Sustainability in organic breeding

Improving the entire system or adjusting some genes?

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Summary

This briefing provides an overview of the organic food and farming movement's understanding of sustainability in crop breeding. As IFOAM Organics Europe, the European organic umbrella organisation and voice of organic with the EU institutions, we wrote this document to assess and counter the European Commission's narrow and problematic approach to sustainability traits in plant breeding.

The European Commission's approach to sustainability and innovation in our agrifood systems in the legislative proposal on so called "New Genomic Techniques" (NGTs), especially in the breeding sector, has significant shortcomings. **A product or an agriculture production system cannot be declared "sustainable" solely based on a given plant variety, let alone a trait.** Moreover, the alleged benefits of genetic engineering for sustainability, spanning from pest resistance to drought resistance, are currently based on assumptions and remain theoretical industry promises.

While innovation in breeding is needed, there are no shortcuts to circumvent the complexity of our food systems. So, breeding should not be reduced to using genetic engineering. The rich experience in organic agriculture over the past decades shows that an agroecological perspective of our food systems, relying on a combination of strategies and tools and on ecosystem interactions, is what creates long-term resilience. Using its system-based approach with biodiversification and ecosystems' health at its core, organic breeding offers resilient pathways to sustainability and innovation in agriculture.

In this briefing, two case studies show organic breeding's success in the transformation to sustainable production systems. Organic breeding offers socially innovative approaches that have environmental and socio-economic benefits, using inclusive systems of participatory breeding. These approaches heavily contrast with the harmful monopolisation of genetic resources into the hands of a few multinational companies through encroaching intellectual property rights on varieties and traits, which is legitimised by genetic engineering.

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Political context and alleged benefits

> *The European Green Deal sets important cross-cutting political objectives for food, biodiversity, the climate, digitalisation, and forests. As seeds are the basis of life, the current revision of the Plant Reproduction Material (PRM) legislation can greatly contribute to this. However, in its recently proposed framework on new GMOs or "New Genomic Techniques" (NGTs), the European Commission's approach seems to be heavily impacted by the industrial agriculture's narrow and curative view on 'sustainability' and 'innovation'.*

Sustainability in agricultural breeding, especially 'sustainable' crop characteristic(s) and property(ies), is a hot topic on the EU's political agenda. On the one hand, the Revision of the Plant Reproductive Material (PRM) legislation aims to align EU legislation on plant and reproductive material with the political objectives of the European Green Deal. On the other hand, the recently proposed framework on new GMOs, or the so-called "New Genomic Techniques" (NGTs), also includes criteria for "NGT products containing traits relevant for sustainability". The Commission's idea is to develop regulatory incentives for certain NGT crops falling under "Category 2 NGTs"[1] such as an accelerated procedure for risk assessment, to steer the development of these NGT crops toward 'favourable' traits (Article 22, referring to Annex III). In Recital 33 of its proposal, the Commission writes: "The criteria to trigger these incentives should focus on broad trait categories with the potential to contribute to sustainability (such as those linked to tolerance or resistance to biotic and abiotic stresses, improved nutritional characteristics or increased yield)".

The traits qualifying as "containing traits with the potential to contribute to a sustainable agri-food system" (2023/0226, Recital 33) that are elaborated on in Annex III of the legislative proposal on NGTs are very broad and include provisions on yield, tolerance or resistance to biotic stresses (e.g., pests) and abiotic stresses (e.g., traits suited for changing climate conditions, like drought-resistance), efficient resource use, plant protection products and fertilizer reductions, nutritional characteristics, and characteristics that enhance the sustainability of storage, processing, and distribution (See Figure 1.). The only crop trait which is explicitly excluded from this list is related to herbicide tolerance, due to its long-standing track record of blatant negative impacts on the environment, including biodiversity above and below ground and particularly pollinator populations. Excluding herbicide tolerance from regulatory benefits is sensible, especially considering that a JRC study from 2021 found that 6 out of 16 current pre-commercial NGTs relate to pesticide resistance. Though they are very unsustainable, they are by far the most common plant trait in the promising development stages.

[1] The draft legislative proposal on NGTs adopts a differentiated approach in the regulatory framework, based on the risk profiles of the NGT crops, rather than the technique used. The risk profile is outlined in Annex I of the proposal which states that an NGT plant is considered equivalent to conventional plants when it differs from the recipient/parental plant by no more than 20 genetic modifications. Automatically, if a plant fulfils the criteria set out in Annex I, it is legally considered a Category 1 NGT plant, and when a plant does not fulfil the criteria set out in Annex I, it will be classified as a Category 2 NGT plant.

However, it is crucial to critically assess the assumed contribution of NGT crops' sustainability in the Commission's proposed traits under Part 1 of Annex III as well. Proponents of new GMOs often invoke apparent "sustainability" arguments to justify a deregulation of genetic engineering. For instance, in October 2021, Bayer AG[2] wrote in their contribution to the public consultation on New Genomic Techniques: "Proportionate and science-based requirements will foster the transfer of EU scientific capacity into innovative products for a competitive and sustainable agri-food system". In a report from 2022, the agrifood giant wrote: "Bayer, along with many experts, believes that GM crops, as a component of intensive agriculture, contribute to sustainable and resilient food production", among other things listing improved protection from weeds, insects, diseases, and extreme weather, and reduced greenhouse gas emissions.

> It is noteworthy that 6 out of 16 current pre-commercial NGTs relate to pesticide resistance. Though very unsustainable, they are the most common plant trait in "promising" development stages.

Hence, it is urgent to dissect what sustainability and innovation mean in the context of our agrifood systems, especially in the breeding sector – not only from the agrifood industry, but also from the perspective of agroecology and organic production.

ANNEX III

Traits referred to in Article 22

Part 1

Traits justifying the incentives referred to in Article 22:

(1) yield, including yield stability and yield under low-input conditions;

(2) tolerance/resistance to biotic stresses, including plant diseases caused by nematodes, fungi, bacteria, viruses and other pests;

(3) tolerance/resistance to abiotic stresses, including those created or exacerbated by climate change;

(4) more efficient use of resources, such as water and nutrients;

(5) characteristics that enhance the sustainability of storage, processing and distribution;

(6) improved quality or nutritional characteristics;

(7) reduced need for external inputs, such as plant protection products and fertilisers.

Part 2

Traits excluding the application of the incentives referred to in Article 22: tolerance to herbicides.

Figure 1. Annex III delineates the traits relevant to sustainability to justify regulatory incentives for Category 2 NGTs under Article 22.

[2] Since 2018, the German chemical company Bayer AG owns Monsanto. No longer using the name, Monsanto's previous product brand names were maintained

Defining resilience and sustainability in breeding – Keeping a system perspective

> *Industrial agriculture is a key driver behind the current climate and biodiversity crises and a threat to rural livelihoods and food and nutrition security. Only a system perspective on our agroecosystems can create resilient, healthy, and robust agronomic systems. This starts at the selection of the seed and continues into the growing of the plant. Organic plant breeding contributes to this as it preserves the integrity of the genome, cell and interaction of all cell components.*

A healthy environment with a prospering flora and fauna above and below ground is one of humanity's most precious goods and the bedrock of our food system. We are its beneficiaries, tasked with responsible stewardship towards nature. Unsustainable and industrial agriculture is the largest driver of biodiversity and habitat loss, and it contributes to climate change, contaminating soils and water bodies, treating workers unfairly, and threatening rural livelihoods, as well as food and nutrition security. To make our food systems truly sustainable, we need to transition away from input-intensive, short-term fixes, which include the promotion of specific technologies with unproven benefits and potential unintended effects and risks.

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Organic plant breeding[3] considers breeding an important element to create agroecological systems which fit into the cycles and ecological balances in nature. Organic plant breeding respects the genetic integrity of a plant, its crossing barriers and regulatory principles, and intends to safeguard the fertility, the autonomy and the evolutionary adaptation of crop plants. Technical-material interventions in these complex regulatory processes of the interactions of all cell components, are thus rejected in organic breeding because of the unforeseeable consequences and the need to preserve the integrity of a plant, including down to its cell level. **In organic's approach, resilience comes from the health and robustness of the agronomic system as a whole, not a specific crop or variety.** In other words, one trait cannot be called sustainable, only the cultivation of crops can take place sustainably.

According to the European Consortium for Organic Plant Breeding (ECO-PB)'s position paper, the aims of organic plant breeding are fourfold:

- Breeding goals need to match the respective crop species and aim at the sustainable use of natural resources and at the same time account for the dynamic equilibrium of the entire agroecosystem.
- Breeding needs to support sustainable food security and sovereignty, and the common welfare of society.
- Breeding needs to sustain and improve the genetic diversity of the crops,

[3] To clarify, there are three categories of varieties in organic farming: (1) Varieties derived from conventional plant breeding that are suitable for organic farming with the exemption of GMOs; (2) 'Breeding for Organic', meaning varieties derived from plant breeding programmes with a special focus on the breeding goals or selection environments for organic agriculture; (3) 'Organic Plant Breeding', meaning varieties derived from organic breeding programmes or organic on farm breeding, which have been bred under organic farming conditions. This briefing paper talks specifically about the third (3) category of varieties.

- Breeding needs to contribute to the development and adaptation of crops to future growing conditions, which may be more unpredictable and volatile (e.g., climate change).

Organic plant breeding is executed under organic conditions, meaning among other things, that the organic management must be adapted to local conditions, ecology, culture, and scale. Additionally, as the principle of ecology explains, inputs should be reduced by reuse, recycling, and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources. Pesticide use, chemical fertilizers, or other synthetic inputs are not allowed. So, the selection of suitable crops is based on an evaluation beginning from the seed to the grown plant under organic conditions. This has inherently pushed the organic movement to be a driver for nature-based regenerative systems of agroecological innovation. For example, the LIVESEED project has a multidimensional view of breeding, which aims for improved symbiosis and interactions between microbes, plants, and soil microbes (see Figure 2 below).

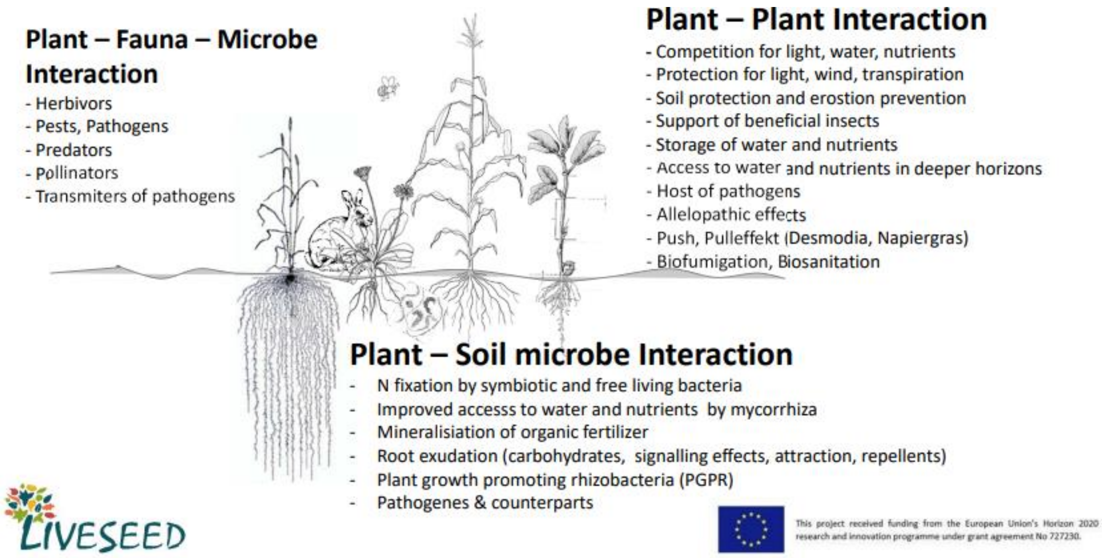

Figure 2. Scheme on breeding for improved symbiosis from the LIVESEED project (Source).

Problematically, genetic engineering and the trait-focused approach to breeding which the Commission adopts in the recent legislative proposal on NGTs, misleadingly gives the impression that one can easily tweak the property(ies) of a plant according to a specific wish list in an isolated manner.

> "Organic agriculture's rich experience shows that a systems perspective of our agroecosystems is what creates its resilience."

Organic agriculture's rich experience shows that a systems perspective of our agroecosystems is what creates its resilience. The organic principles of care, health, ecology, and fairness guide the vision that a truly sustainable agricultural system puts the preservation and improvement of soil fertility, genetic diversity, the conservation of natural resources, and the strive for a stable ecological equilibrium at its core. Organic production, whether in breeding, farming, processing, distribution, or consumption, strives to sustain and enhance the health of ecosystems and organisms from the smallest organism in the soil to human beings. Organic farming can reduce emissions as it builds on reduced inputs, closed nutrient cycles, and fertile soils. It provides many animal welfare and environmental benefits for soils, water, and biodiversity. For example, farms under organic management contain about 30% more species and pollinators compared to conventional agricultural systems. Feeding animals on well-managed grasslands also contributes to putting carbon back into the soil. Organic farming and agroecological practices are part of the solution to transition to sustainable food systems and climate resilience (for an overview of the ecological benefits of organic agriculture, read more in our publication 'Organic farming and biodiversity - Policy options' or consult our infographic).

No shortcuts – Crops are not silver bullets

> *A single crop or crop's trait is not a silver bullet. Our agroecosystems are complex and based on the interaction of many genes, environmental and geophysical factors, and symbiotic relationships with other species. Breeding needs to factor in all these aspects instead of limit itself to single properties of the genome.*

Crop breeding is a complex endeavour. Advocates of genetic engineering present breeding as a straightforward and trait-focused process. However, despite often being presented as such, crops are not silver bullets – extensive experience in the breeding sector shows **there are no shortcuts to circumvent the complexity of our agroecosystems**.

Crop properties are based on the interaction of many genes, and are impacted by environmental and geophysical factors, including soil health, and symbiotic relationships with other species. Breeding needs to take these complexities into account and cannot only considers the genome's properties. Further, there are important trade-off effects in breeding, whereby the expression of a certain trait affects another trait. In other words, when selecting a specific trait, other traits might unintentionally be altered or less pronounced.

Proponents of NGTs often give the false impression that it is possible to tweak plants according to a wish list with no repercussions, but the trade-off effects are a good example of the limits to this. One example is a gene edited wheat with altered baking quality, which is supposed to form less acrylamide, a substance suspected of causing cancer, during the baking process. For this, the function of several copies (alleles) of a gene (TaASN2 gene) was blocked. However, many seeds of this wheat were no longer able to germinate with reduced growth. In addition, the genetically modified wheat shows unexpected properties regarding the concentration of several amino acids and specifically the asparagine content. Another example is a genetically modified Pilton wheat with virus resistance against a fungal disease known to affect leaves and grains. However, this came at a loss of the plant's fitness resulting in slower growth rates and premature flowering.

> "Advocates of genetic engineering present breeding as a straightforward and trait-focused process. However, despite often being presented as such, crops are not silver bullets – extensive experience in the breeding sector shows there are no shortcuts to circumvent the complexity of our agroecosystems."

Considering the nuances of complexity, two crop properties are often highlighted by advocates of genetic engineering and new GMOs. Pro GMO-advocacy is reflected in Annex III of the legislative proposal, mostly in two arguments. Firstly, tolerance/resistance to biotic stresses, including plant diseases, and secondly tolerance/resistance to abiotic stresses, including those connected to climate change. As common arguments promoting new breeding techniques, these two crop properties merit further reflection.

The case of pest resistance

> *Plant health relates to the integrity and vitality of the entire living ecosystem. Considering plant health as the absence of disease in a single plant will only lead to short-term solutions. Specifically, genetically modifying a plant's genome to make it less vulnerable to one threat will, in many cases, lead to herbicide-resistant weeds and increased pesticide use. Organic's system approach to plant health care creates more resilient agroecosystems.*

Regarding resistance/tolerance to biotic stresses, i.e., pest resistance, pro-GMO actors often emphasise that gene-altered crops contribute to sustainability because they need less plant protection products. There are various issues with this argument. To begin with, it defines plant health as the absence of illness. Organic, however, sees plant health in relation to the integrity and vitality of living (eco)systems.

Further, the current generation of GMOs has promised reduced pesticide use, while the last decades of experience with these crops evidenced the opposite. The 2023 report by Foodwatch International shows how the industry has failed to deliver on this promise. To the contrary, genetic engineering has led to a "herbicide lock-in", creating herbicide-resistant weeds and environmentally damaging pesticide use. In a case study on the USA, where genetically engineered crops are widely used, research shows pesticide use increased by an estimated 183 million kgs, or about 7% between 1996–2011. The empty promise of pesticide reduction is repeated with the new generation of genetic engineering. The same Foodwatch report and scientific literature concludes that **the potential of these new technologies and the current crops in development seems to be nearly zero**.

Moreover, pest resistance often refers to monogenous disease resistance. Monogenous resistance results in a treadmill effect, where **pests tend to adapt and become resistant to the resistance traits of a crop, as part of a natural evolutionary process. So, a new pest resistance needs to be developed and the spiral continues.** Breeding experts show that genetically narrow resistances, which focus only on one pest, are rarely successful in the long-term. Similarly, the strive for "resistance", meaning a complete defence against a pathogen is often unsuccessful. So, resilient breeding should rather focus on inhibiting a pathogens' penetration capacity, growth, and reproduction to consequently limit the damage potential. Furthermore, aiming for horizontal tolerance to various pathogens, albeit much more complex and time-intensive, is crucial for the future of more resilient and sustainable breeding.

Example 1: Scab resistance in Ahrensburg

The developments in scab resistance in conventional breeding over the past decades give some insight into the issue: These cultivars were created by crossing modern disease-susceptible varieties with a certain gene of the wild apple *Malus floribunda* to obtain the so-called Vf-resistance against apple scab. However, the virulent strains of apple scab developed soon after the broader market introduction of the cultivars with Vf-resistance. In other words, the scab resistance was broken quickly. Some documented cases dating to 1993 or even earlier: a good example are the 'Prima' cultivars in Ahrensburg: After scab symptoms have been observed in fields at Ahrensburg in 1984, the seedlings of the Prima cultivars have been selected as resistant to Vf in the greenhouse. Yet, already four years later, in 1988, small scab lesions were found on those Vf selections in the orchard.[4]

[4] Note: in general, the breakdown of resistance depends heavily on the cultivar itself, and on the pressure from the disease itself at the specific site.

Example 2: Bt maize in Spain

A similar case occurred in Spain with a genetically modified maize (with Bt toxins), being cultivated since 1998. The transgenic maize was engineered for insect resistance against the corn borer, also known as the European corn worm, which is a moth and a pest of grain, particularly maize. Bt toxins in GM maize differ in important ways from its natural Bt form in bacteria: As this study explains: "Natural Bt bacteria spores contain an inactive toxin which can only become active in specific larvae, therefore only specific insects are killed. On the contrary, many Bt plants contain an artificial, truncated Bt gene and less processing is required to generate the toxin, so that they can affect non-target species. Furthermore, natural Bt degrades within three days and does not remain in soil, which is not the case for Bt toxin from GM crops".

As the pest spiral prognoses, as soon as 2003 research had found that the corn borer already had developed a resistance and the Bt toxins even had negative impacts on non-target species. For instance, next to the mortality rate of beetles, the mortality of Green Lacewing (*Chrysoperla carnea*) larvae almost doubled after ingesting European corn borers fed on GM maize. In addition, recent studies have suggested that mortality rates among insects can create impacts on insectivorous birds or other components of the food web (such as bats), as well as other insect-mediated ecosystem functions and services such as soil and freshwater functions (nutrient cycling, soil formation, decomposition, and water purification), biological pest control, pollination services. Interestingly, in terms of yield, the last years demonstrate that even in the regions where the corn borer is present it is not true that Bt corn yields more.

Climate change and complex sustainability challenges

> *Our ecosystem is complex. This complexity and interconnectedness create resilience. Meddling with our ecosystem's interactions causes challenges for sustainability and our climate. In organic production, breeding should fit into the natural cycles and ecological balances. So, organic farmers and growers select crops suitable for the conditions it naturally grows in. At least 60 genes have been linked to drought tolerance, so manipulating one or a few genes is likely not a solution to complex issues.*

Another common argument that is voiced by NGTs promoters is their contribution to sustainability issues brought about by changing climatic conditions. These promises are misleading and lack substance, remaining theoretical for now. Only few of the GMOs currently marketed or researched address sustainability issues that require the modification of complex traits, as the 2021 JRC study on NGT products shows. This is not surprising because climate resilience and other sustainability challenges are very difficult or impossible to achieve by manipulating one or a few genes. For example, at least 60 genes have been linked to drought tolerance, which in turn are influenced by environmental conditions. So, GMO production focuses on modifying simple traits benefitting industrial agribusiness, like non-browning fungi and questionable herbicide-tolerant crops.

For example, DuPont Pioneer[5] commissioned a study in 2017 on drought-resistant maize using CRISPR/Cas. Increased yield compared to wild plants was only observed at flowering time, not during the grain-fill period which is the most important for maize growth. The crop is therefore unlikely to make it to the market. Further, no data was available to substantiate any claims of safety or market relevance.

[5] DuPont, is an American multinational chemical company. In 2015, DuPont and the **Dow Chemical Company** agreed to a reorganization plan in which the two companies would merge and split into three. As a merged entity, **DuPont** simultaneously acquired Dow and renamed itself to DowDuPont, and after 18 months spun off the merged entity's material science divisions into a new corporate entity bearing Dow Chemical's name and agribusiness divisions into the newly-created **Corteva**; DowDuPont reverted its name to DuPont and kept the specialty products divisions.

As the 2021 report by Friends of the Earth Europe stated: "[…] The efforts to develop these innovations are diverting the conversation away from the huge climate-destroying elephants in the room: intensive agriculture and unsustainable mass production and consumption. An industry based on driving demand for environmentally damaging animal products can never be sustainable no matter how many genes are edited or cows are 'optimised".

An isolated trait is never enough to prove "sustainability", which must be based on a systemic assessment of the entire agricultural system. Organic and other agroecological systems offer pathways to more sustainable food and farming systems, which reduce greenhouse gas emissions, build crop resilience, and stabilise yields, based on decades of successful practice on the ground coupled with scientific insights.

Case study 1 – Nordic maize: Robust cultivation systems adapted to climatic conditions

The first case study relates to the creation of organic varieties aimed to adapt to changing climate conditions. Nordic Maize was founded in 2002 and is a small innovative, independent maize breeding company, focusing on the Northern European maize market. Their breeding programs combine maize elite and open-source germplasm from multiple international breeding programs to ensure genetic diversity. The varieties are adapted to Northern Europe's shifting climates and windy conditions and thrive in a robust cultivation system.

In 2011, Nordic Maize bred the first so-called "ultra early" maize variety, which enables a harvest already in September, leaving sufficient time to plant a winter crop and enable efficient crop rotations (visualised in Figure 5). The company also resorts to extensive measures like cover crops, including for example, undersows of buckwheat-facelia or clover mixtures. Small breeding companies like Nordic Maize are an important source of innovation in the breeding sector, as they create 'out-of-the-box' varieties aimed to serve agriculture instead of investors and shareholders.

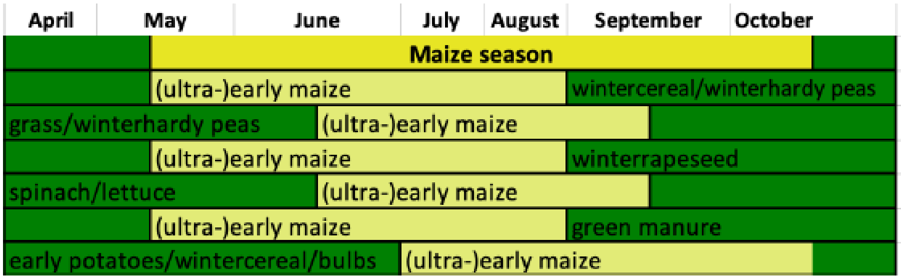

Figure 5. Crop rotation scheme of Nordic Maize Breeding

Organic: aiming for (bio-)diversification

Important to sustainability in organic crop breeding is striving for biological diversification of genetic material. Obtaining genetic diversity through outcrossing old and local varieties is central to organic breeding. Genetic diversity within and between species allows plants to adapt to changing environmental conditions and enables us to improve our crops through breeding according to our needs. Research widely acknowledges that crop diversity is the basis for productivity, resilience, and adaptive capacity of agricultural systems (Gepts, 2006; Hajjar *et al*., 2008; Renard & Tilman, 2019; Sirami *et al*., 2019; Egli *et al*., 2020). It also shows that the host plant's genetic diversity significantly influences the infestation pressure and virulence[6] of fungal diseases (source).

"Genetic diversity within and between species allows plants to adapt to changing environmental conditions and enables us to improve our crops through breeding according to our needs."

Conventional breeding, leading to genetic erosion

Organic's approach to breeding contrasts with that of the agrichemical industry. In the last decades, the breeding sector has focused on a few successful lines. Terms like 'genetic erosion', coined by the Food and Agriculture Organization of the United Nations (FAO), point to dramatic losses of our genetic resources. The dominant presence of only a few variety lines in horticulture and agriculture has led to a problematic reduction of genetic resources in plant breeding.

A further complication relates to the fact that many varieties, from fruit trees to yams and shallots, are asexually propagated vegetatively[7]. This makes it easy to breed the most desired / superior plant endlessly and without variation, which is important for popular cultivars like the Jonagold or Gala apple. Problematically, it also results in the issue that all trees of a variety are genetically the same. Specifically, each plant is an exact genetic clone, leading to high vulnerability to diseases. This is particularly important in fruit growing, as in permanent crops an inoculum, which is the part of the pathogen that can initiate the infection,[8] can adapt and build up over years in

[6] Virulence refers to a pathogen's or microorganism's ability to cause damage to a host.
[7] Vegetative propagation is a process in which plants reproduce asexually from stems, roots and leaves.
[8] Inoculum refers to the pathogen(s) that lands on or is otherwise brought into contact with the plant (Source: Science Direct).

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a plant. Using the same genetic material, so the same resistance genes, on large-scale puts a strong selection pressure on the pathogens and inoculum, making it easy for them to quickly adapt, and break through the plant's resistance – potentially leading to high yield losses and/or total failure of the entire variety.

Market acceptance is an important component limiting the genetic diversity that can be introduced in conventional and organic breeding programs. Consumers have rigid expectations on their "ideal" product. For modern fruits, consumers demand crispness, juice content, and a flawless appearance, combined with a long shelf life. However, there is a slow increase in consumer awareness on the sustainability of their produce. More and more, consumers ask for more natural products, buy "flawed" or "wonky" fruit. They (we) are also increasingly aware of food waste's burden. A quicker shift in consumers' mindsets is necessary to enable the much-needed shift towards more genetic diversity and diversification in the breeding sector. To realise this, education, policymakers, and food providers can all play a role.

Case study 2 – Scab resistance in German apple breeding

In the debate around "sustainability" in breeding, pro-NGT narratives often give the impression that innovative breeding addressing contemporary environmental challenges is reserved for gene editing techniques. However, the organic movement has a rich experience developing innovative and robust varieties – partially overlapping with the breeding goals laid out in Annex III of the Commission's proposal. However, organic always considers breeding activities with an eye on entire agricultural system's sustainability, not that of a certain plant.

In this section, we will give an example of organic fruit breeding which focused on a variety's vitality and multi-tolerant qualities, rather than monogenous resistance to a pest.

From 1,000 apple varieties to 10-20

Namely, this case study pertains the development of new varieties of organic apples. While Germany was once characterized by an abundance of apple biodiversity, hosting more than 1,000 apple varieties, now there are only about 10-20 varieties available on the market, which have strong inbreeding tendencies and are repeatedly plagued by diseases like scab, caused by the fungus, *Venturia inaequalis*. Research found that the increased scab outbreaks in the apple cultivars are likely to be caused by the extreme genetic impoverishment of modern breeding varieties.

Crossing species to increase variety

To enrich the genetic diversity of apple breeds, apfel:gut e.V.[9] has been breeding new varieties and preserving old and rare varieties of apples and pears on-farm in 10 locations in various locations in Germany – in an organic and participative way since 2019. The project observes 450 parental varieties under zero spray conditions. Breeders travel from farm to farm to select the best performing varieties and cross them in a recombinant pattern. They select seedlings focusing on vitality and the loss of susceptibility. If a plant has a high level of vitality[10], despite biotic and abiotic stress situations, it is positively selected.

In this example, modern varieties are always crossed with "old" and partly unknown varieties. This is important because many old apple varieties have been resistant to scab, some of them for centuries, and are also robust in regard to other pests. On each orchard, seedlings of the offspring variety are planted in different pedo-climatic conditions. The fruit farmers cultivate the seedlings on the farms under organic growing conditions and can be active in the breeding process themselves.

[9] Formerly known as project apfel:gut under the umbrella of the saat:gut e.V.
[10] One typical symptom for vitality is a shining green leaf, even if a disease occurs.

Promising results of new local varieties

Apfel:gut e.V. produces robust and stably-resistant varieties, relying on the increased cross-breeding of certain multi-resistant and tolerant old apple varieties combined with modern, aromatic and high-yielding varieties (gene pyramidisation). If the offspring of a combination proves particularly vital in the first trial and performs well for fungal diseases, scab, powdery mildew, canker and "topaz spots", the project crosses these and their offspring in subsequent years. One result is the creation of local varieties which might be of interest for local consumption and retail, strengthening the cultural heritage and short supply chain in the region.

Other innovation in organic breeding – Knowledge exchange and participatory breeding

Organic's breeding approach is innovative, just like the way in which it achieves resilient breeding. The organic sector promotes a decentralized participatory plant breeding sector and strengthened knowledge exchanges among extensive networks.

Creating networks for knowledge exchange

A good example of a streamlined network exchange is the project Network Organic Plant Breeding: Possibilities and methods, boundaries between classical and "genetic" breeding methods, participatory plant breeding which ran from 2012 to 2013. It entailed a partnership between various stakeholders in the German organic plant breeding sector to better co-ordinate and link the exchange of ideas and information. Projects like BIOFRUITNET, INNOBREED and LiveSeeding[11], in which IFOAM Organics Europe and/or our members are involved, promote this vision of collecting and synthesizing existing knowledge in a stable European innovation network to ease exchange and co-creation of expertise among organic growers, researchers, and advisors.

> "The organic sector promotes a decentralized participatory plant breeding sector and strengthened knowledge exchanges among extensive networks."

For the past 10 years, the Organic Farm Knowledge platform has been stimulating knowledge exchange among organic farmers, farm advisers, and scientists, providing and promoting a wide range of tools and resources to enhance productivity and quality in organic farming across Europe. The platform covers a variety of themes from crop production to animal husbandry, seeds, breeding, and organic fruit growing.

Involving relevant actors for participatory breeding

Participatory breeding is a widely successful model which contributes to breeding innovation in organic. The strength of the participatory approach comes from partnerships between many relevant actors with different working backgrounds to collaborate testing, renewing, and promoting underutilized or forgotten crops, species, and varieties. This inclusive approach to breeding is characterised by growers who are directly involved in the decision-making processes within the entire breeding process, for instance, in defining breeding goals or the selection work. In participatory breeding, crossing and raising of seedlings often takes place directly on farms. This increases breeding's efficiency and diversity by networking with breeding programs for local conditions.

[11] And its predecessor Liveseed, www.liveseed.eu

Involved stakeholders span the entire supply chain, helping the breeding sector to be more suited for farmers, processors, retailers, and other value chain actors. Beyond the value chain, however, participatory breeding also involves other actors, from the political sphere to ecologists, and many more (Figure 3.). This helps open new avenues of thinking about the future of breeding in a transparent and systemic way, based on the insights of multi-faceted and rich experience of the actors involved.

This innovation in the approach to breeding helps support the development of new concepts for the ownership of cultivars and their financing. Due to its many benefits and importance for the future of resilient and biodiverse breeding, it is crucial for policymakers to ramp up funding for (research in) participatory organic breeding programs, which currently still lack significant and reliable public investments and are often dependent on donations.

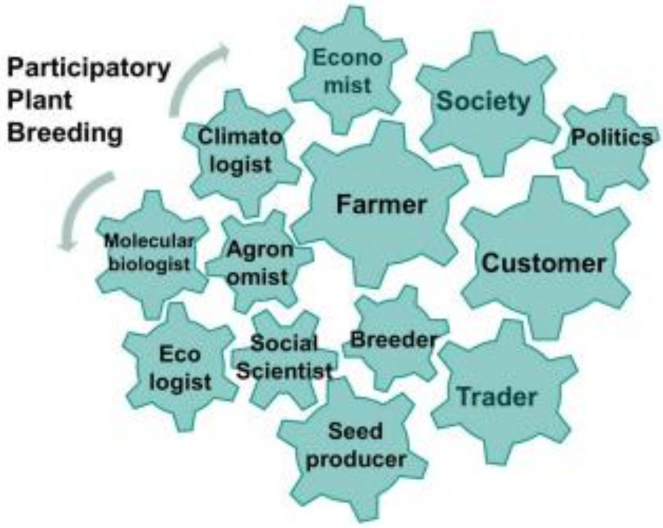

Figure 3. LIVESEED Scheme of Participatory Plant Breeding (Source: Organic eprints).

Regarding varieties and seedlings as common good

Some participatory breeding programs are geared towards innovations involving new "common property-based" breeding. "Here knowledge, varieties and seedlings are treated as are treated as common property, shared among each other and jointly further developed", explains Prof. Stefanie Sievers-Glotzbach of the research projects of the RightSeeds and EGON research projects. This approach includes a strong commitment to collective responsibility for common goods, such as genetic biodiversity, decentralising resources like seeds and seedlings which belong to the community, knowledge sharing, and decentralized decision-making.

Going against the (agroindustry's) grain

Participatory breeding and organic breeding are important counter-movements to an increasingly problematic issue in the seed sector, namely the monopolization of genetic resources to big companies, often multinational industries which are also connected to the agrochemical industry.

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To secure more avenues of profit, these companies often resort to intellectual property (IP) rights and patent claims. These increases farmers' and breeders' dependency on "protected" seeds (e.g., thorough strict contractual obligations), and threaten them through costly patent infringement claims.

In contrast to conventional plant breeding, both the processes and products of new genetic engineering techniques are patentable under the EU Biotechnology Directive 98/44. As a 2022 report by GLOBAL 2000 argues, patent claims are very broad and can apply to all cells, seeds and plants containing the same introduced (i.e. non-native) genetic sequence from a long list of crop species – also from conventional breeding. Over 3,500 patents on plants have been granted by the European Patent Office in the past 30 years (see Figure 4.).

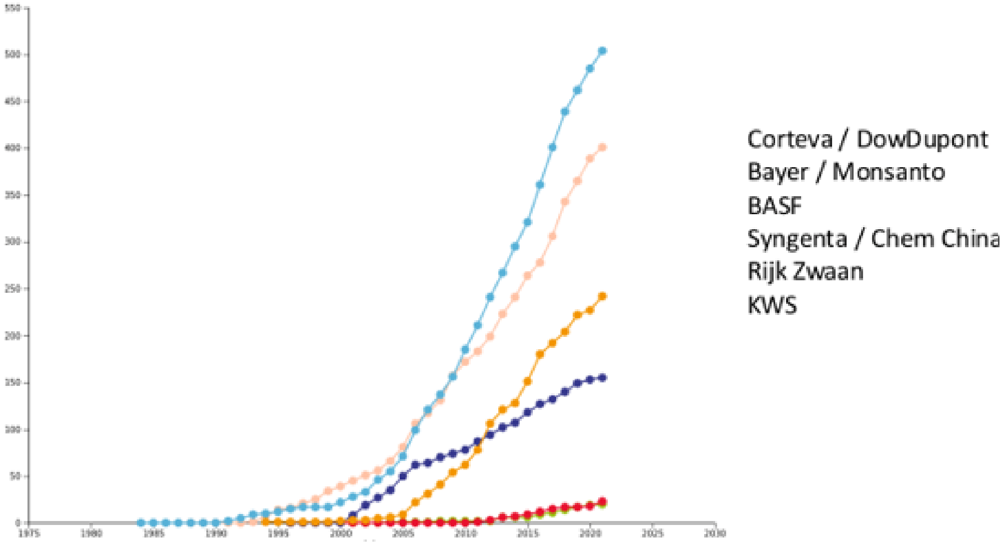

Figure 4. All EPO patents granted on plants, categorized by individual companies and accumulated since 1990. (Source: No Patents on Life).

New genomic techniques and patents: A problematic alliance

Gene editing exacerbates the issues with patents and intellectual property rights as new genomic techniques are often used to legitimize patent claims on crops. Patenting crops and traits hinders innovation because it reduces the much-needed genetic diversity to develop new crops or limit it to those who have paid for a licence. As seeds are the first step of the production chain, this impacts both the control of seeds and the control of food production.

In addition, some breeding techniques offer a technical-biological possibility to protect one's own breeding material more strongly from the breeding use of third parties. This includes, for example, the transfer of cytoplasmic male sterility (CMS) by means of cell fusion. These modern breeding techniques can limit both the farmer's privilege and the breeder's exemption[12].

There are strong efforts to enable a participatory and wide circulation of genetic material in the breeding sector. However, there are increasing threats of a harmful concentration of genetic resources into the hands of a few (agrochemical) multinationals driven by, among other things, patent claims. Genetic engineering will only worsen these issues.

A common NGO letter IFOAM Organics Europe sent to EU Agricultural Ministers and Commissioners in July 2023 explains the connection between monopolization of genetic resources in the seed sector and the recent push for genetic engineering by NGT developers: "Espacenet, the database run by the European Patent Office, lists around 700 patent applications for "Crispr-Cas9 and plants" alone. Over 20,000 patent applications referencing the term "Crispr-Cas9 plant" have been submitted at international level. The patent applications typically cover both the specific technical process (e.g. the use of Crispr-Cas9 to increase starch content in potatoes), as well as the specific trait or traits resulting from the process (e.g. resistance to a certain disease on germination under higher temperatures). The scope of the patent claims is often very wide. The patents typically claim all plants with the specified trait, regardless of how the plants were bred. In this way, the scope of patents can also apply to conventionally bred plants and peasant, local, and traditional seeds, even though these should not be patentable under EU law – and can extend not only to plants and seeds, but also to the harvest and food products containing the trait. There are examples of patents with the claims extending to silage and animal feed, beer, salads and sandwiches. Anyone who wishes to commercially use a plant containing a patented trait must ask the patent holder for consent, agree to contractual limitations on the use of the trait, and pay licence fees."

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[12] The breeder's exemption allows breeders to use the variety as a crossing parent without permission, stimulating competing breeders by using each other's innovations to develop better varieties faster. When working with patents, breeders can no longer work freely with each other's varieties. In other words, breeders can only work with their own genetic resources. This narrows the genetic base and also slows progress and innovations.

Conclusion

Breeding should consider strengthening the system, not a single part of it

The organic movement has been and continues to be at the forefront of developing and promoting nature-based regenerative systems of agroecological innovation. **Organic breeding is the basis for a self-determined, sovereign, and thriving organic agriculture sector in Europe.** Many best practice examples in organic breeding exist and are flourishing. It is crucial to support the organic breeding sector and its vision with strong policies. The European Green Deal and its Farm to Fork and Biodiversity Strategies rightfully highlight the organic's role in transitioning to sustainable food systems – setting a target to expand European agricultural land under organic production to 25% by 2030.

It is important for innovation in breeding to consider breeding as more than the promotion of genetic engineering focussing on specific "desired" traits. This holds especially true considering that the sustainability claims of alleged contributions of old and new GMOs remain largely theoretical and have mostly been limited to misleading statements on the hypothetical potential of pesticide reduction and climate-resilient gene-edited crops.

Organic breeding offers many benefits and innovations:

- Strong products: More resilient cultivars and breeds
- Genetic enrichment: more biodiverse cultivars and breeds
- Co-benefits: A system approach to breeding, strengthening the existing and complex ecosystem
- Innovation: Novel socio-economic approaches to breeding
- Participation: A participatory approach to breeding

Strong products & co-benefits

In organic breeding, farmers, and growers develop more resilient cultivars and breeds suitable to the principles and conditions of organic farming. These are fit for our changing climate and contribute to food security and the livelihood of future generations.

Organic breeding provides many benefits, including marketable goods and public goods and services, like locally adapted cultivars and breeds satisfying farmers', processors' and consumers' needs. It also contributes to organic farming's overall goal of preserving and enhancing biodiversity and the agroecosystem as it aims for improved symbiosis and bases its robustness on interactions already taking place in nature.

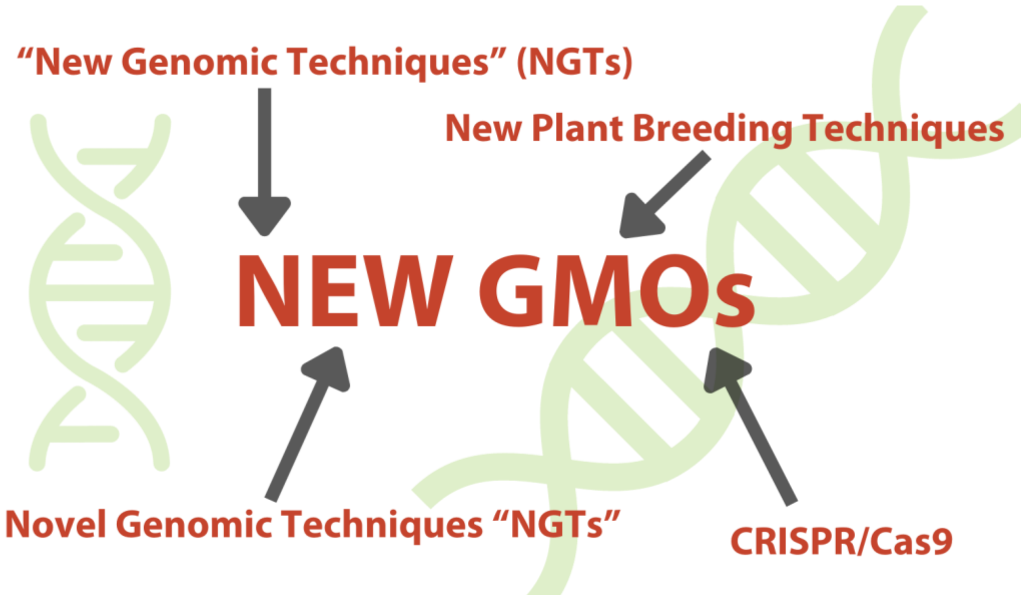
Innovation means participation and sharing, not only technologies

Besides innovation geared towards ecological objectives and providing healthy and nourishing varieties, organic breeding can also entail socio-economically novel approaches. The organic breeding sector is often connected to a participatory approach of breeding, strengthening alliances and knowledge exchange among many stakeholders with different working backgrounds. This ensures collaboration in testing, renewing and promoting underutilized or forgotten crops, species, and varieties.

This approach starkly contrasts multinational industries' approach, including agrochemical and seed companies, that develop and GMOs to (further) monopolise genetic materials through intellectual property rights. Patents on crops and traits hinder innovation as they reduce the necessary genetic diversity to develop new crops and/or limit access to it to those who paid for a licence. Additionally, breeders and farmers experience a constant threat of costly legal patent infringement cases. As seeds are the first step of the production chain, patents impact the control of seeds and the control of food production.

For successful organic breeding, the entire supply chain should be involved. **Breeding is a concern for breeders and farmers, and all stakeholders in the supply chain, up to the processing level. There is no sustainable food production without suitable seeds at its core and starting point.** In other words, there is a direct link between breeding targets and the wider vision for a transformation of our food systems, in which all organic operators have a stake. This also goes for financing of organic breeding which is still insufficient and fragmented. There are already many successful cases in Europe, where the organic value chain is supporting the financing of organic breeding effectively. The involvement of other supply chain actors is crucial as issues that concern breeding and seeds specifically, especially in relation to a deregulation of genetic engineering will trickle down to the whole supply chain, in terms of increased financial, regulatory, and reputational burden.

It is important to understand breeding in a systemic context of defining resilience and sustainability. Contrary to what gene editing suggests, there are no shortcuts to bypass the complexity of food production. While cultivars are constantly adapted and improved, **breeding needs to be understood within a broad framework of sustainable cultivation practices and supply chain production**. This is the understanding of agricultural systems and innovation that Europe so desperately needs in the face of various environmental challenges.



For more information about the European organic movement's position and work on organic seeds, organic breeding and old and new GMOs, please visit www.organicseurope.bio.