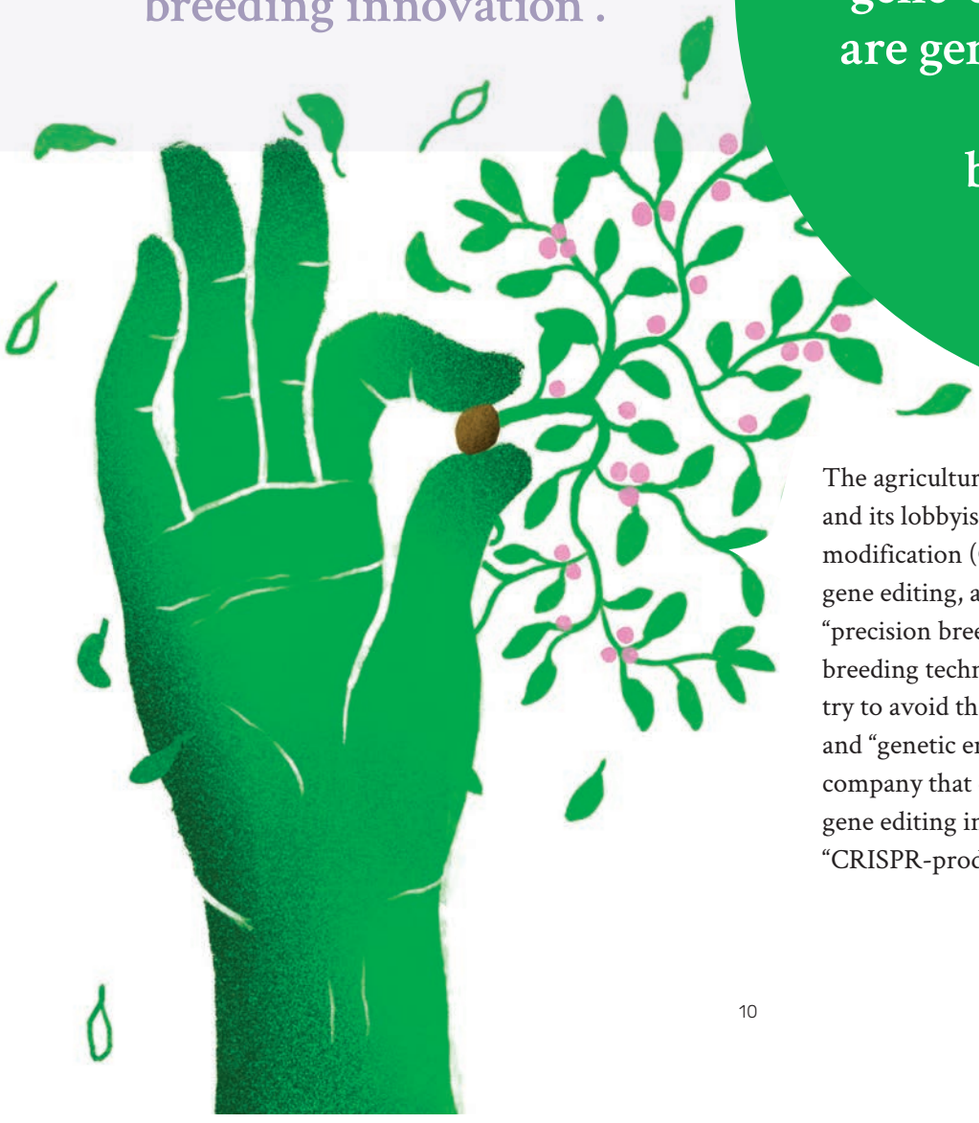
1. Gene editing is genetic engineering, not breeding

MYTH

Gene-editing techniques are "new breeding techniques", "precision breeding" or "breeding innovation".

REALITY

Technically and legally, gene-editing techniques are genetic modification techniques, not breeding methods.



The agricultural biotechnology industry and its lobbyists often refer to new genetic modification (GM) techniques, especially gene editing, as "breeding innovation", "precision breeding techniques" and "new breeding techniques".[1,2,3,4] They strenuously try to avoid the terms "genetic modification" and "genetic engineering". Corteva, the company that controls the use of CRISPR gene editing in crop plants, even argues that "CRISPR-produced plants are not GMOs".[5]

European institutions also avoid the terms "genetic modification" and "GMO". The Council of Ministers introduced the term "novel genomic techniques",[6] which the Commission adapted to "new genomic techniques".[7] The Commission also talks about "new techniques in biotechnology".[8]

The use of the term "breeding" appears to be an attempt to give an air of naturalness to the new genetic engineering techniques and thus convince the public to accept them. It may also be an attempt to make the application of GMO regulations appear counterintuitive and illogical: If gene-edited products are not GMOs, why should they be regulated as GMOs?

However, gene-editing techniques are not breeding techniques. They are technically and legally GM techniques, give rise to genetically modified organisms (GMOs), and fall within the scope of EU GMO laws, as confirmed by the European Court of Justice ruling of 2018.[9,10]

EU law defines a GMO as an organism in which "the genetic material has been altered in a way that does not occur naturally by mating and/or natural recombination".[11] This wording accurately describes the way in which older-style transgenic and new GMOs, such as gene-edited plants, are produced. Genetic modification employs artificial techniques that require direct human intervention in the genome. In contrast, the terms "mating and/or natural recombination" describe natural processes used in conventional plant and animal breeding.

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EU GMO law exempts some GMOs, such as those produced using a decades-old technique called mutation breeding (also called random mutagenesis), from its requirements for authorisation, traceability and labelling. But this is only possible if they were produced using techniques that have a "long safety record".[9] This is clearly not the case with gene editing.

HOW DOES GENE EDITING WORK?

Old and new GMOs have more in common than proponents would have us believe. Of three steps involved in genome editing – gene delivery, gene editing, and whole plant regeneration in tissue culture – the first and last essentially remain the same. The first step, delivery of foreign genetic material into the plant cells (also called GM transformation) is usually done with the help of small circular DNA molecules (plasmids) that are introduced into the cells using a soil bacterium called Agrobacterium tumefaciens or a method called particle bombardment. The plasmid then inserts itself into the plant cell's DNA.

Regarding the "editing step", the majority of gene-editing applications involve first cutting the DNA with enzymes, called nucleases, which are supposed to act only at chosen sites in the genome of a living cell.

These gene-editing applications are called "site-directed nuclease" or "SDN" procedures. The SDN creates a double-strand break in the DNA. The enzymes most commonly used for this cutting are the Cas family of proteins (for CRISPR) and FokI (for TALENs and Zinc Finger Nucleases).[12]

The cutting event triggers alarm signals in the cell, as broken DNA is dangerous to the organism. So the cell initiates a DNA repair process to mend the double-strand DNA cut. While the initial break in the DNA can be targeted to a specific site in the genome, the subsequent "repair" is carried out by the cell's innate repair mechanisms and cannot be controlled by the genetic engineer.'

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The repair is often not clean or precise, but can result in "chromosomal mayhem" in the genome, to cite the title of a commentary on studies on CRISPR/Cas gene editing in human embryos.[13]

The result of the repair is called the "edit". Researchers must select from many edited organisms to obtain the one they desire.[12]

Some divide SDN procedures into SDN-1, SDN-2, and SDN-3.[14] They can be defined as follows:

• SDN-1 refers to disruption of the function of a gene (also known as gene knockout). The repair of the double-strand break in the DNA results in either a deletion (removal) of part of the gene or the insertion of additional DNA base units, which are taken from the genome of the organism that is being edited. This disrupts the sequence of the gene and thus knocks out its normal function.

• SDN-2 refers to gene alteration. While the break is repaired by the cell, a repair template is supplied that is complementary to the area of the break, which the cell uses to repair the break. The template contains one or several DNA base unit sequence changes in the genetic code, which the repair mechanism exchanges into the plant's genetic material, resulting in a mutation of the target gene. The mutated gene will then produce an altered protein product with an altered function.

• SDN-3 refers to gene insertion. The DNA break is accompanied by a template containing a gene or other sequence of genetic material. The cell's natural repair process uses this template to repair the break, resulting in the insertion of new genetic material (foreign DNA, which can include a whole new gene). The aim is to confer novel functions and characteristics on the organism.

Another gene-editing technique is oligonucleotide-directed mutagenesis (ODM). ODM does not cause a double-strand break in the DNA. Instead it involves the introduction of short sequences of synthetic DNA and RNA – called oligonucleotides – into the cells. The oligonucleotide interacts with the cell's DNA, tricking the cell's repair mechanisms into altering the cell's own DNA to match that of the oligonucleotide.

All these techniques will change the biochemistry of the plant – this is the aim of gene editing – so that a new trait can result.

GENE EDITING IS GENETIC MODIFICATION

Although GM and conventional breeding will result in the creation of new varieties, the two are distinct methods and are not interchangeable. Gene editing is clearly a GM technique but conventional breeding is not, however hard the agricultural biotech industry tries to blur the boundaries.

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