Chapter 34
Prospects for Plant Genome Editing

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Genome editing – the focus of this book – is a set of methods that provide opportunities to precisely and efficiently improve crop traits by tailoring genes and regulatory domains. In combination with genetic modifications (GM), RNA interference (RNAi), epigenetics and the range of -omics technologies, they offer multiple methods for enhancing crop production, crop protection, crop quality and climate change adaptation. Combining these technologies with traditional breeding and careful management of crop cultivation methods in integrated systems can make major contributions to improving the sustainability of agricultural production, particularly in response to climate change. These technologies could also contribute to achieving United Nations' Sustainable Development Goals and national/EU policy objectives for agriculture, food safety, food security and the environment.

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1 Technology

Genome editing in plants is often referred to as precision breeding due to the precise nature of the methods used compared with some other genetic modification and mutation breeding techniques. Genome editing technologies exceeded initial expectations as a tool in plant science and breeding and are quickly adopted in most life-science laboratories as a precise and high-throughput tool for targeted crop improvement. They became the method of choice in many research studies. The future of genome editing relies on expanding the technology toolbox with more efficient multiplexing and high-throughput strategies, applications towards chromosomal rearrangements and epigenetic changes together with more tools for efficient delivery of editing components and regeneration of edited cells.

2 Crop Improvement

Genome editing has already been applied for numerous trait improvements in crops. By now, there are more than 100 applications of genome editing on at least 28 different plant species, some of which have been described in this book. In planta genome editing methods still need to be optimized in a broader range of plant species before to achieve a significant commercial impact. This especially stands for time and costs related to the development of specialized regeneration protocols for individual plant lines. It is therefore important to broaden the targets for crop improvement by gaining knowledge about biological processes and genes involved, as well as the interaction of biological processes with the environment.

Although being known as a very precise technology, off-target, pleiotropic and other unintended effects have occasionally been reported. The regular plant breeding procedures, however, are expected to manage this by careful screening and testing of new breeding lines through several generations prior to multiplication and commercialisation.

Technical innovations will expand the genome editing toolbox and further strengthen its technical and economic advantages in crop improvement. However, genome editing will still mostly complement rather than replace conventional plant breeding methods in crop improvement. Further applications of genome editing technologies in crop improvement depend largely on the economic and legal framework, as well as public perceptions of the technology itself.

3 Regulations

Government regulation for new genomic techniques (NGTs) that comprise, among others, genome editing must be science-based, predictable, risk-proportional, and harmonized with international trading partners. Harmonization and predictability would reduce investment risk and increase spending in R&D whereas risk-proportionality would balance the costs of respective innovation with the social benefits secured through risk avoidance. That is why it is important that appropriate and science-based policies and regulations are in place that allow rapid and thorough assessment of any risks associated with the products of.

A recent draft European Commission proposal in July 2023 defines an NGT (Category 1) plant as a plant obtained by directed mutagenesis, cisgenesis, and intragenesis, that is equivalent to a conventionally bred plant and does not contain any genetic material imported from outside the breeders' gene pool and contains a very limited number of changes to the plants genome. Therefore, the Commission defines NGT plants as GMOs that do not contain any "foreign" DNA. For NGT crops, the Commission introduces two categories that are regulated differently:

1. Category 1 NGT plants do not differ from plants from conventional breeding and/or could have arisen through natural or conventionally induced mutations. They are considered GMOs equivalent to conventionally grown plants provided that they meet the criteria further defined in Annex I.
2. Category 2 NGT plants are all other NGT plants that do not correspond to Category 1. The European Commission proposal specifies that plants which have acquired a herbicide-tolerance through gene editing always fall under Category 2.

According to the draft document Category 1 NGT plants are exempt from the existing GMO regulations. From this it can be deduced that Category 1 NGT plants are not subject to any specific risk assessments for health and the environment and will not require monitoring, labelling or traceability along supply chains. However, Category 1 NGT plants (and their products) are not unregulated. They will require notification to the relevant competent authority in order to allow confirmation of the categorisation before release or marketing. In addition, regulations governing activities with conventionally bred plants apply to them and -depending on the type of modification- other obligations such as imposed by the Novel Food Regulation (EU) 2015/22 must be met.

For Category 2 NGT plants, there are different procedures for release and placing on the market. The approval process is the usual GMO procedure based on the guidelines for genetically modified organisms (VO (EC) 1829/2003) with associated detection methods and traceability.

This proposal would potentially bring the EU more in line with regulatory authorities from other parts of the world and facilitate the commercialisation of many genome edited crops. This is especially important for controlled release of products of new breeding systems and technologies in field trials to assess the performance and net contribution that new varieties can make to sustainable farming systems and for environmental impact assessments. NGT varieties could also be assessed for their contribution towards managing crop production in relation to climate change and other externalities influencing food production and supply chains. However, while this proposal finally provides a concrete basis for an adapted regulatory framework, it will take several years before the new Regulation will be finalized and become effective, meanwhile stifling the dynamic research, development and market environment.

4 Public Perception

Public perception is one of the critical parameters influencing the development and commercialization of plants produced with the use of NGTs. General positive attitudes towards genome editing, both in the public and stakeholder acceptance, can support the implementation of relevant regulations in different countries. Like the legal situation and state of genome editing that is diverse worldwide, the public perception of plant gene technologies differs across regions. These differences in opinions are not grounded in science but rather in politics, psychological, social, cultural, personal and economic factors.

Engaging citizens in the development of innovations in life sciences is critical, and there is a potential advantage in communicating biotechnology and genome editing to society. The engagement of scientists and experts in public debates about the future of NGTs is crucial and may encourage scientists to make more effort in public debates regarding the benefits of genome editing products. Scientists, policymakers and entrepreneurs should create more opportunities for the public to participate in relevant meetings and activities (e.g., citizen science projects). Moreover, these interactions facilitate monitoring shifts in the acceptance of NGTs by the public.

5 PlantEd

The COST Action PlantEd (CA 18111) has since 2019 brought together scientists, plant breeders and other stakeholders to discuss many aspects of plant genome editing and this book reflects many to the issues considered during this Action. In a survey circulated among the 608 experts involved in PlantEd to estimate the value and impact of the network, 90% agree (completely or somewhat) that they have obtained new ideas and knowledge about plant genome editing by being part of the PlantEd network, 86% agree that they have obtained new connections and potential collaborators through the network, and 88% agree that PlantEd has contributed to the development of plant genome editing in Europe and beyond. This emphasizes the importance of the Action itself, as well as the importance of constant delivery of broad knowledge about genome editing technology to general public and stakeholders. This should facilitate the adoption of NGTs in crop improvement and agricultural production that should further contribute to food security and sustainability of agricultural production in changing climate and unstable market conditions.