS 2021).

Australia

Australia with genetically modified crops of canola, cotton and saffron (*Crocus sativus*) has instigated an industry driven scheme referred to as 'Market Choice' to provide a means for both GM and non-GM crops to co-exist. Interestingly, the majority of farmers surveyed are growing both GM and non-GM canola crops suggesting that concern about co-existence is not an insurmountable issue. Yet when asked about pollen flow from GM canola concerns were higher for non-GM growers (about 40% agreed there was problem) than GM canola growers (about 10% considered pollen flow a problem) (Hudson and Richards 2014).

The Market Choice criteria for GM canola (also referred to as the 'national market access framework' (NMAF) (DAFF 2007)) involves a 5-step process (Agricultural Biotechnology Council of Australia 2008; Grain Trade Australia 2019, 2024):

1. Australian regulatory approval gained from the gene regulator (OGTR – Office of the Gene Technology Regulator).
2. Market requirements are identified and the need for segregation understood to meet the various requirements of domestic and international consumers.
3. Threshold levels for Adventitious Presence of GM seeds established:
    - Australian Adventitious Presence thresholds have been established for the presence of GM traits in canola at 0.5% for seed (Australian Seed Federation) and 0.9% for grain (NACMA CSO1 Canola standard).
    - Adventitious Presence thresholds established with key trading partners, such as Japan (5%) and Europe (0.9%) if an approved GM event, but zero if it is an unapproved event (Roïz 2014) – for contractual or labelling purposes.
4. Importing market approvals are in place and GM canola varieties have approvals in key importing countries.
5. Supply chain processes to meet market requirements and protocols are available to segregate GM and non-GM seeds throughout the supply chain (Viljoen et al. 2004).

This process has been successfully employed across Australia with few major issues resulting.

Europe

In the late 1990s, the European Commission developed a policy framework for the 'coexistence' of GM with non-GM and organic crops resulting in a policy that sought to avoid or manage political-economic conflict over the use of GM crops (EUR-Lex 2003a, 2003b; Binimelis 2008; Levidow and Boschert 2008; Binimelis et al. 2016; Karky and Perry 2019). EU guidelines for ensuring co-existence, although non-binding for Member States, outline 12 principles which include transparency, stakeholder involvement, science-based decision making, a system built on existing means of crops segregation, focus on authorised GM varieties, and consideration of liability rules (Grossman 2007). It was suggested that the operator (farmer) who is introducing the new production type bear the responsibility of implementing the farm management measures necessary to limit gene flow and inform neighbours of their plans to plant a GM crop.

Economic impact where co-existence has not been effectively achieved

The co-existence of organic, non-GM, and GM crop/plant production systems has its challenges, and in some situations may result in economic impacts that were unintended (Beckmann and Wesseler 2007). Early in the use of GM crops it was 'argued that if GM technology is adopted, the cost of production for conventional and organic technologies could increase due to additional measures taken to prevent crop contamination, and that the value of conventional and organic production could be reduced due to the adoption of tolerance levels for the adventitious presence of GM material' (Merel and Carter 2005).

Internationally, significant and documented examples of ineffective containment of GM crops that have been documented include:

- StarLink™ maize, which contained two transgenes was released with approval for animal but not human consumption, i.e. as a split license (Uchtmann 2002; Carter and Smith 2003). However, in 2000 StarLink™ maize was detected in tacos resulting in recalled products, loss of export sales and an estimated cost of between US$100 million to US$1 Billion (Fischhoff and Fischhoff 2001; USDA 2012).
- Volunteer maize in a test site for ProdiGene, a biopharma technology grown to produce a pig vaccine against transmissible gastroenteritis virus

(TGEV), caused contamination of the subsequent soybean crop resulting in US$2.7 million loss for soybeans destined for human consumption (Price and Cotter 2014).

- In the two years from November 2013 China rejected over 887,000 tonnes of U.S. maize containing unapproved GM traits. For example, MIR162, which contains a Bt protein toxic to a variety of maize pests was used as an excuse to create trade disruptions with the USA (Han and Garcia 2015). This was influenced by non-GM related changes to the supply of corn and sorghum.
- In 1999, the USDA approved two LLRice events with herbicide tolerance (LLRice62 and LLRice06) for commercial use (FoodNavigator Europe 2024), but neither was progressed because growers were not interested in producing rice not yet approved for sale in major importing nations such as Japan and the European Union (Endres and Gardner 2006; Strauss 2010). A contamination incident that occurred in 2005 with LLRice but not involving these two approved events, but rather LLRice601 a variety that the USDA had not previously approved for commercial release and that was last field tested in 2001. As a result rice futures plunged, and Japan and European countries banned the import of U.S. rice. Numerous lawsuits ensued, with the largest of these, in July of 2011, Bayer CropScience agreed to pay up to $750 million to farmers in Missouri, Arkansas, Texas, Louisiana and Mississippi to settle lawsuits (USDA 2012).
- In 2009, DNA from the deregistered GM linseed cultivar Triffid was detected in a shipment of Canadian linseed exported to Europe, causing a large decrease in the amount of flax planted in Canada and a major shift in export markets (Booker et al. 2017). Major changes were made to ensure the removal of transgenic flax from the supply chain. Losses to the Canadian economy were incurred as a result of the reduction in flax production and export opportunities. Estimated cost from this incident in Canada were CAN$30 million and in Europe in excess of €39 million (Smyth 2014).
- A series of field trials of herbicide (glyphosate) resistance GM creeping bentgrass (*Agrostis stolonifera*) run between 1999 and 2005 resulted in two events where gene flow from the GM plants occurred resulting in GM bentgrass establishing in uncultivated habitats in Oregon (Reichman et al. 2006; Charles 2011). Spread was attributed to both pollen-mediated intraspecific hybridizations and from crop seed dispersal.

These examples indicate that effective co-existence of GM and non-GM crops is a strategy that needs to be worked on rather than just assumed. It requires communication and cooperation across the supply chain from seed growers, suppliers, farmers and purchasers/distributors for the product.

Stewardship principles

Many USA licensees of GM and gene editing technologies are obligated to participate in stewardship programmes provided by the IP owner to ensure responsible use and management of resulting products (Bayer 2024; Corteva 2024). These programmes aim to ensure GM and gene editing products are grown and marketed in a way that meets regulatory requirements. They are linked to the 'Excellence Through StewardshipTM' (ETS) Programme (WHO 2003; ETS 2011; ETS 2019). In June 2008, ETS was incorporated as an independent non-profit organisation to take over responsibility to 'promote the responsible management of plant biotechnology, primarily by developing and encouraging implementation of product stewardship practices and by educating stakeholders and the public about those practices' (ETS 2011).

Discussion and conclusion

Over the past 30 years the use of genetic modification in crop plants has driven the development of improved insect-protected, herbicide-tolerant, stress tolerant, and nutritionally enhanced crops (Huesing et al. 2016). Uptake globally has been exceptional such that in 2022 there were 202 million ha in production (ISAAA 2023) rising to 206 million ha in 2023 (AgbioInvestor 2024).

Effective co-existence of GM and non-GM plants is an important consideration and through appropriate communication and knowledge sharing this can be achieved. New Zealand needs to learn from issues that occurred in the first decade of GM crop use and determine effective methods for ensuring co-existence of GM, non-GM and organic farming systems. This will involve approval from the gene regulator to use the specified GM crop, forage or pasture plant, an understanding of market requirements and the need for segregation, a determination of the acceptable threshold level for adventitious presence of GM in the seed mix or final product, appropriate import approvals from countries for which the GM technology or product is being exported to, and supply chain processes that meet market requirements and effectively segregate GM and non-GM seeds and products. In the field on-farm co-existence will be reliant on agronomic strategies such as planting times, crop placement, separation distances and physical containment to limit pollen dispersal and seed movement, which could be assisted by using biological/ molecular containment through genetic manipulation to disrupt the pollination and fertilisation process. Co-existence of GM and non-GM crops has been and is possible but will require community cooperation and effective communication.

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