ANNEX I: LOBBYING ARGUMENTS

The EU science organisations EPSO, ALLEA and EU-SAGE use the same arguments in favour of deregulation as the industry (see "Gene editing myths and reality"[1]). They say that the technology is "precise" and that the resulting products are "nature-identical", "safe", "undetectable" and "indispensable" for sustainable agriculture. Just like the industry, they hide the fact that gene editing is genetic modification (GM) and results in regulated genetically modified organisms (GMOs). Instead they prefer to talk about "precision breeding", "new breeding techniques", or "new plant breeding techniques".

The scientists-turned-lobbyists ignore findings by their fellow molecular biologists who have shown that gene editing is not precise and that its products carry genetic changes that can be very different from those occurring naturally or resulting from older methods of mutagenesis breeding (chemical- or radiation-induced). They ignore the fact that no studies have been published that ascertain the safety of gene-edited organisms for consumers and the environment. Their enthusiasm for the technology itself contrasts sharply with their lack of enthusiasm for research into detection techniques – a related field of science.

Like the seed companies themselves, the scientists – often GMO developers themselves – prefer to speculate about potential applications and highlight early-stage proof-of-concept research, rather than taking a hard look at existing applications, like Cibus's gene-edited canola and Calyxt's gene-edited soy, and the real value and risks involved.

Precision

LOBBYING CLAIM: GENE EDITING IS PRECISE.

ALLEA said: "Genome editing encompasses the efficient, precise and time-saving introduction of mutations in the genetic blueprint of cultivated plants by making use of one of a variety of targeted molecular editors."[2]

EPSO said: "Experts demonstrate, on the basis of peer-reviewed publications that genome editing is more precise [than conventional breeding and chemical- and radiation-induced mutagenesis breeding], since the site and/or nature of the mutation is pre-determined without causing more unintended mutations in the genome than conventional breeding."[3]

EU-SAGE said: "New genome editing technologies follow the same principle [as mutagenesis breeding], but with a higher efficiency and precision, as they apply only one or a few targeted mutations – the type of changes that can also occur naturally or through traditional mutagenic approaches."[4]

REALITY: GENE EDITING IS NOT PRECISE, AS SHOWN BY A LARGE AND GROWING NUMBER OF STUDIES IN HUMAN, ANIMAL AND PLANT CELLS.

It is true that the initial double-strand break in the DNA caused by the gene editing "scissors" (nuclease) can be targeted to a specific site in the genome. Claims of precision only consider this one step. But the subsequent repair process that forms the "edit" is not under the control of the genetic engineer – it is at the mercy of the cell's DNA repair process. This process is not precise and gives rise to many genetic errors, also known as unintended mutations (DNA damage). These occur at both the desired editing site (so-called target site) in the genome as well as other locations (so-called off-target sites). Types of mutations found include large deletions, insertions, and rearrangements of DNA.[5]

In addition, the tissue culture process that is applied to GMO plants (including gene-edited ones) induces many mutations.[6]

Taken together, all of the above mutations can lead to the creation of new gene sequences producing new mutant proteins, with unknown consequences to the health of consumers or to wildlife. In plants, these mutations could result in altered gene functioning, leading to altered biochemistry, which could include the production of novel toxins or allergens.[7]

However, most such effects in gene-edited plants will be missed due to the inadequacies of current analytical processes. A scientific review explained: "The vast majority of plant studies using genome editing applications are looking for off-target effects in a biased manner by investigating solely at in silico predicted sites of the genome, whilst a scant minority of these studies are using unbiased WGS [whole genome sequencing] approaches to identify off-target effects".[8]

EPSO's claim that gene editing does not cause more mutations than conventional breeding is unfounded since the studies that would be needed to reach this conclusion have not been done. There are no studies using unbiased screening methods that compare the frequency and type of unintended off-target and on-target genetic errors in gene editing with those in conventional breeding and mutagenesis breeding – let alone any that conclude that gene editing is more precise in its outcomes. On the contrary, existing evidence cited above shows a wide variety of unintended genetic errors from gene editing.

In addition, the screening methods commonly used to analyse genetic errors in gene-edited organisms are unreliable and will miss many such errors.[9] An appropriate method would be whole genome long-read DNA sequencing. Thus claims of precision for this technology are statements of faith, based on a "don't look, don't find" approach.

Moreover, EPSO misleadingly conflates "conventional breeding" with mutagenesis breeding. Mutagenesis breeding is defined as genetic modification under EU law but has been exempted from the requirements of the law – safety assessment, traceability, and labelling – due to its perceived history of safe use.[10] However, for the plant itself, mutagenesis breeding is not safe – it results in large numbers of deformed and non-viable plants.[11]

Thus EPSO is making the wrong comparison. Gene editing should be compared not with the highly mutagenic technique of mutagenesis breeding but with standard conventional breeding. In standard conventional breeding, mutations are a low frequency event[12] – or breeders would not be able to do their jobs. And conventional breeding has an undeniable history of safe use. In contrast, gene editing has no history of use in foods and crops, let alone safe use.

Naturalness

LOBBYING CLAIM: CHANGES MADE IN GENE EDITING ARE THE SAME AS COULD HAPPEN IN NATURE AND NO MORE RISKY.

ALLEA: "Genome-edited crops with DNA changes that can as well spontaneously occur in nature or result from mutation breeding methods are considered to be generally as safe as crops with the same DNA changes obtained through conventional methods. In other words, a genome-edited crop with a specific mutation is as safe as a conventional crop containing the same mutation."[13]

EPSO: "Safety concerns [with "new genomic techniques" or NGTs] should not differ from those relevant to plants obtained using methods with a history of safe use, because NGT mutations could also arise in nature or during conventional breeding programs."[14]

EU-SAGE: "The European legislation is being interpreted to mean that genome edited crops are subject to the GMO regulatory provisions, also in cases where the edit is not different from what is present in nature or can be achieved by conventional breeding methods. The latter makes no sense from a scientific point of view and shows that the current EU GMO legislation is no longer fit for purpose."[15]

REALITY: THERE IS NO EVIDENCE THAT ANY GIVEN GENE-EDITED ORGANISM IS THE SAME AS COULD HAPPEN IN NATURE; IF IT WAS, IT WOULD NOT BE PATENTABLE.

In order to claim intellectual property rights on gene-edited technologies and products, companies need to demonstrate novelty, an inventive step, and a technical aspect. So for the purposes of patent law, gene-edited plants are definitely not nature-identical. Companies appear to be telling the public and regulators one thing (that their gene-edited organism could occur in nature) and patent offices the opposite (that it could not occur in nature). Both cannot be true.

Moreover, the notion that gene editing can produce changes that could happen in nature is entirely theoretical. If someone wanted to prove that their gene-edited GMO was the same as could happen in nature, they would have to find a naturally bred organism that was exactly the same, both in terms of the full genetic sequence and in terms of its molecular composition (the proteins and natural chemicals that make up the structure and function of the organism). To our knowledge, this has not been done.

It is highly unlikely that such an objective analysis would conclude that the gene-edited organism is the same as a naturally bred one, because gene editing has been shown in many research studies not to be precise but to produce extensive genetic errors.[16] Such errors have never been shown to arise from natural breeding with equal type, extent, and frequency.

Importantly, the claims of naturalness are usually limited to the intended "edit" or specific mutation, while sweeping conclusions are drawn about the naturalness and safety of the whole GM organism. This ignores the fact that gene editing causes an extensive range of genetic errors that can affect the organism as a whole. The EU GMO legislation applies to the GMO as a whole, not only the desired genetic modifications in it. This is fully justified in the light of the (often overlooked) genetic errors caused by genetic engineering approaches, both older-style and more recent.

LOBBYING CLAIM: GENE EDITING PRODUCES SIMILAR GENETIC ERRORS TO OLDER TECHNIQUES OF MUTAGENESIS BREEDING, BUT FEWER OF THEM.

ALLEA: "Scientific evidence shows that the level of uncertainty about the consequences of the mutagenesis process is much higher in conventional mutagenesis than in modern targeted forms of mutagenesis."[17]

EPSO: "There is broad scientific consensus that unintended DNA alterations produced by genome editing are of the same type but orders of magnitude less frequent than those produced by older methods such as EMS [chemically-induced] or radiation mutagenesis."[18]

EU-SAGE: "Conventional mutagenesis is exempt from the provisions of the GMO legislation because of its long safety record. Nevertheless, this method incites hundreds or even thousands of random mutations with unknown effects and consequences... New genome editing technologies follow the same principle, but with a higher efficiency and precision, as they apply only one or a few targeted mutations – the type of changes that can also occur naturally or through traditional mutagenic approaches."[19]

REALITY: THIS CLAIM IS BASELESS AS THERE ARE NO STUDIES USING RELIABLE SCREENING METHODS THAT COMPARE THE FREQUENCY AND TYPE OF GENETIC ERRORS IN MUTAGENESIS BRED AND GENE-EDITED PLANTS.

However, there is clear experimental evidence showing that assumptions that gene editing only causes small changes or only the intended changes are false. Unintended effects can include large deletions and rearrangements of DNA.[20]

There is also evidence that mutations induced by gene editing can be very different from those induced by chemicals or radiation in mutation breeding. A scientific review shows that gene editing can produce changes in areas of the genome that are otherwise protected from mutations.[21] Also, gene-editing techniques enable complex alterations of genomes that would be extremely difficult or impossible to achieve with conventional breeding or mutation breeding.[22]

In light of this evidence, gene-edited organisms must be subjected to risk assessment that takes account of the novel genomic combinations and thus the specific risks resulting from the processes used in gene editing.[23] As the authors of a peer-reviewed paper stated, "Characteristics of some genome editing applications, e.g., the small extent of genomic sequence change and their higher targeting efficiency, i.e., precision, cannot be considered an indication of safety per se, especially in relation to novel traits created by such modifications. All nGMs [new genetic modification techniques] considered here can result in unintended changes of different types and frequencies. However, the rapid development of nGM [new GM] plants can compromise the detection and elimination of unintended effects. Thus, a case-specific premarket risk assessment should be conducted for nGM plants, including an appropriate molecular characterization to identify unintended changes and/or confirm the absence of unwanted transgenic sequences."[24]

The point about unwanted transgenic sequences is based on findings that gene editing can inadvertently lead to the insertion into the organism's genome of:

- foreign contaminating DNA
- the full (rather than the intended part) of the repair template DNA molecule (used in SDN-2 and SDN-3), or
- fragments of the plasmid DNA (circular molecules of DNA derived from bacteria), which encode for the gene-editing tool and are introduced into cells at the start of the gene editing process.

For more information, see "What is gene editing?" in the main report, "Behind the smokescreen: Vested interests of EU scientists lobbying for GMO deregulation".

Contrary to EPSO's statement, no "scientific consensus" can be claimed on the type and frequency of genetic errors arising from gene editing compared with mutagenesis breeding, as there is no evidence base on which to formulate a consensus – the required comparative studies have not been done.

For more information, see "Gene editing myths and reality", p21–24.[25]

Safety

LOBBYING CLAIM: GENE-EDITED CROPS ARE AS SAFE FOR PEOPLE'S HEALTH AND THE ENVIRONMENT AS CONVENTIONALLY BRED ONES.

ALLEA: "Plants that were subjected to targeted genome edits, which do not add foreign DNA, do not present any other health or environmental danger than plants obtained through classical breeding techniques, and are as safe or dangerous as the latter."[26]

EPSO: "With regard to ethical concerns raised about GM crops and extended to NGTs, EPSO considers that… there is no specific potential harm to human health since NGT-plants are indistinguishable from mutants obtained by methods considered to have a safe history of use and are produced by methods that are less invasive than classical transgenesis shown to have no negative impact on mammalian health."[27]

EU-SAGE: "Organisms that have undergone simple and targeted genome edits by means of precision breeding and which do not contain foreign genes are at least as safe as if they were derived from classical breeding techniques."[28]

REALITY: GENE-EDITED CROPS CAN POSE THREATS TO HEALTH AND THE ENVIRONMENT.

Contrary to these groups' claims, scientists who are independent of the agricultural biotechnology industry point to the imprecision of gene editing techniques and emphasise that their outcomes are unpredictable, with potentially dangerous implications. A statement signed by 61 international scientists said, "Current genetic modification techniques – including gene editing and gene silencing – are not sufficiently specific to introduce only the intended molecular changes. Unexpected molecular changes could result in the production of novel toxins and allergens or unpredictable impacts on other organisms and ecosystems."[29]

A peer-reviewed paper confirmed, "Unintended effects in genome-edited crops could lead to a variety of unexpected effects… [these] could lead to changes in the organisms' biochemistry, including its metabolic and protein profile, which, in turn, could affect its toxicity and allergenicity. As this could impact food, feed and environmental safety, any genome-edited organism would need to be screened genome-wide for genetic irregularities."[30]

Another paper stated: "Modification of crops by NPBTs [new plant breeding techniques, including gene editing] can result in various changes in gene expression in the NPBT and consequently in the phenotypic characteristics of the NPBT… Effects on gene expression are commonly associated with phenotypic changes, i.e. they may result in compositional or developmental changes, which can be associated with adverse effects on health and/or environment."[31]

Also contrary to these groups' statements, the risks posed by gene-edited plants and other organisms are not confined to the introduction of foreign DNA or genes. Unintended genetic changes in gene-edited crops can still alter the pattern of gene function within the organism. This can change biochemical pathways and lead to compositional changes, which could include the production of novel toxins and allergens or altered levels of existing toxins and allergens.[32]

Such unintended changes or genetic errors, including large insertions, deletions, and rearrangements of DNA, have been found to occur even in a so-called SDN-1 gene-editing procedure in rice. SDN-1 refers to the gene disruption type of editing, where no foreign DNA or repair template are deliberately inserted. This was a surprise because the researchers were only intending to make small insertions and deletions in the genome.

The authors of the paper warned that CRISPR-Cas "may be not as precise as expected in rice". They said, "early and accurate molecular characterization and screening must be carried out for generations before transitioning of CRISPR-Cas9 system from lab to field". They added, "Understanding of uncertainties and risks regarding genome editing is necessary and critical before a new global policy for the new biotechnology is established".[33]

This study shows that SDN-1 gene editing, in which no foreign DNA or genes were inserted, can cause widespread genetic damage, which may have implications for public health and the environment.

As mentioned above, the types of changes caused by gene editing are different from those caused by mutagenesis breeding (EPSO's "mutants obtained by methods considered to have a safe history of use") and thus may pose different and specific risks.[34]

EPSO's assertion that crops derived from "classical transgenesis" (older-style GM) have been "shown to have no negative impact on mammalian health" is false. Numerous animal feeding studies reveal negative impacts on mammalian health from GM crop consumption.[35] Over 300 scientists and legal experts signed a statement attesting that there is "no consensus" on the safety of GM crops and foods.[36]

Strong regulation must be maintained to ensure that similar or worse outcomes, compared with these effects from older-style GM organisms, do not result from gene-edited crops and foods. Minimally, gene-edited crops and foods must be kept under the existing GMO regulations, but also, the risk assessment guidelines need to broadened to encompass the special and unique risks posed by these novel organisms.[37]

For more information, see "Gene editing myths and reality", p25–35.[38]

Non-detectability

LOBBYING CLAIM: GENE-EDITED PRODUCTS CANNOT BE DISTINGUISHED FROM PRODUCTS DEVELOPED WITH CONVENTIONAL BREEDING.

ALLEA: "[Gene-edited] crops with small edits cannot be detected".[39]

EPSO: "Mutations induced by genome editing technologies cannot be unequivocally distinguished from natural mutations, nor can they be differentiated from those induced by conventional mutagenesis techniques."[40]

EU-SAGE: "The current regulatory system involves implementation and enforcement challenges in the EU, relating in particular to the detection of NGT [new GM techniques] products that contain no foreign genetic material."[41]

REALITY: GENE-EDITED PRODUCTS CAN BE DETECTED AND POTENTIALLY ALSO DISTINGUISHED FROM PRODUCTS DEVELOPED WITH CONVENTIONAL AND MUTAGENESIS BREEDING.

The detection of individual plant varieties is generally acknowledged as feasible by the plant breeding sector. In 2019 the International Seed Testing Association (ISTA) concluded on methods for variety testing that "DNA-based techniques are 1) developed and used by breeding companies and seed companies 2) mature and available for seed testing, already used in many laboratories, in many countries".[42]

In 2021 the European Commission acknowledged the effectiveness of biochemical and molecular techniques (BMT) in the identification of plant varieties by issuing Implementing Directive (EU) 2021/971. The Directive contains amendments to legislation concerning food crop seed varieties. It states, "The use of BMT enables certification authorities to identify the plant variety on the basis of laboratory analysis instead of visual phenotypic observation of the plants in the field." It adds, "BMT in plant breeding and seed testing are developing fast and their use in the seed sector is increasingly important."[43]

It is not credible to suggest that only non-GM varieties would be identifiable via these techniques, whereas GM varieties would not be.

Under the EU's GMO legislation, GMO developers are required to submit a test that correctly identifies and quantifies the presence of the GM crop, and to deliver "reference" sample material for that crop. The GMO detection test is not required to identify the GM technique used to engineer the crop.

This requirement must be maintained and enforced for gene-edited GM organisms. For Cibus's SU Canola, the developer submitted a reliable detection method to Canadian authorities, so we know that it is possible.

The identification and detection of unknown GM varieties engineered with gene editing should also be possible. For this to happen, developers and EU authorities would need to acknowledge what is scientifically known – that gene editing not only produces the intended change in the genome, but also a range of unintended changes that, if characterised, could be used as molecular markers to distinguish GM from non-GM varieties. The EU and its Member States should invest in research efforts to establish the detection strategies and methods needed to achieve this.

Sustainability

LOBBYING CLAIM: WE NEED TO EMBRACE GENE EDITING TO REDUCE PESTICIDE USE AND MEET SUSTAINABILITY GOALS.

ALLEA: "There is a broad consensus that genome-edited crops will make a critical contribution in the coming years to make food systems more sustainable and more resilient to climate change."[44]

EPSO: "Genome editing permits the efficient translation of biological knowledge of genes into traits useful for a sustainable agriculture. It is not the only answer to current challenges of agriculture, such as the overuse of pesticides and inputs, climate change, crop monocultures or the desire for improved human food. However, together with other levers such as the reduction of waste, innovative culture systems or precision agriculture, genome editing can contribute to meeting and managing these challenges by enhancing genetic progress towards more diverse, better adapted and yet high yielding plant varieties."[45]

EU-SAGE: "Subjecting crops obtained through modern genome editing to GMO regulations will deny European consumers, producers, researchers and entrepreneurs important opportunities in sustainable agriculture."[46]

REALITY: WE ALREADY KNOW HOW TO REDUCE PESTICIDE USE AND IMPROVE SUSTAINABILITY WITH PROVEN AGROECOLOGICAL METHODS.

Claims have been made for decades that agricultural genetic engineering (of which gene editing is the latest example) can reduce pesticide use and provide crops adapted to climate extremes such as drought. However, these claims have proven false. GM crops have led to increased pesticide use[47] and have not proved more tolerant to drought than non-GM crops.[48]

Conventional breeding continues to outstrip GM in developing crops with durable resistance to pests and diseases, drought tolerance, enhanced nutritional quality, and tolerance to salinity.[49] This is because these are genetically complex traits, the product of many genes working together in a precisely regulated way. Such traits will be extremely difficult or impossible to achieve by manipulating one or a few genes, which is all that gene editing and genetic modification in general can achieve.

We already know how to reduce pesticide use and make farming more sustainable, using agroecology[50] and high-performing conventionally bred crops[51] that are adapted to local conditions.[52] Gene editing is an expensive distraction from these proven-successful approaches. Narrowly focused genetic manipulations cannot provide solutions to agricultural problems – whole systems approaches are needed.

For more information, see “Gene editing myths and reality”, p54–60.[53]

Lobby groups do not reflect the evidence

As is clear from the above evidence, the positions presented by EPSO, ALLEA and EU-SAGE do not reflect the scientific evidence, which shows that gene editing results in numerous genetic errors, generates changes that cannot be obtained by other means, and raises specific safety concerns.

Instead of making unfounded claims about the supposed naturalness, safety, non-detectability or sustainability of GM crops engineered with gene editing, scientists should endeavour to develop the evidence base on unintended outcomes and risks. They should strive to develop detection strategies and methods to support the application of the EU’s GMO legislation, as interpreted by the EU’s highest court.

REFERENCES ANNEX I

1 Robinson, C (2021). Gene editing myths and reality. The Greens/EFA in the European Parliament. February. https://www.greens-efa.eu/en/article/document/gene-editing-myths-and-reality/

2 ALLEA (2020). Genome editing for crop improvement. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

3 EPSO (2019). On the ECJ ruling regarding mutagenesis and the Genetically Modified Organisms Directive. 19 February. https://epsoweb.org/epso/epso-statement-on-the-court-of-justice-of-the-eu-ruling-regarding-mutagenesis-and-the-gmo-directive/2019/02/19/

4 EU-SAGE (2018). Regulating genome-edited organisms as GMOs has negative consequences for agriculture, society and economy. Dec. https://www.eu-sage.eu/sites/default/files/2020-02/Position%20paper%20on%20the%20ECJ%20ruling.pdf

5 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2 ; Robinson C, Antoniou M (2019). Science supports need to subject gene-edited plants to strict safety assessments. GMWatch.org. 20 Nov. https://www.gmwatch.org/en/news/latest-news/19223 ; Agapito-Tenfen SZ et al (2018). Revisiting risk governance of GM plants: The need to consider new and emerging gene-editing techniques. Front Plant Sci 9. doi:10.3389/fpls.2018.01874

6 Latham JR et al (2006). The mutational consequences of plant transformation. J Biomed Biotechnol 2006: 1–7. http://www.ncbi.nlm.nih.gov/pubmed/16883050

7 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2 ; Agapito-Tenfen SZ et al (2018). Revisiting risk governance of GM plants: The need to consider new and emerging gene-editing techniques. Front Plant Sci 9. doi:10.3389/fpls.2018.01874 ; European Network of Scientists for Social and Environmental Responsibility (ENSSER) (2019). ENSSER Statement: New genetic modification techniques and their products pose risks that need to be assessed. ensser.org. 8 Nov. https://ensser.org/publications/2019-publications/ensser-statement-new-genetic-modification-techniques-and-their-products-pose-risks-that-need-to-be-assessed/

8 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2

9 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2

10 European Parliament and Council (2001). Directive 2001/18/EC of the European Parliament and of the Council of 12 March 2001 on the deliberate release into the environment of genetically modified organisms and repealing Council Directive 90/220/EEC. Official Journal L. 106:1-39. http://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32001L0018

11 Acquaah G (2007). Principles of Plant Genetics and Breeding. Wiley-Blackwell. http://bit.ly/17GGkBG ; Van Harten AM (1998). Mutation Breeding: Theory and Practical Applications. Cambridge University Press.

12 Jain SM (2010). Mutagenesis in crop improvement under the climate change. Romanian Biotechnological Letters 15(2):88-106. https://tinyurl.com/ydert6dq

13 Dima O et al (2020). Genome Editing for Crop Improvement. ALLEA – All European Academies. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

14 EPSO (2020). On the EC Study on New Genomic Techniques (NGTs). https://epsoweb.org/download/20_05_27_epso_ec-new-genomic-techniques-study_statement/

15 Inzé D (2020). EU-SAGE letter to European Commission. 30 Jan. https://www.eu-sage.eu/sites/default/files/2020-02/EU-SAGE letter to European Commission.pdf

16 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2 ; GMWatch (2020). Gene editing: Unexpected outcomes and risks. GMWatch.org. 3 Aug. https://www.gmwatch.org/en/67-uncategorised/19499-gene-editing-unexpected-outcomes-and-risks

17 Dima O et al (2020). Genome Editing for Crop Improvement. ALLEA – All European Academies. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

18 EPSO (2019). On the ECJ Ruling Regarding Mutagenesis and the Genetically Modified Organisms Directive. https://epsoweb.org/epso/epso-statement-on-the-court-of-justice-of-the-eu-ruling-regarding-mutagenesis-and-the-gmo-directive/2019/02/19/

19 EU-SAGE (2018). Regulating genome-edited organisms as GMOs has negative consequences for agriculture, society and economy. Dec. https://www.eu-sage.eu/sites/default/files/2020-02/Position%20paper%20on%20the%20ECJ%20ruling.pdf

20 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2 ; Robinson C, Antoniou M (2019). Science supports need to subject gene-edited plants to strict safety assessments. GMWatch.org. 20 Nov. https://www.gmwatch.org/en/news/latest-news/19223

21 Kawall K. New possibilities on the horizon: Genome editing makes the whole genome accessible for changes. Front Plant Sci. 2019;10. doi:10.3389/fpls.2019.00525

22 Kawall K, Cotter J, Then C. Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe. 2020;32(1):106. doi:10.1186/s12302-020-00361-2

23 Kawall K, Cotter J, Then C. Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe. 2020;32(1):106. doi:10.1186/s12302-020-00361-2

24 Eckerstorfer MF, Dolezel M, Heissenberger A, et al. An EU perspective on biosafety considerations for plants developed by genome editing and other new genetic modification techniques (nGMs). Front Bioeng Biotechnol. 2019;7. doi:10.3389/fbioe.2019.00031

25 Robinson C (2021). Gene Editing Myths and Reality: A Guide through the Smokescreen. The Greens/EFA in the European Parliament. https://www.greens-efa.eu/en/article/document/gene-editing-myths-and-reality/

26 Dima O et al (2020). Genome Editing for Crop Improvement. ALLEA – All European Academies. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

27 EPSO (2020). On the EC Study on New Genomic Techniques (NGTs). https://epsoweb.org/download/20_05_27_epso_ec-new-genomic-techniques-study_statement/

28 EU-SAGE (2018). Regulating genome-edited organisms as GMOs has negative consequences for agriculture, society and economy. Dec. https://www.eu-sage.eu/sites/default/files/2020-02/Position%20paper%20on%20the%20ECJ%20ruling.pdf

29 European Network of Scientists for Social and Environmental Responsibility (ENSSER). ENSSER Statement: New genetic modification techniques and their products pose risks that need to be assessed. ensser.org. Published November 8, 2019. https://ensser.org/publications/2019-publications/ensser-statement-new-genetic-modification-techniques-and-their-products-pose-risks-that-need-to-be-assessed/

30 Kawall K, Cotter J, Then C. Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe. 2020;32(1):106. doi:10.1186/s12302-020-00361-2

31 Eckerstorfer M, Miklau M, Gaugitsch. New Plant Breeding Techniques and Risks Associated with Their Application. Environment Agency Austria; 2014. http://www.ekah.admin.ch/fileadmin/ekah-dateien/New_Plant_Breeding_Techniques_UBA_Vienna_2014_2.pdf

32 Kawall K et al (2020). Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe 32(1):106. doi:10.1186/s12302-020-00361-2 ; Agapito-Tenfen SZ et al (2018). Revisiting risk governance of GM plants: The need to consider new and emerging gene-editing techniques. Front Plant Sci 9. doi:10.3389/fpls.2018.01874 ; European Network of Scientists for Social and Environmental Responsibility (ENSSER) (2019). ENSSER Statement: New genetic modification techniques and their products pose risks that need to be assessed. ensser.org. 8 Nov. https://ensser.org/publications/2019-publications/ensser-statement-new-genetic-modification-techniques-and-their-products-pose-risks-that-need-to-be-assessed/

33 Biswas S et al (2020). Investigation of CRISPR/Cas9-induced SD1 rice mutants highlights the importance of molecular characterization in plant molecular breeding. Journal of Genetics and Genomics. 21 May. doi:10.1016/j.jgg.2020.04.004

34 Kawall K (2019). New possibilities on the horizon: Genome editing makes the whole genome accessible for changes. Front Plant Sci 10. doi:10.3389/fpls.2019.00525

35 For example: Krimsky S (2015). An illusory consensus behind GMO health assessment. Science Technology Human Values. 7 Aug. 1-32. doi:10.1177/0162243915598381 ; Séralini GE et al (2011). Genetically modified crops safety assessments: Present limits and possible improvements. Environmental Sciences Europe 23(Article number: 10 (2011)). doi:10.1186/2190-4715-23-10 ; El-Shamei ZS et al (2012). Histopathological changes in some organs of male rats fed on genetically modified corn (Ajeeb YG). Journal of American Science 8(10):684-696. https://www.academia.edu/3405345/Histopathological_Changes_in_Some_Organs_of_Male_Rats_Fed_on_Genetically_Modified_Corn_Ajeeb_YG_ ; Gab-Alla AA et al (2012). Morphological and biochemical changes in male rats fed on genetically modified corn (Ajeeb YG). Journal of American Science 8(9):1117-1123. https://www.academia.edu/3138607/Morphological_and_Biochemical_Changes_in_Male_Rats_Fed_on_Genetically_Modified_Corn_Ajeeb_YG_ ; De Vendomois JS et al (2009). A comparison of the effects of three GM corn varieties on mammalian health. Int J Biol Sci 5:706–726. http://www.ncbi.nlm.nih.gov/pubmed/20011136 ; Malatesta M et al (2008). A long-term study on female mice fed on a genetically modified soybean: effects on liver ageing. Histochem Cell Biol 130:967-977. http://www.springerlink.com/content/cw661u3345p6q464/

36 Hilbeck A, Binimelis R, Defarge N, et al. No scientific consensus on GMO safety. Environmental Sciences Europe. 2015;27(4). doi:10.1186/s12302-014-0034-1 ; European Network of Scientists for Social and Environmental Responsibility (ENSSER). Statement: No Scientific Consensus on GMO Safety; 2015. https://ensser.org/press_release/pr01-15/#more-179

37 Kawall K, Cotter J, Then C. Broadening the GMO risk assessment in the EU for genome editing technologies in agriculture. Environmental Sciences Europe. 2020;32(1):106. doi:10.1186/s12302-020-00361-2

38 Robinson C. Gene Editing Myths and Reality: A Guide through the Smokescreen. The Greens/EFA in the European Parliament; 2021. https://www.greens-efa.eu/en/article/document/gene-editing-myths-and-reality/

39 Dima O, Bocken H, Custers R, Inzé D, Puigdomènech P. Genome Editing for Crop Improvement. ALLEA - All European Academies; 2020. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

40 EPSO. On the ECJ Ruling Regarding Mutagenesis and the Genetically Modified Organisms Directive. EPSO; 2019. https://epsoweb.org/epso/epso-statement-on-the-court-of-justice-of-the-eu-ruling-regarding-mutagenesis-and-the-gmo-directive/2019/02/19/

41 EU-SAGE (2021). The European Sustainable Agriculture through Genome Editing (EU-SAGE) network, representing scientists at 134 European Plant Science Centres welcomes the study of the European Commission on new genomic techniques. https://tinyurl.com/hu2cs9c

42 UPOV (2019). DNA-based methods for variety testing: ISTA approach. https://www.upov.int/edocs/mdocs/upov/en/bmt_18/bmt_18_3.pdf

43 EU Commission (2021). Commission Implementing Directive (EU) 2021/971 of 16 June 2021. Official Journal of the European Union 17.6.2021. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32021L0971

44 Dima O, Bocken H, Custers R, Inzé D, Puigdomènech P. Genome Editing for Crop Improvement. ALLEA - All European Academies; 2020. https://allea.org/portfolio-item/genome-editing-for-crop-improvement/

45 EPSO. On the ECJ Ruling Regarding Mutagenesis and the Genetically Modified Organisms Directive. EPSO; 2019. https://epsoweb.org/epso/epso-statement-on-the-court-of-justice-of-the-eu-ruling-regarding-mutagenesis-and-the-gmo-directive/2019/02/19/

46 EU-SAGE. Regulating genome-edited organisms as GMOs has negative consequences for agriculture, society and economy. Published online December 2018. https://www.eu-sage.eu/sites/default/files/2020-02/Position%20paper%20on%20the%20ECJ%20ruling.pdf

47 Benbrook C. Impacts of genetically engineered crops on pesticide use in the US – The first sixteen years. Environmental Sciences Europe. 2012;24(24). doi:10.1186/2190-4715-24-24

48 Voosen P. USDA looks to approve Monsanto's drought-tolerant corn. New York Times. http://nyti.ms/mQtCnq. Published May 11, 2011.

49 GMWatch. Non-GM successes. gmwatch.org. Published 2020. http://www.gmwatch.org/index.php/articles/non-gm-successes ; Gilbert N. Cross-bred crops get fit faster. Nature News. 2014;513(7518):292. doi:10.1038/513292a ; Robinson C. Is the public to blame for collapse of the GMO venture? – Part 2. GMWatch. Published May 8, 2018. Accessed July 9, 2018. https://www.gmwatch.org/en/news/latest-news/18266-is-the-public-to-blame-for-collapse-of-the-gmo-venture-part-2

50 International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). Agriculture at a Crossroads: Synthesis Report of the International Assessment of Agricultural Knowledge, Science and Technology for Development: A Synthesis of the Global and Sub-Global IAASTD Reports. Island Press; 2009. https://tinyurl.com/y5bxkld3

51 GMWatch. Non-GM successes. gmwatch.org. Published 2020. http://www.gmwatch.org/index.php/articles/non-gm-successes

52 Climate-ADAPT. Use of adapted crops and varieties. climate-adapt.eea.europa.eu. Published March 26, 2020. Accessed March 18, 2021. https://climate-adapt.eea.europa.eu/metadata/adaptation-options/use-of-adapted-crops-and-varieties

53 Robinson C. Gene Editing Myths and Reality: A Guide through the Smokescreen. The Greens/EFA in the European Parliament; 2021. https://www.greens-efa.eu/en/article/document/gene-editing-myths-and-reality/