Climate-neutral
2050

Modern methods to develop crops

Through thousands of years, farmers and plant breeders have selected individual plants with the best properties within the natural variation and used these to develop crops through plant breeding (traditional plant breeding through crossing and selection).

In the first half of the twentieth century methods were developed to increase the genetic variation of the crops. These include creation of random variation by ionized or chemical treatment (mutagenesis).

Later, methods were developed to transfer specific traits (genes) from one organism to another (genetic modification or transgenes).

Recently, there have been tremendous developments within plant breeding.

Within the recent decades, methods have been developed for highspeed analysis of whole genomes of plants thereby documenting the precise genetic characteristics of the plants. New methods have also been developed to introduce targeted and precise changes into the plant genome without inserting foreign genes (precision breeding).

Precision breeding
Precision breeding uses natural enzymes that can recognise specific spots in the genome where a new variation (a mutation) is wanted. At the specific site, the targeted enzyme cuts the double stranded DNA molecule (chromosome). Afterwards the DNA is spliced together by the plants' own repair systems.

New methods have been developed to introduce targeted and precise mutations into the plant genome without inserting foreign genes (precision breeding).

Two plant breeding methods

Precision breeding	Genetic modification
The double-stranded DNA molecule is cut at a specific position whereby an unwanted gene is inactivated without any other genes being inserted. This process takes place naturally every day in thousands of plants.	A gene is transferred to the plant from another organism that is not naturally compatible.
Thousands of new varieties based on traditional breeding methods are approved every year in the European Union.	Only one plant variety has been approved in the last 20 years in the European Union.
Mutagenesis	Transgenesis

These processes occur naturally in all plant cells when sun light induces mutations and creates the natural variation we find in nature. Such as in barley where a spontaneous mutation has made the plant resistant to the fungus mildew.

However, only very few of these natural variants lead to improved properties and they may take years to discover. Precision breeding makes it possible to introduce the variations targeted in spots into the genome, where it is known it will result in improved properties. For example enhanced resilience towards climate change or resistance to pests so that the farmer avoids either loss of yield or costs to protect the crop with pesticides.

Therefore, precision breeding possesses the potential to become very important supplementary techniques to both traditional plant breeding methods and traditional mutagenesis techniques.

The latter two introduce random mutations within the genome necessitating a long and expensive screening process to identify the positive mutations.

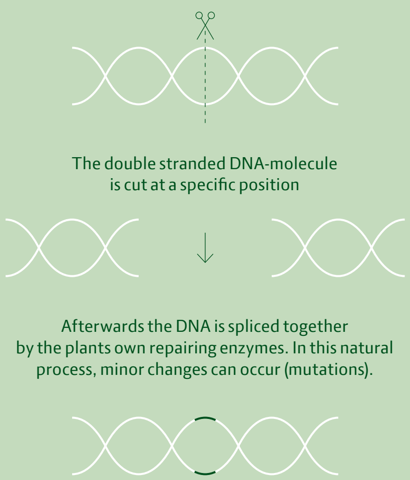
Precision breeding and mutagenesis or genetic modification

Precision breeding aims – just like traditional mutagenesis – to introduce small variations within the plant genome, resulting in improved characteristics such as inactivation of unwanted properties. In precision breeding, only the desired mutation occurs in the crop that is grown in the fields.

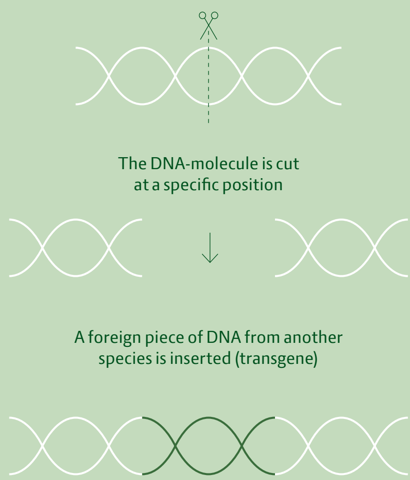
Precision breeding and traditional mutagenesis differ from genetic modification in that no foreign genes are introduced. The only changes are the inactivation of unwanted properties. Therefore, it is impossible to assess whether a characteristic has been introduced by chance in a natural process or through precision breeding.

Two different pathways for plant breeding

Precision breeding



Genetic modification



New plant breeding methods can deliver solutions to the challenges of climate change

The global community is facing huge challenges. First and foremost to secure the food supply in a changing climate.

Plant breeding is a prerequisite to ensure robust plant varieties, but the development of these is time-consuming and the results can be unsure. New plant breeding techniques are important tools to ensure a sustainable food production in the European Union.

The most important tool is precision breeding which introduces targeted and precise changes in the crops where needed. These techniques may improve crop resilience towards new pests and diseases reducing the need to use pesticides. The precision breeding techniques introduce changes that could also occur naturally, but these are very difficult to detect.

New plant breeding techniques are important tools to ensure a sustainable food production in the European Union.

Three main advantages of precision breeding

- **More precise than traditional plant breeding.** Mutations can be induced with ionic radiation or chemicals – just as they are induced by sun light. These mutations are induced at random whereas precision breeding techniques can inactivate a specific unwanted gene without other changes.

- **Faster. In traditional plant breeding it normally takes more than a decade to develop a new plant variety.** This is problematic when it comes to climate change adaptation. With precision breeding new varieties adapted to climate change can be developed much faster.

- **Not restricted to multinational companies.** Precision breeding techniques are cheap and therefore within reach for small and medium sized companies whereas only the largest multinational biotech companies can meet the cost of genetic modification.

Precision breeding techniques have several advantages compared to traditional plant breeding.

Possibilities with precision breeding

- **Crops resistant to pests and diseases or tolerant to draught.** These challenges will be more frequent with climate change and will accelerate in the future. Developing new plant varieties, such as wheat resistant to the fungus mildew, can reduce the loss of yield or the cost of pesticides to control this disease. The production will thus become more sustainable – both economically and environmentally.

- **Reduced loss of nutrients.** Developing perennial wheat grass with deep and extensive roots reduces the leaching of nutrients, reduces erosion, accumulates carbon in the soil and enables reduced tillage compared to traditional annual wheat. Perennial wheat grass has, however, a tendency of seed shattering and therefore the grains are lost before harvest. This can be avoided through a mutation in one specific gene.

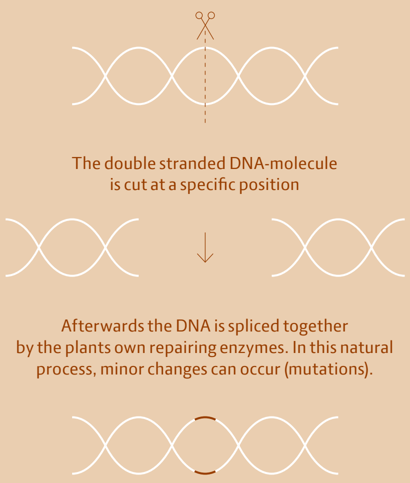
- **Reduced allergy.** Allergic reactions are typically induced by a single or a few genes in the crops. Targeted mutations through precision breeding can inactivate these genes and remove the allergen in the crop.

- **Climate friendly crops.** Grasses are perennial crops that accumulate carbon in the soil and reduce the emission of carbon dioxide due to tillage. The development of grasses that supply humans and live-stock with protein or grasses with higher digestibility or improved protein profile has the potential to reduce the carbon footprint of the food production. This is also possible with potatoes with improved starch content. Both are examples of crops developed with precision breeding that will increase the productivity and hence reduce the land use and emission of greenhouse gases.

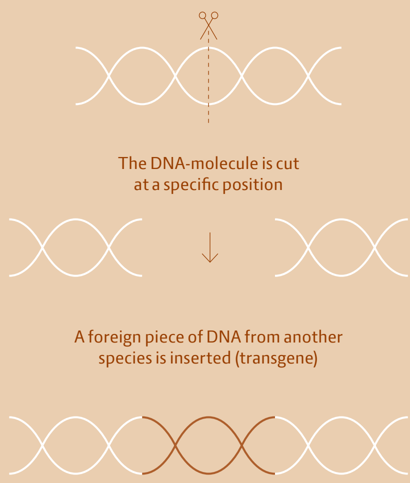
- **Eliminating carcinogens.** A substance in potatoes can lead to the creation of carcinogenic substances (acrylic amide) when the potatoes are fried. Precision breeding can eliminate these substances.

Two different pathways for plant breeding

Precision breeding



Genetic modification



Climate-neutral 2050

Modernisation of the EU regulation of precision breeding needed

According to directive 2001/18 all genetically modified organisms must be approved case by case before marketing within the European Union. Several non-GM plant breeding techniques are exempted from the directive including mutagenesis where the changes in the plants could have been introduced in nature through mutations.

Precision breeding, where a specific gene is inactivated without inserting foreign genes, is not directly addressed in the directive as the techniques were not yet developed when the directive was adopted.

Because these techniques lead to the same changes as the techniques that are exempted from the regulation, Sweden and France concluded that precision breeding should not be regulated as a GMO. This was, however, overruled in the European Court of Justice ruling in July 2018 with the argument that precision breeding was not specifically addressed when the directive was adopted.

The market approval procedure for genetically modified crops is very costly and takes several years. Every year several thousand plant varieties developed with traditional breeding techniques are being marketed whereas only one genetically modified variety has been marketed for the last twenty years (a maize variety).

Two ways to deregulate precision breeding

On 29th April 2021, the European Commission published a Commission Working Staff document on precision breeding and other new plant breeding techniques with the purpose to bring the European Union out of the deadlock caused by the 2018 court ruling stating that all crops developed with precision breeding must be approved as GMOs.

There are two basic approaches:

1. Updating the current directive so that precision breeding of plants is exempted from the comprehensive GM legislation just like other mutagenesis techniques. The Commission is now considering whether this can be achieved by revising the annex with the mutagenesis exemption or administratively. Both approaches would take a few months.

2. Amending the GMO-directive and the basic approval system for GM crops in the European Union. This must follow the basic process of amending the EU legislation which normally takes four to six years as a minimum.

It does not need to be one or the other. However, to ensure access to the new techniques and opportunities the first approach should be addressed right away but this does not exclude the second in the long run.

Update the existing rules now – change the directive in the long run

European plant breeders and farmers must have immediate access to use the precision breeding techniques as this is critical to solve the challenges of climate change.

The mutagenesis exemption must be revised without delay to include the precision breeding techniques where no new genes are inserted.

If we are to solve the challenges of climate change now, there is not enough time to adopt a new directive as this will take several years.

Next steps – impact assessment and legislative initiatives

The European Commission concluded in the Commission Staff Working Document on 29th April 2021that access to the new plant breeding techniques is important in which it is concluded that access to the new breeding techniques is important for plant breeding putting special emphasis on precision breeding. The document was requested by the Council and following the presentation for the Member States and the Parliament, the Commission will proceed with an impact assessment and legislative initiatives.