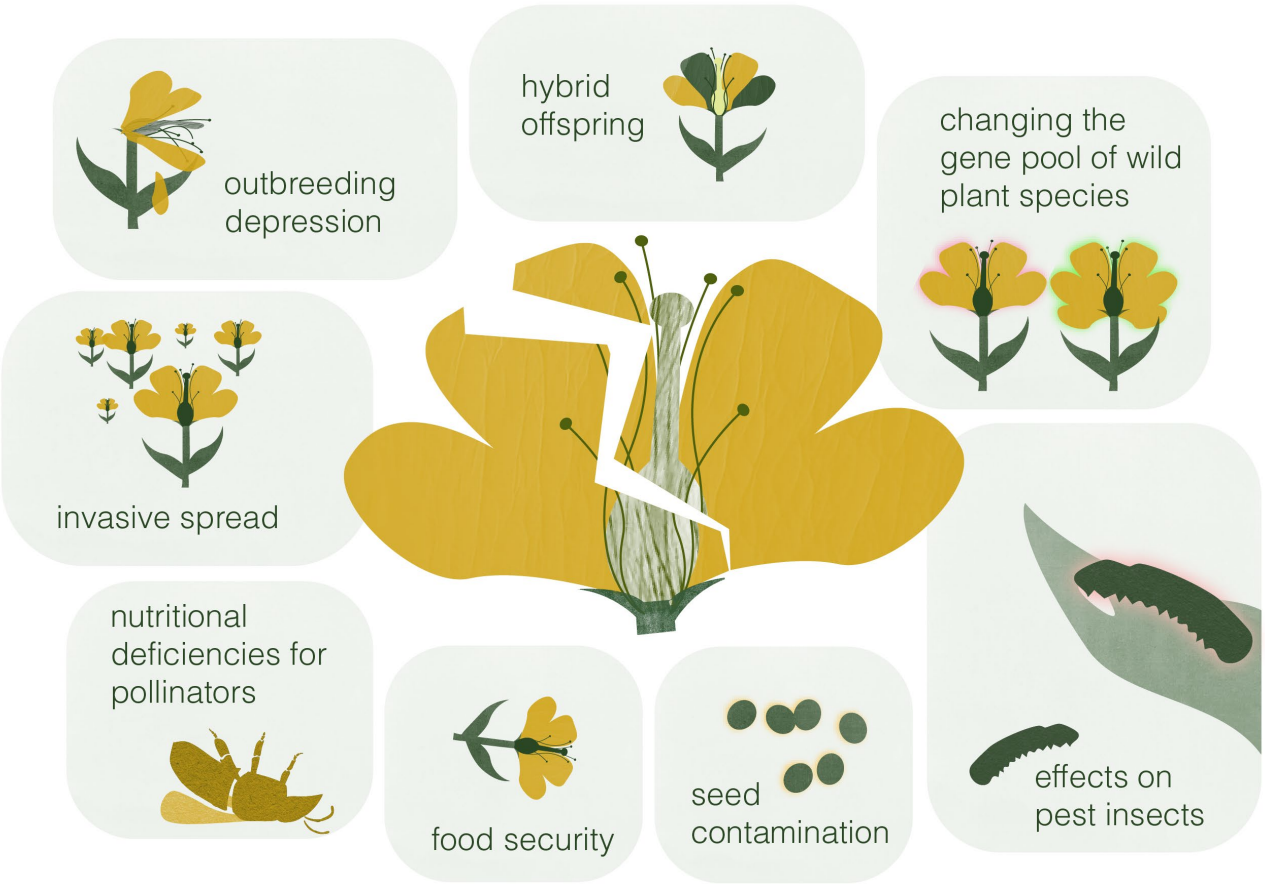
TESTBIOTECH Background 14 - 1 - 2026

Manipulated flowering in NGT plants: A crack in ecosystems[1]

Testbiotech
Institute for Independent Impact Assessment in Biotechnology

CRISPR technology enables comprehensive changes in flowering plants with cascading effects



[1] The title is inspired by the book 'A Crack in Creation' by Doudna & Sternberg (2017), Pengiun Random House

Summary

New genetic engineering (or new genomic techniques, NGTs) makes it possible to mimic natural gene variations, but also to go way beyond conventional breeding and create plants and other organisms that are new to ecosystems. These NGT organisms are different from those created by conventional breeding methods such as random mutagenesis. This can be explained by the following factors:

- Certain regions in the genome are virtually inaccessible by conventional breeding. However, NGTs can overcome several of these constraints.
- In many cases, it is sufficient to introduce only minor genetic changes in specific regulatory units of plant genomes to achieve unique combinations of gene variants that are hardly achievable using previous breeding methods.
- The range of affected species is increasingly expanding and now also includes species that have not been used or were inaccessible for breeding purposes up to now. This also comprises wild plant species.

The applications of NGTs are constantly expanding, one recent focus is on traits associated with the very essence of plant reproduction, such as flower morphology and flowering timing. For example, a recent Chinese study demonstrated that the architecture of flowers can be changed by NGTs in order to enable pollination by AI trained robots. Other authors have identified a general trend in the scientific literature towards using NGTs to manipulate flowering time.

The range of affected species is increasingly expanding and now also includes species that have not been used or were inaccessible for breeding purposes up to now. This also comprises wild plant species.

Species or genera that have been targeted in this respect include plants which are able to outcross and spread in the environment such as to other fields: alfalfa/lucerne (*Medicago sativa*), alpine rockcress (*Arabis alpina*), thale cress (*Arabidopsis thaliana)*, aspen (*Populus tremuloides)*, false brome (*Brachypodium sylvaticum)*, camelina/false flax (*Camelina sativa*), wall bellflower *(Campanula portenschlagiana)*, oilseed rape (*Brassica napus*), rice (*Oryza sativa)*, green millet (*Setaria viridis*) and sorghum (*Sorghum bicolor*). Depending on the changes in flowering introduced by NGTs, these plants may show enhanced gene flow and uncontrolled spread of their intended as well as unintended effects. This may also result in reduced fitness in wild plant species belonging to homeland biodiversity. When exchanging pollen, they also may cross with other NGT plants and thus facilitate to acquire and spread several NGT traits in combination. Furthermore, crossing and hybridisation may cause unwanted characteristics that are not predictable.

It is an additional matter of concern that NGT plants with manipulated flowering have already been filed for patent by companies such Monsanto (Bayer), Pairwise, Philip Morris, Pioneer (Corteva) and Syngenta (ChemChina). Driven by the interest in profits, the companies will try to enter the market as soon as possible. This will increase pace and scale of releases as well as the pressure on ecosystems.

Environmental risk assessment and monitoring is essential to prevent harm for natural populations and biodiversity. If NGT plants are new to the environment and inherit gene variants unlikely to be reproducible with conventional breeding, they should be risk assessed for a broad range of hazards. These can include changes in plant-pollinator interactions (and other beneficial insects), threats to protected species and conservation of natural populations as well as effects on pest insects, plant health and food security.

The proposed future regulation of NGT plants in the EU is not adequate for the safe handling of NGT plants, especially in respect to harmful effects on wild plant populations and communities. It would allow for releases of so-called NGT 1 plants classified as equivalent to conventionally bred plants without environmental risk assessment. However, many of these NGT plants are in fact 'new' to the environment and exhibit characteristics that go far beyond what might be expected from previously used breeding methods. In regard to wild plants, it should be taken into account that these do not even have a history of breeding.

It is a matter of concern that companies such as Monsanto already filed patents on NGT plants with manipulated flowering.

NGT plants with changes in the reproductive system including e. g. 'robo flowers', advanced first flowering in poplars or early flowering in camelina, or changes in the nutritional composition of pollen. This can cascade through the entire ecosystem by increasing asynchrony within and between population and mismatch in flowering. It increases the exposure of associated insect populations to environmental stressors. Thus, unless subjected to adequate risk assessment, NGT plants with changed flowering pose substantial risks to the environment as they could potentially disrupt ecosystems and/or food security.

Approvals for commercial cultivation and also for experimental releases should only be considered after detailed risk assessment. This finding is especially relevant to plants that can persist in the environment and hybridise in particular with wild plant species. If NGT plants inherit genotypes that were previously unknown and are unlikely to be achievable by previous breeding methods, this must be defined as a trigger for mandatory in-depth risk assessment of their effects to the environment by taking into account their phenotypic characteristics.

Introduction

Flowering is a crucial process in the life cycle of most plants: It is key to reproductive success of individuals and the genetic diversity of the species, it is a prerequisite for the potential of a species to adapt to environmental change. In addition, flowering is a decisive factor for co-evolution and environmental interactions such as those between plants and pollinators. These are mediated by the shape, colour or scent of flowers, their nutritional compounds in nectar and pollen, and their time of flowering. Intervening with these factors can severely disrupt the ability of reproduction within and among populations, as well as interactions with associated animals. Such interventions are carrying the risk of cascading effects up to the functional level of ecosystems. Given the ongoing global biodiversity crisis, special attention must paid to these aspects.

Flowering is a crucial process in the life cycle of most plants. It is a decisive factor for co-evolution and environmental interactions such as those between plants and pollinators.

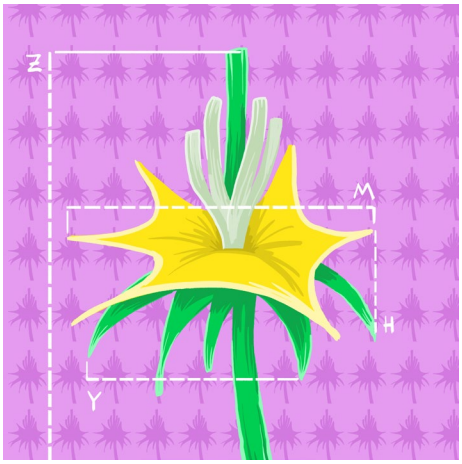
Manipulation of flowering has been a goal in plant breeding since many years. For example, the adaptation of flowering phenology to different geo-climatic zones by using the natural variability and plasticity of plant genomes is a well-established strategy. However, the transfer of wild plants across climatic zones has been strongly regulated by law, as phenological mismatches and local maladaptation of other traits affected by flowering time can disrupt individual fitness and thus increase the risks of extinction (for example by outbreeding depression).

New genetic engineering (or new genomic techniques, NGTs) makes it possible to mimic natural variations but also to go way beyond. Not only several regions in the genome are hardly accessible

by conventional breeding (random mutagenesis). Much more, in many cases, it is sufficient to introduce only minor genetic changes especially into specific regulatory units of plant genomes to achieve unique combinations of gene variants that are hardly achievable from previous breeding methods (Mundorf et al., 2025; Juhas et al., 2025; Koller, 2025). In addition, the range of affected species is increasingly expanding and now includes wild species that have not been used or were inaccessible for breeding purposes. Thus, genotypes that are new to the environment and may not be achievable by previous breeding methods require specific attention of the legislator.

Manipulating flowering to facilitate pollination by robots

In a recent publication by Chinese researchers (Xie et al., 2025) it is shown that the flower architecture in tomatoes (*Solanum lycopersicum*) and soybeans (*Glycine max*) can be changed by NGTs in a way to enable pollination by robots.



Tomatoes and soybeans reproduce through self-pollination. The aim of the NGT research was to significantly change the architecture of the flowers to enable robotic pollination for breeding purposes or to substitute insect pollination. For this purpose, the female stigma were exserted and in addition the male stamina (producing pollen) should become sterile. Changing the morphology of the flowers should help to overcome the barriers of self-pollination for speeding up further breeding, including pollination by AI trained robots.

This trait was realised by changing the activity of genes involved in flower development. Several deletions and inversions were introduced into regulatory DNA sequences. The total number of genetic changes was kept at a low level (below the threshold of 20 as permitted in Annex I of the deregulation proposal, see below). Nevertheless, the resulting genotype is previously unknown in this species. Some elements such as exserted stigmata also occur in wild relatives of tomato. However, these characteristics are caused by other gene variants and also do not exhibit male infertility. Furthermore, the morphology of the flower is different. Therefore, such NGT plants must be considered ‘new’ to the environment.

Even though the NGT plants may be primarily used in the green house for breeding purposes, they were nonetheless also tested in the environment. Not all flowers exhibited male sterility, therefore, such field trials may result in unwarranted gene flow, especially if such traits were to be explored in wild plant species such as *Arabidopsis* (see below).

Overview of NGT applications for manipulating flowering

Flowering is manipulated using NGTs for various purposes. For example, there is interest to accelerate, expedite, delay, or prevent flowering, to shorten or prolong vegetative growth (for overview see Hodaei and Werbrouck, 2023). Other applications may alter the colour, structure or scent and may lead to changes in plant composition or fertility. The plant species used in these experiments include crop plants (such as maize and wheat), horticultural plants (such as tomatoes), ornamental plants (such as petunia), trees (such as poplar) and also wild plants such as *Arabidopsis* (Lanctot et al., 2025; Xie et al., 2025; Ashwini et al., 2024; Klocko et al., 2023; Hodaei and Werbrouck 2023; Sirohi et al., 2022).

From 2015 to 2023, more than 100 publications are listed, covering a wide range of plant species, with a particular focus on altering the flowering time.

Hodaei and Werbrouck (2023) identified "*a striking trend in the scientific literature regarding the manipulation of the flowering time using CRISPR technology*". From 2015 to 2023, they list more than 100 publications, covering a wide range of plant species, with a particular focus on altering the flowering time. Most applications are in rice (22), *Arabidopsis*/thale cress (15), soybean (11), tomato (8), cabbage (7), oilseed rape (5), wheat (5) and alfalfa/lucerne (3). Other plants such as alpine cress, apple trees, aspen, false brome, camelina/false flax, gentian, maize, green millet, sorghum and tobacco are also listed. Many of these species are either wild plants or wild relatives in the regions where they are cultivated. Thus, depending on the NGT traits, outcrossing can be considered almost certain not only in other fields but also in local wild plant populations.

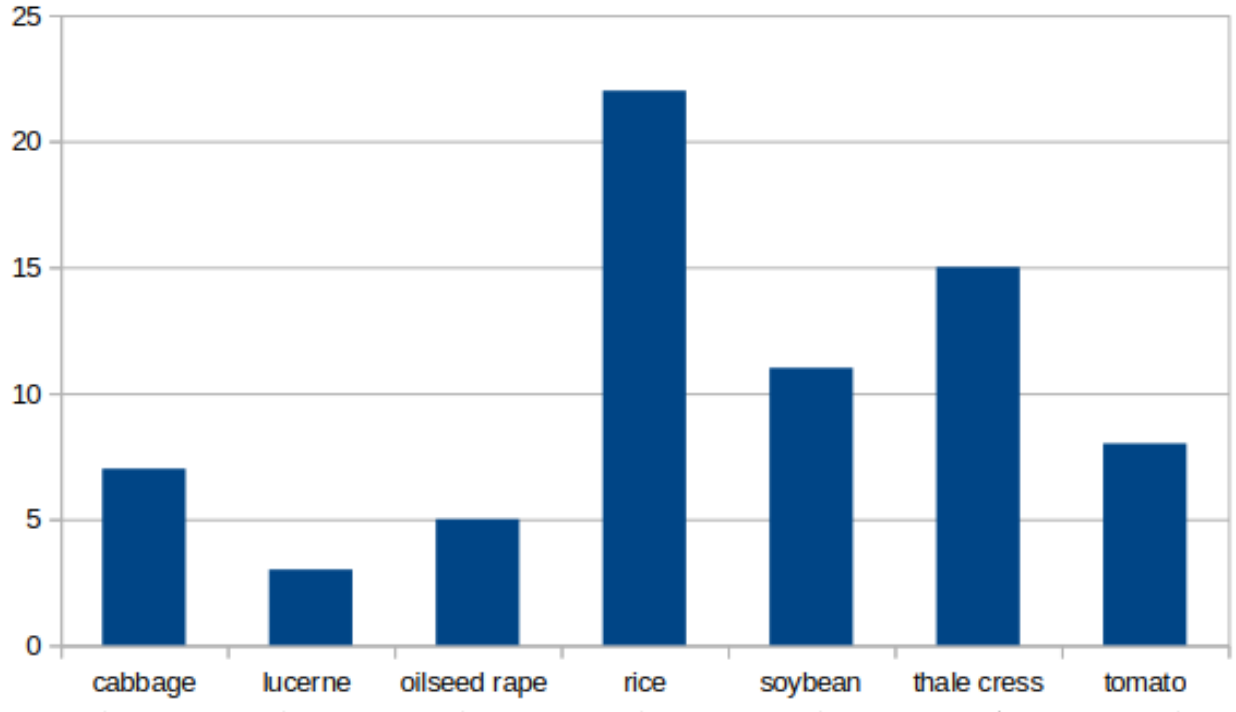


Figure 1: Hodaei and Werbrouck (2023) identified more than 100 NGT applications, with a particular focus on altering the flowering time.

Other publications mention further NGT applications to introduce changes in flowering in species such as poplar (Klocko et al., 2023; Ortega et al., 2023), blueberries (Omori et al., 2025), and various ornamentals (Raheena et al., 2025; Ashwini et al., 2024; Mekapogu et al., 2023; Sirohi et al., 2022; Giovannini et al., 2020), again including species naturally occurring in Europe such as wall bellflower (Raheena et al., 2025).

Patent applications and interest in fast track market approvals

NGT plants with manipulated flowering have also been filed for patent by companies such as Monsanto (Bayer), Pairwise, Pioneer (Corteva), Philip Morris and Syngenta (ChemChina). Some examples:

- In patent application WO2025042825 (Monsanto), genetic changes in regulatory units are claimed as invention that also can be used to alter flowering (such as the structure of floral organs). Claimed species are "*a corn plant, a rice plant, a sorghum plant, a wheat plant, an alfalfa plant, a barley plant, a millet plant, a rye plant, a sugarcane plant, a cotton plant, a soybean plant, a canola plant, a tomato plant, an onion plant, a cucumber plant, an Arabidopsis plant, or a potato plant.*"

- According to patent application WO2025064734, the US company Pairwise wants to alter flowering in black raspberry. As it is described in the patent: "*(…) optionally producing plants having improved characteristics for breeding and production, optionally, including a reduced time to initiate flowering, a longer duration of flowering, and/or improved yield characteristics. The invention further relates to black raspberry plants produced using the methods and compositions of the invention.*"

- In their patent application WO2021031059, the companies Pioneer and Sinobioway (US/CN) claim methods conferring delayed or accelerated flowering time. Listed in the claims are the following species: "*rice, maize, soybean, sunflower, sorghum, canola, wheat, alfalfa, cotton, barley, millet, sugar cane and switchgrass.*"

Driven by the interest in patents, the companies will try to enter the market as soon as possible, increasing the pace and scale of releases as well as the pressure on ecosystems.

From the patent description it seems to be likely that most of these plants would fulfill the criteria for so-called NGT 1 plants as suggested by the EU, which would allow fast market approval without environmental risk assessment. Driven by the interest in profits, the companies will try to enter the market as soon as possible during the lifetime of the patents. This will increase the pressure for fast track marketing and increase the pace and scale of releases as well as the risks for the ecosystems. The EU would foster potential damage to the ecosystems by introducing its NGT 1 category (see below).

Risk scenarios and risk related matters

Changes in flowering have also been achieved by previous breeding methods and therefore, some of the risks are well known. However, NGTs can go beyond anything that might be achieved though conventional breeding (Koller, 2025).

One reason is that it is practically impossible for conventional breeding methods (random mutagenesis) to access a certain genomic regions in plants, but NGTs are known to escape these constraints (Koller 2025). Furthermore, it is possible to introduce several small changes in regulatory DNA elements that in this distinct combination are unlikely to be achieved through conventional, non-targeted methods (Mundorf et al., 2025; Juhas et al., 2025; Koller, 2025). One example is the case of creating ‘robo flowers’ in tomato and soy (Xie et al., 2025). Such NGT interventions often are powered by AI. The development of such NGT applications will be greatly accelerated in the very near future (Mundorf et al., 2025; Juhas et al., 2025).

Concerning the protection of the environment, the question arises of whether the respective genotype (and phenotype) is already known from conventional breeding methods or if it has to be considered ‘new’ to the environment. In addition, the scale and pace of releases and the resulting level of exposure e. g. to pollinators should also be part of risk assessment. Moreover, the simultaneous presence of several NGT plants within a shared environment has to be considered: Due to spontaneous crossings, hybrid plants inhabiting several NGT traits can occur (see Koller et al., 2023).

Effects caused by manipulated flowering can cascade through the entire ecosystem by increasing asynchrony within and between population and endanger associated insect populations.

It also must be noted that ‘equivalence to conventional breeding’ is completely irrelevant when it comes to wild plants as they have not been bred to date. A lot is known about the genome of crop plants and specific agro-ecosystems, while for the above list of species targeted for manipulation of flowering by NGTs, only very limited data are available. At the same time, gene flow from NGT wild plants into wild populations is not only a risk but a certainty, when these plants are released into nature. Depending on the NGT-induced changes in flowering, the plants may exhibit reduced or enhanced gene flow and uncontrolled spread of intended or unintended effects and may also result in hybrid plants (and their traits) without precedent.

Changes in flowering time can result in decoupling of flowering in natural populations, i.e. flowering time mismatches that will decrease individual fitness. Also, since changes in a single trait often affect other plant characteristics (trade-offs), outcrossing will not only change flowering but also associated traits relevant for the persistence of wild plants. Thus, in order to prevent harm to natural populations and homeland biodiversity, environmental risk assessment and case-by-case monitoring must be made mandatory for any instances of wild plant modifications.

Several plausible scenarios have to be taken into account:

- If flowers are changed to prevent gene flow, as attempted in the case of transgenic oilseed rape (Pinochet et al., 2011) and other cultivated plants, this also may affect pollinators feeding on the pollen (and nectar). As these pollinators also pollinate many other species, cascading effects resulting from pollinator loss can occur and thus affect entire plant communities and ecosystems.

- If flowers are changed to increase their outcrossing ability, this can facilitate uncontrolled spread. For example, in the case of the ‘robo flowers’ with exserted female organs, some variants did show non-sterile male pollen (Xie et al., 2025). Such plants may spread faster and cross more frequently, they also acquire several NGT traits in combination through spontaneous stacking. If similar research is conducted with species that can persist and propagate in the environment, this may significantly change the interactions of these plants with the environment. For example, many NGT interventions are first applied in *Arabidopsis* before introduced in other plant species. Naturally, *Arabidopsis thaliana* plants show high selfing ability and a low outcrossing rate. Changing the flowering characteristics may turn NGT *Arabidopsis* into noxious weeds or invasive species or *vice-versa*, impede their ability to persist in their natural habitats. Since species of *Arabidopsis* are distributed globally with regional genomic variations (see for example Bastias et al., 2024), this may cause widespread environmental consequences. It is to be expected that deregulation of NGT 1 applications will result in widespread uncontrolled field trials with *Arabidopsis thaliana* across the world. Beyond *Arabidopsis thaliana*, there are further genera of plants such as *Brachypodium* or *Panicum* that are considered as especially useful for genetic research (Arana & Pico, 2025) and therefore may become used in field trials frequently. At the same time, these species are known to spread quickly in the environment.

- Similarly, attempts to accelerate first flowering e.g. as attempted in poplars (Ortega et al., 2023; Klocko et al., 2023), may cause disruption and asynchrony in natural poplar populations due to the ‘easy’ natural gene flow of NGT plants to wild populations, with effects cascading to coexisting plant species and animal interactions.

- Early flowering such as introduced in camelina (Bellec et al., 2022) always carries the risk of premature flowering in periods of late frost. There are actually good reasons why specific flowering times have evolved in certain environmental conditions. Delayed or early flowering (Hodaei and Werbrouck, 2023) may also cause problems for pollinators, as they would be

unable to find food at the time of the year when they need it; this would also have a cumulative effect on animals feeding on these insects, e.g. birds.

- NGT applications that indirectly affect flowering should also be considered: For example, if the oil or protein content are changed in plant composition, this can affect the nutritional quality of the pollen, which is an important food for pollinating insects. Their health may thus be adversely affected due to malnutrition (Kawall, 2021; Koller et al., 2024). In other cases, pest insects may benefit from a higher concentration of plant constituents in reproductive the organs as well as seeds that enhance their fitness, e.g. due to a higher rate of reproduction (Colombo et al., 2018).

- Furthermore, any crossing or hybridisation with other NGT plants or also wild plant species may result in new undesirable characteristics that cannot be predicted (see for example Bauer-Panskus et al., 2020).

Regulatory issues

According to the current EU proposal for future regulation of NGT plants would allow fast-track approvals for NGT plants considered to be equivalent to those obtained from conventional breeding, only requiring certain criteria to be met. This may at first appear to be a plausible approach. However, the adequate implementation of future EU regulation will depend upon how similarity (equivalence) is actually established. Whatever the case, any future regulation of NGT plants must be science-based and take the precautionary principle into account, including the requirements of the Cartagena Protocol[2] and the ECJ decision (European Court of Justice, Case C-528/16).

The EU concept explicitly includes all plant species, even wild plants. It is based on a fundamental misconception and thus not in accordance with current scientific evidence.

In this context, the EU plans to introduce the category of so-called NGT 1 plants. Plants in this category would not be subject to environmental risk assessment and benefit from fast-track market approval. The relevant criteria are defined in Annex I of the proposed regulation: In short, they set a limit of 20 genetic changes that can (each) include changes of up to 20 nucleotides and/or longer cisgenic insertions and/or inversions and deletions per monoploid chromosome. They could be applied to all NGT plants that do not inherit transgenic elements.

This concept explicitly includes all plant species, even wild plants. It is based on a fundamental misconception and thus not in accordance with current scientific evidence. In short, the proposal does not consider that recombinant enzymatic mutagens, such as CRISPR/Cas, give rise to biological effects that are frequently very different to those resulting from physicochemical mutagens (or other methods of conventional breeding). It further overlooks the fact that the relevant differences do not primarily depend on the overall number of mutations, or the number of substituted nucleotides (per each of the genetic changes) or the number of deletions/inversions (see Koller, 2025).

Moreover, as elaborated above, the equivalence criterion is immaterial for wild plant species, i.e. species which are at increased risk of extinction, quite often due to intensive agricultural practices.

[2] https://www.testbiotech.org/en/news/planned-eu-deregulation-of-ngt-plants-in-conflict-with-international-law/

It is important to know that national and international legislation restricts the introduction of new traits into wild populations, as it carries a risk of outbreeding depression, i.e. the introduction of detrimental traits into the wild. Therefore, NGT regulation should be brought into line with conservation protection for wild species.

Currently, huge loopholes remain for NGT plants, even though these can exhibit new gene variants simply through minor changes in their nucleotides. They may also have major deletions and inversions which are new to the environment and cannot be reproduced through conventional breeding. In addition, the loopholes would also allow fast track approvals for NGT plants which may pose considerable risk to the environment.

In order to prevent harm to natural populations and homeland biodiversity, environmental risk assessment and case-by-case monitoring must be made mandatory for any instances of wild plant modifications.

The loopholes in the proposed regulation would allow the release of NGT plants with highly fitness-relevant characteristics without environmental risk assessment. The examples given above (Xie et al., 2025; Ortega et al., 2023; Bellec et al., 2022; Kawall, 2021) could be classified as NGT 1 plants, but nevertheless exhibit unprecedented genotypes in the environment. In other cases, e.g. those listed by Hodaei and Werbrouck (2023), further examination would be needed to determine the degree of similarity to conventionally bred plants. However, there are no requirements for assessment in the proposed future regulation of NGT plants.

Therefore, the proposed compromise text neither allows safe handling of NGT plants, nor is it in accordance with the Cartegena Protocol. Unsurprisingly, several scientific experts and institutions have explicitly criticized the flawed proposal due to its negligence of scientific evidence and the high environmental risks associated with deregulation (see, for example, ANSES, 2024; Bohle et al., 2023; Eckerstorfer & Heissenberger, 2023, GFÖ, 2023; Testbiotech, 2025, Mundorf et al., 2025; Juhas et al., 2025; Koller, 2025).

Conclusions

NGT plants with changes in flowering may result in significant alterations in wild plants both individually, or in populations and communities, which can have cascading effects throughout an entire ecosystem. Mandatory risk assessment must be included in regulation, particularly if gene flow and spread into the environment is likely (which is the case for wild plants and their relatives). Risks for the integrity of wild populations and ecosystems threatening the homeland biodiversity of the EU have to be minimised, and similarity or dissimilarity to existing geno- and phenotypes have to be proven, prior to release.

Risk assessment also has to consider the risks of progeny plants resulting from hybridisation with NGT plants.

If NGT plants are new to the environment and inherit gene variants that are unlikely to be reproducible through conventional breeding, risk assessment should include hazards connected to the specific plant or its relatives. Further, it should include risks to pollinators and other insects, their predators, protected species and natural populations as well as effects on pest insects, plant health and food security. Risk assessment also has to consider the risks of progeny plants resulting from hybridisation with NGT plants.

The proposed future regulation of NGT plants in the EU is inadequate to allow the safe handling of NGT plants. It unnecessarily represents an open invitation to release NGT plants that are new to the environment and associated with significant risks, but without requesting mandatory risk assessment. Without adequate risk assessment, NGT plants with changed flowering have a significantly increased potential to become disruptive in ecosystems and / or threaten food security.

Approval for commercial cultivation - and also for experimental releases - should only be considered after detailed risk assessment. This finding is especially relevant to plants that can persist in the environment and exhibit gene flow to other plants, especially to wild plant species. If NGT plants inherit genotypes that were previously unknown and unlikely to be achieved through previous breeding methods, this has to be defined as a regulatory trigger for in-depth risk assessment of their effects in the environment, including their phenotypic characteristics.

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