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Opinion

Europe's Farm to Fork Strategy and Its Commitment to Biotechnology and Organic Farming: Conflicting or Complementary Goals?

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The European Commission's Farm to Fork (F2F) strategy, under the European Green Deal, acknowledges that innovative techniques, including biotechnology, may play a role in increasing sustainability. At the same time, organic farming will be promoted, and at least 25% of the EU's agricultural land shall be under organic farming by 2030. How can both biotechnology and organic farming be developed and promoted simultaneously to contribute to achieving the Sustainable Development Goals (SDGs)? We illustrate that achieving the SDGs benefits from the inclusion of recent innovations in biotechnology in organic farming. This requires a change in the law. Otherwise, the planned increase of organic production in the F2F strategy may result in less sustainable, not more sustainable, food systems.

Highlights

Sustainable food systems will require profound changes in people's consumption patterns and lifestyles, which is true regardless of the farming methods used and does not change the fact that organic farming often requires more land than conventional farming for the same quantity of food output.

Some features of organic farming in the EU contribute to the Sustainable Development Goals (SDGs); other features may jeopardize the achievement of SDGs 2, 13, and 15. The negative indirect effects of additional land-use change may outweigh the positive direct effects on global climate and biodiversity, so that a large-scale switch to organic farming in the EU could possibly turn out to be a disservice to global sustainability.

Achieving the SDGs would benefit from the inclusion of biotech innovations in organic farming.

The implementation of required changes in the EU law is unlikely under current political realities but is nevertheless recommended from a scientific perspective.

The European Commission (EC) recently launched its Farm to Fork (F2F) strategy. This strategy is a cornerstone of the European Green Deal and is instrumental in working toward the United Nations Sustainable Development Goals (SDGs) [32]. The F2F strategy acknowledges that new innovative techniques, including biotechnology, may play a role in increasing sustainability. At the same time, organic farming will be promoted, and at least 25% of the EU's agricultural land shall be under organic farming by 2030.

How can both biotechnology and organic farming be developed and promoted simultaneously to contribute to the overall aim of achieving the SDGs? It is a common interpretation that the current EU legal framework regulates many products resulting from novel techniques in plant breeding as genetically modified (GM) organisms (GMOs), while organic farming and processing of organic products legally exclude the use of GMOs. Hence, combining these two components of the F2F strategy appears conflicting and challenging, if not impossible, even though the two could actually fit together very well if legally permitted (Figure 1).

Through a few cases, we illustrate that achieving the SDGs benefits from the inclusion of biotechnology innovations in organic farming. To make this possible, we advocate for a change in the EU law. Implementation of such a legal change is unlikely under current political realities. Many EU and national policymakers and interest groups, including nongovernmental organizations (NGOs), seem to prefer coexistence policies whereby organic production and modern biotechnology are strictly separated. Notwithstanding the fact that it is hard to justify such a strict separation of 'organic,' 'conventional,' and GMO from a scientific point of view, without legal change, the planned increase of organic production in the F2F strategy may result in less sustainable, not more sustainable, food systems.

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SUSTAINABLE DEVELOPMENT GOALS	Organic farming in combination with agricultural biotechnology
2 ZERO HUNGER	✓ Higher food diversity (number of species grown) ✓ Higher food quantity (yield) ✓ Higher food quality (nutrient composition and safety)
13 CLIMATE ACTION	✓ Lower greenhouse gas emissions from land use ✓ Lower greenhouse gas emissions from land-use change
15 LIFE ON LAND	✓ Lower use of synthetic pesticides and fertilizers ✓ More biodiversity on farmland ✓ More natural biodiversity (less land-use change)

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Figure 1. Expected Benefits for SDGs Resulting from the Combination of Organic Farming with Agricultural Biotechnology.

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The Legal Framework: Determining the Toolbox

In order to produce or market an agricultural product or foodstuff in the EU as an organic product, EU law requires separating organic production from the use of GMOs. Recital 23 Regulation (EU) 2018/848 stipulates that organic production and consumers' perception of organic products are incompatible with GMOs. As a result, according to Article 11 Regulation (EU) 2018/848, 'the use of GMOs in organic production is prohibited.' To be precise, 'GMOs, products produced from GMOs, and products produced by GMOs shall not be used in food or feed, or as food, feed, processing aids, plant protection products, fertilisers, soil conditioners, plant reproductive material, micro-organisms or animals in organic production.' To determine whether products shall not be used, operators may rely on their labeling in accordance with the EU rules on labeling of organic products in combination with the rules on labeling of GMOs. In principle, the majority of food and feed on the EU market 'containing, consisting of or produced from GMOs' (Article 2, Regulation 1829/2003), with GMOs understood as defined in Directive 2001/18, require labeling. As to the interpretation by many academics and stakeholders of the judgment *Confédération paysanne*, the products of most novel breeding technologies, including targeted mutagenesis through genome editing, are subject to the GMO regulations [1,2]. Others argue that certain applications of targeted mutagenesis may still be excluded postjudgment [3,4]. Labeling exemptions apply to the adventitious or technically unavoidable presence of traces of GMOs, as long as they do not exceed the threshold level of 0.9%, as defined under Regulation 1829/2003. This threshold applies to the labeling of GMOs that have been authorized for import and processing. For GMOs that have not been approved, a zero tolerance applies, while for those that have received a positive risk assessment by the European Food Safety Authority, a zero tolerance applies for food, with a threshold of 0.1% for feed. In case the respective product is not labeled as GMO, operators may assume that no GMOs or products produced from GMOs have been used in the manufacture of purchased food and feed products [Article 11(3), Regulation (EU) 2018/848].

Article 11, Regulation (EU) 2018/848 only prohibits the use of 'GMOs, products produced from GMOs, and products produced by GMOs.' Arguably, organic production of food with GMOs is legally not explicitly prohibited. This means, for example, that organic production of foods using GM microbes can be common practice if the food is considered produced 'with' GMOs. Organic beer, bread, and cheese are allowed to be produced with the enzymes or directly with GM yeast and GM bacteria. European consumers have been consuming products made with GMO technology for over 35 years [5].

Increasing Organic Agriculture and SDG Achievement: Without Breeding Innovations

The existing legal framework leads us to assess whether the focus of F2F on increasing organic production contributes to achieving the SDGs while not using GMO techniques (including those novel techniques that are commonly considered as such). Organic farming is considered to cause less environmental damage than conventional agriculture. It promotes higher levels of agrobiodiversity and uses less environmental pollutants (e.g., synthetic pesticides and inorganic fertilizer) [6], contributing to achieving SDGs 13 and 15 (Figure 1). While some facets of organic farming can contribute to the achievement of these SDGs, we focus on those aspects where it does not or only to a limited extent and where biotechnological innovations have the potential to serve as a remedy. Given that food demand continues to rise globally and that hunger reduction is central to SDG 2, production quantities remain relevant and need to be factored in. Many of the positive environmental effects of organic production on the SDGs disappear when evaluating per kilogram of food rather than per hectare of land and while taking absolute amounts needed into consideration [7]. One hectare of organically cultivated land produces a lower crop yield than one hectare of conventionally cultivated land under conditions that allow effective use of conventional farming methods. This 'organic' yield gap can vary by crop type and several other factors; studies suggest that it is in a magnitude of 20–25% under experimental conditions and up to 50% under practical farming conditions [8,9].

Increasing organic agricultural land from 7.5%, as currently observed in the EU, to at least 25% of total agricultural land by decree might have various unintended land-use implications. Effects could range from a mere conversion of existing conventional farmland to organic without much yield loss in certain regions (e.g., areas with low-yield conventional farming systems) to larger yield losses (in areas with high-yield conventional farming systems), entailing the need for additional conversion of forests, swamps, or other natural habitats within the EU or elsewhere through rising food imports [9]. Already today, with only 7.5% of the EU land under organic farming, Europe is a major importer of vegetable oil and feed protein (e.g., palm oil, soy), contributing to deforestation in Southeast Asia and South America [10]. More precisely, the EU already imports about 5 million tons of soybeans from Brazil or 55% of the total imports of soybean,[i] some of which has been linked to illegally forested land [11]. Imports and global land requirements would rise with more of the EU farmland being converted to organic. Using more land for agricultural production threatens natural biodiversity and therefore jeopardizes the achievement of SDG 15. Also, land conversion is responsible for half of the total climate effects of agriculture. Studies predict that the GHG emissions from additional land conversion would offset any potential direct climate benefits resulting from a switch to organic agriculture [12], jeopardizing the achievement of SDG 13.

Reducing consumers' meat consumption and food waste [13] does not alter these results. Sustainable food systems will require profound changes in people's consumption patterns and lifestyles, but this is true regardless of the farming methods used and does not change the fact that organic often requires more land than conventional agriculture for the same quantity of food output.

Beyond the yield gap, there are further environmental problems jeopardizing SDG 15 caused by organic farming. Especially in organic potato and horticultural production, toxic copper-based pesticides are widely used to control fungal diseases [33]. Furthermore, a few relevant insect pests in organic farming can only be controlled with certain broad-spectrum biological insecticides that are known to also harm honeybees and other nontarget organisms.[ii]

Climate change will challenge current farming systems. Increasing mean temperatures, changing rainfall patterns, and more frequent weather extremes will create new stresses for crop plants and will also alter pest and disease pressure with dramatic consequences [14]. Organic farming with more diverse production can potentially increase system resilience to a certain extent [15]. However, by prohibiting chemical and biotech innovations, organic farming has fewer tools available for rapid adaptations, which will likely be required with changing climate in order to avoid major production shortfalls.

While some aspects of organic agriculture in the EU contribute to the achievement of the SDGs, significant features could jeopardize the achievement of SDGs 2, 13, and 15 in particular. Especially in terms of global climate and biodiversity, the negative indirect effects of additional land-use change may outweigh the positive direct effects, so that a large-scale commanded switch to organic farming in the EU could possibly turn out to be a disservice to global sustainability.

Organic Agriculture and SDG Achievement: With Breeding Innovations

Innovations in breeding technologies can contribute to remedying the potential negative impacts of organic farming on certain SDGs. Several of the breeding goals set for the improvement of organic agriculture, including the development of hardier plants [16], could be reached more efficiently through genome editing and related new techniques.

Biotechnological breeding innovations could reduce organic agriculture's risk of more land conversion by narrowing the yield gap. Recent advances, including systems such as CRISPR/Cas9 and a rapidly evolving suite of tools based on CRISPR/Cas9, complement classic breeding methods and provide further opportunities for efficient trait management. Targeted introduction of controlled deletions or insertions to inactivate genes, the precise mutagenesis of single DNA bases, or the substitution of small DNA fragments [17] facilitates rapid crop improvement, regardless of the agricultural production system. For certain traits that require only the targeted inactivation of a gene, this potential has already been substantiated only a few years after the advent of efficient genome editing techniques [18].

Crop plants are constantly under threat from pathogens and pests, while the use of synthetic pesticides is prohibited with organic farming. Pest pressure is particularly high in tropical climate that favors the rapid spread of microorganisms or herbivorous insects. According to predictions, it will further increase. Many crop-producing countries are expected to be fully saturated with pests and pathogens by 2050 if current trends of spread continue [14]. Some of the practices used in organic farming to control crop damage have questionable impacts on consumer and environmental health. Genome editing approaches could have a rapid positive impact on pest and disease resistance in crop plants without negative environmental and health externalities; in other words, they could achieve breeding goals that would make it easier for organic farming to contribute to SDGs 2, 13, and 15 [19]. An example is the *Mlo* gene, which confers durable resistance to powdery mildew in barley. The recessive resistance allele *mlo* is a loss-of-function variant discovered decades ago in a landrace and has been widely used in barley breeding ever since [20]. Generating corresponding *mlo* alleles with genome editing techniques in species such as wheat, tomato, grape, and other crops achieves comparable disease resistance [21–23]. Similarly, broad-spectrum resistance to bacterial blight in rice, an important disease in Asian and African countries, was successfully engineered by changing only a few bases in the promoters of genes encoding SWEET proteins [24]. The pathogen can no longer activate expression of these sugar exporters and thus lacks the extracellular nutrient supply essential for its virulence. Many more examples of pest and disease resistance through gene editing exist [1,25].

Increasing crop diversity is expected to make agriculture more resilient to climate change and to improve the quality of human diets, thus contributing to the achievement of SDGs 2, 3, 13, and 15. However, a few major crop species (rice, wheat, maize) currently account for the majority of the calories consumed globally. The gradual improvement of these species since the Neolithic revolution 12 000 years ago has taken crop diversity through a bottleneck. Thanks to progress in molecular genetics, many of the key alterations that resulted in the dominance of a limited number of crop species are now known. Two examples are dwarfing genes (known as 'Green Revolution genes') involved in the synthesis or signal transduction of the phytohormone gibberellic acid and genes controlling the response of plants to day length [26]. Systematic generation of variation in these major breeding targets will enable rapid improvement of orphan crops and thereby boost crop diversity. *De novo* domestication of wild species through genome editing has already been demonstrated [27].

Many agronomic traits are quantitative in nature (i.e., influenced by multiple genes and gene–environment interactions). Combining favorable alleles in one genotype is a huge and often insurmountable challenge with conventional breeding methods alone. For example, close genetic linkage results in the simultaneous selection of a favorable allele and a neighboring disadvantageous allele such as the disease susceptibility allele *Lr67sus* in wheat that is found next to the *RhtD1b* semidwarf allele, a major contributor to increases in wheat yields over the past 60 years [28]. With gene editing tools, the precise introduction of base edits can be applied to break such 'linkage drag' and combine the resistance allele with the semidwarf allele.

Changing the Law as a Remedy: Political Obstacles

Organic farming and modern biotechnology can both contribute to achieving the SDGs, but each has its particular strength, so combining both approaches could unleash important positive synergies (Figure 1). To reap these synergies and achieve the objectives of the European Green Deal and F2F strategy, the related EU legislation, which excludes GMOs from organic production, needs to be changed.

The legislative procedure for changing Regulation (EU) 2018/848 or any other EU legislative act concerning organics corresponds to the ordinary legislative procedure, which involves the EU Commission, which formally proposes the measure, and the Council and the Parliament. Parliament and Council examine in parallel a possible proposal by the Commission. However, the Parliament acts first and decides whether to adopt the proposal, requests amendments, or rejects it altogether. After the Parliament has adopted its position, the Council decides on the Parliament's position. Usually, the Council adopts a different position, which opens the second reading of the proposal, and potentially a third reading, which represents the final stage of the ordinary legislative procedure. In the majority of cases, the proposals are adopted after the first reading through tripartite meetings between the Commission, the Parliament, and the Council known as 'trialogue' meetings, which aim to bring these three actors to agreement.

With regard to changing the EU policies governing organics, both the involvement of the Parliament and the voting procedure in the Council pose likely obstacles. In the past, voting according to the comitology procedure has shown that there is not a qualified majority of the member states in favor of or against the authorization of new GMOs [29,30]. A potential change in the law may mirror this voting behavior, as the majority required in the procedure to initiate legal change is calculated in the same way [1]. Turning to the Parliament, because it is excluded from the comitology procedure, in the past, with the majority of its members, it adopted resolutions only to express its position on GMOs, not organics. These resolutions were dismissive of authorizing new GM crop varieties. For example, on February 16, 2014, the Parliament not only adopted a resolution against the authorization of GM maize event 1507 but also asked the Commission 'not to propose to authorize any new GMO variety and not to renew old ones until the risk assessment methods have been significantly improved.'[iii] Therefore, the majority in both relevant EU institutions is rather against the authorization of GMOs, which suggests that a majority is also likely to reject a modification of organic laws to allow the inclusion of new molecular breeding techniques [1]. To facilitate policy change, it would be essential to effectively communicate that (i) molecular breeding does not necessarily result in plants that would fall under the GMO regulation and (ii) not all innovations in breeding by default represent a violation of the organic principle of preserving the integrity of the cell.

Concluding Remarks

Promoting the increase of organic production without simultaneously allowing the use of novel breeding techniques in organic agriculture, the F2F strategy will likely fail to deliver on its promise of moving toward realizing the SDGs. Combining organic farming and modern biotechnology could unleash important synergies, as both have their specific strengths in contributing to the SDGs. However, such combination would require a change in the EU law, namely allowing the use of modern biotechnology, and novel breeding techniques in particular, in organic production. The EU has the ambition to lead the world in developing policies to mitigate and adapt to climate change. It requires higher yields to expand the contribution of agriculture to the bioeconomy and a faster capacity to adapt to a changing climate that is provided by modern biotechnology [31]. The current regulation retards the European capacity to address the climate change challenge. Improved scientific communication is required to gradually overcome some deeply rooted prejudices among policymakers and the wider public (see Outstanding Questions).

Outstanding Questions

How can a regulatory framework be designed that allows harnessing the combined benefits of organic farming and innovations in biotechnology?

How can effective communication be designed to illustrate that many biotech breeding innovations are not a violation of the organic principle of preserving the integrity of the cell?

How can effective policies be designed to manage the conflicting goals of the EU Commission's F2F strategy?

Which features of organic farming contribute to and/or jeopardize the attainment of the SDGs?

Which features of biotechnological innovations can help to remedy the weaknesses of organic farming with respect to achieving the SDGs?

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Author Contributions

K.P. managed and revised the manuscript and wrote the introduction, the legal part, and the conclusion. M.Q. drafted the section on increasing organic agriculture and SDG achievement without breeding innovations. S.C. and A.P.M.W. drafted the section on organic agriculture and SDG achievement with breeding innovations. J.T. drafted the section on changing the law as a remedy: political obstacles. All contributed to discussion and revision of the drafts.

Declaration of Interests

L.F. is a Non-Executive Director of the Board of Directors of Syngenta. The other authors have no interests to declare.

Resources

[i]https://www.cbs.nl/en-gb/news/2020/40/soybean-imports-from-brazil-up-by-40-percent

[ii]https://www.umweltbundesamt.de/publikationen/entwicklungsperspektiven-der-oekologischen

[iii]www.europarl.europa.eu/sides/getDoc.do?type=TA&reference=P7-TA-2014-0036&language=EN&ring=B7-2014-0007#def_1_12

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