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NEW GENOME TECHNIQUES (NGT) – A RISKY CORPORATE DISTRACTION FROM REAL SUSTAINABLE SOLUTIONS

Questions & Answers regarding pesticide use and other impacts on agriculture

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CONTENT

WHY IS THIS IMPORTANT?

Agriculture in the European Union to date has been largely[1] free from the cultivation of genetically modified organisms (GMO). However, newer methods of genetic engineering, so called New Genomic Techniques (NGTs), are now being discussed as a way to reduce pesticide by developing new pest and/or disease resistant varieties or certain crops. There is a narrative that is becoming increasingly heard that genetically modified crops are needed to achieve the “Farm to Fork” goals by 2030. This has been stressed by multiple stakeholders (see e.g. EC 2022).

BACKGROUND

For decades, genetic engineering has been proposed as an instrument to reduce pesticide use (see e.g. Avery 1995)[2].

Doyle stated in 1999 that: ***“Biotechnology can be part of the solution by making agriculture more productive and reducing pre-harvest losses to insects, plant diseases, and competition with weeds. Improving the nutritional quality of staple foods and enhancing the resistance of crops to drought, cold, and salt will also increase productivity and upgrade human diets”*** (Doyle 1999).

However, as the first genetically modified plants were commercially released in 1996, they were made resistant to the herbicide glyphosate. These plants can be sprayed with the weedkiller and won’t be harmed. The business model is to sell patented, genetically engineered seeds together with the pesticide(s)[3]. Herbicide resistant crops are still the most common GMOs. Herbicide tolerant crops are also a major focus of genome editing (see JRC 2021).

Maize and cotton were genetically modified in a way to make them toxic to the larvae of some specific pest species. The results of this technology vary strongly.

[1] Spain and Portugal are the only countries with a small GMO production.

[2] See e.g. Avery DT (1995): Saving the planet with pesticides and plastic. The Environmental Triumph of High-Yield farming. Hudson Institute

[3] There are now several crops with resistance to one or several herbicides incl. glyphosate.

The toxin genetically inserted into maize and cotton kills selected pest species, however this meant that other pest species benefited from the new ecological niche and a (temporary) reduction of chemical control. Outbreaks of new pest populations diminished the pesticide reduction by the toxic plants, especially in cotton (Rui et al. 2015). Naturally (and foreseeably [see Doyle 1999]), the target pests relatively quickly developed resistance to the ever-presenting toxin in the plant (Ordosch et al. 2016, Shrestha et al 2018, Gassmann et al. 2013). Despite, intensive research, fungi resistant GMOs have so far never entered the market.

In the last decades, genetic engineering, when used and applied, has led to a “herbicide lock-in” (Desquilbet et al. 2019): herbicide-resistant weeds and environmentally damaging pesticide use (Schulz et al. 2021; Gujar & Peshin 2021).

OLD PROMISES REPEATED

Proponents of new genetic engineering technologies (NGT) promise the same as proponents of transgenic GMOs. Tripath et al. (2022): ***“Genome editing has the potential to reduce inputs such as fertilizers, pesticides, etc., increase yields, improve nutrition, and develop climate-resilient crops.”***

What is new is the method: instead of transferring genes (transgene) from one species to another, genome editing changes the DNA of species.

However, the technology is not as easy, precise and targeted as promoted. Scientists still know very little about interactions between DNA and cell functioning, and a targeted DNA snippet may appear in different locations and cutting them all out, or editing all, may lead to unforeseen effects (e.g. off-target effects [see Modrzejewski et al. 2020 and Sturme et al. 2022]).

Genome editing and genome research could certainly help to understand genetics and the influence of DNA sequence on certain natural effects, but the application of gene-edited crops in agriculture raises numerous questions and problems.

1. ARE THERE ANY PROBLEMS, THAT COULD BE SOLVED BY NGT, THAT CANNOT BE SOLVED BY EXISTING METHODS?

If designed properly, ecologically based, preventive plant protection can successfully reduce pesticide use to a strict minimum or even zero. However, the biological drivers of pesticide use: lack of diversity on different levels (genetic, spatial, biological, temporal) and over-fertilization must first be addressed. Measures which are suitable to achieve higher diversity are described in Chapter 5.1 in the foodwatch report "Locked-in Pesticides"[4].

However, the current "pesticide lock-in" driven by a socio-economic race to the bottom cannot be solved technologically (ibid.). Promoters of genome editing sell this technology as innovation and a "golden bullet" solution for all agri-environmental problems. But innovation is not synonymous with progress.

Investing in solutions with an unknown outcome while feasible solutions exist shows a lack of foresight and violates the common sense precautionary principle.

[4] See https://www.foodwatch.org/fileadmin/-INT/pesticides/2022-06-30_Pesticides_Report_foodwatch.pdf (25.01.23)

Neve (2018), for example, proposes the genetic modification of black-grass (Alopecurus myosuroides) to solve a black-grass problem. Black-grass is only a problem in narrow cereal crop rotation and became herbicide resistant due to herbicide mis- and overuse (Pallutt & Augustin 2022). Therefore, a traditional measure (proper crop rotation) could solve this weed problem (see Weisberger et al. 2019).

The next table shows the list of all major pests, weeds and diseases in cereals in Germany derived from the IPM (Integrated Pest Management) guidelines (DBV 2021). Almost all pests, weeds and diseases can be prevented by a wider, more diverse crop rotation, which means nothing more than allowing more time between similar/same cereals and planting a higher diversity of crops.

PEST, WEED, DISEASE	PRIMARY PREVENTATIVE IPM SOLUTION(S)
weeds	wider crop rotation, mechanical weeding
aphids	promotion of biodiversity (natural enemies), N-reduction, control of volunteer grain*
Gall midges (Contarinia tritici, Sitodiplosis mosellana)	wider crop rotation
Cereal leaf beetle (Oulema lichenis, O. melanopus)	wider crop rotation
viruses	proper timing of seeding, field hygienic measures, control of volunteer grain
Typhula-blight (Typhula incarnata)	wider crop rotation
Cereal disease (Tapesia yallundae)	wider crop rotation
Blackleg (Gaeumannomyces graminis)	wider crop rotation
Septoria (Septoria tritici)	wider crop rotation
Mildew (Blumeria graminis f.sp. tritici)	soil management, control of volunteer grain, proper timing of seeding, N-reduction, lower seed density
Yellow rust (Puccinia striiformis f.sp. tritici)	wider crop rotation, soil management, control of volunteer grain, proper timing of seeding, resistant varieties
Brown rust (Puccinia spec.)	wider crop rotation, soil management, control of volunteer grain, proper timing of seeding, resistant varieties
Pyrenophora tritici-repentis; Drechslera tritici-repentis	wider crop rotation, soil management, control of volunteer grain, resistant varieties
Sooty mold (Alternaria spp., Cladosporium spp., Epicoccum spp and others=	wider crop rotation, soil management, control of volunteer grain, proper timing of seeding, choice of early varieties
Septoria nodorum, Septoria avenae f. sp. triticea B.)	wider crop rotation, soil management, choice of suitable varieties
Fusarium culmorum, Fusarium graminearum	wider crop rotation, soil management, choice of resistant varieties
Claviceps purpurea	wider crop rotation

* volunteer grain are grain plants which germinate from seeds from the last harvest

Before new technologies with unknown risk potential are being introduced all other means of control must be evaluated and supported. When ecologically based IPM is implemented, neither pesticide use, nor genetic technologies will be needed.

2. WILL GENETIC ENGINEERING ENHANCE CROP DIVERSITY OR LEAD TO EVEN HIGHER GENETIC UNIFORMITY?

Genetic uniformity is a main driver of pesticide use especially in cloned[5] crops and it is a possible threat to food security. The "great famine" in Ireland was caused by the introduction of a new pathogen to an extremely vulnerable, rather new growing system (repeated potato cloning of mainly two varieties without crop rotation). In the past 60 years, traditional, open-pollinated varieties have already been largely replaced by commercial high-yielding and hybrid varieties (Gmeiner et al. 2018). Jaradat (2013) estimates that up to 75% of genetic diversity in wheat was lost in the last century. New forms of breeding may accelerate the decline of genetic variety, especially when genetic engineering is under the control of a few global (pesticide) corporations.

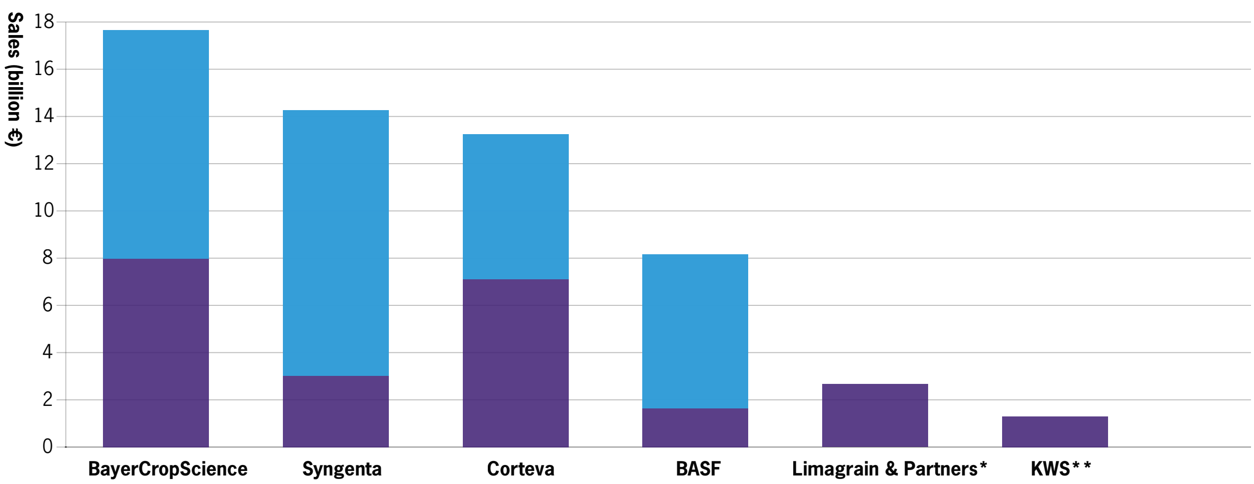
[5] Reproduced by vegetative propagation (most tree fruits, vines banana, potato)

The next figure[6] shows the turnover of the six largest global seed corporates by value. These companies have a share (by value) of about 50% of the global seed market. Four of these companies are also the largest pesticide sellers (by value).

How likely is it that these four companies develop pest and disease resistant varieties and give up the pesticide business? Are they really likely to create sufficiently diverse varieties to establish a resilient growing system independent from pesticides? It seems rather unlikely, unless they can successfully implement a new business model or profit model?

[6] All numbers in the figures from the fiscal reports 2020/2021 of the individual company. Dollar values (given by Syngenta, Corteva) were converted to Euro at a conversion rate of 0,846.

Figure 1:
VALUE OF SALES OF THE LARGEST PESTICIDE/SEED* COMPANIES BY PRODUCT TYPE *



Sales of pesticides (€)

Sales of seeds (€)

*Group sales 2020/21 incl. some non-seed related business | ** 2020/2021

* All data were taken from the latest financial reports of the individual companies. The reports are publicly available on the website of the companies.

3. HOW MUCH TIME IS NEEDED FOR A FULL CONVERSION TO PATHOGEN RESISTANT VARIETIES BY NGTS AND HOW MUCH WILL IT COST?

Let's take the example of one of the most pesticide intensive parts of agriculture: vineyards. Pesticide use in vineyards is particularly high[7], and a large share of the EU fungicide volume is also used in vineyards. This has historic reasons and is an excellent illustration of a path-dependency. Sulphur and copper-based fungicides were discovered in the 19th century as **THE** solution to the "mildews[8]", and other solutions (e.g. resistant varieties[9]) were mostly abandoned. Much of the pesticide volume applied to control mildews is still elementary sulphur, but in conventional wine growing also numerous synthetic fungicides are applied.

Growing fungi resistant vine varieties is a sustainable solution, if genetic diversity and spatial dis-connectivity (mosaic pattern of small blocks of varieties) can be ensured. There are already numerous traditionally bred fungi resistant varieties, and when managed properly, pesticide use is largely reduced (see Lenz 2021). **The promotion of these existing varieties should continue, and a pesticide levy could certainly encourage farmers to change from pesticide intense varieties to the existing robust varieties.**

Genetically engineered, fungi resistant vine varieties do not yet exist on commercial scale. **Promoters of genome edited vines anticipated in 2020 that the first glass of GE wine would be available by 2030.**[10]

That means that genome edited fungi resistant vines are not a solution to reach the targets of the Farm to Fork strategy which calls for 50% reduction in the use and risk of chemical pesticides by 2030. Even if they would exist now a conversion would take rather decades.

There are 3.2 million hectares of vines grown in the EU[11] and each hectare has about 2500-4000 plants. That means several billion genome edited grapevines would need to be planted to achieve a substantial pesticide reduction.

Ideally, a high diversity of vine varieties should be planted to ensure resilience, and to reduce other unforeseen risks, for example climatic risks or new pathogens. Currently, many varieties are genetically closely related or even genetically the same, because they are often clones of a somatic mutation[12] or inbreeds (e.g. Chardonnay). Pinot noir, Pinot blanc and Pinot gris are for example genetically nearly the same, however because of their grape colour, they are counted as three different varieties; they share the same genotype (see e.g. Vezulli et al. 2012).

Because of the lack of diversity, developing and testing of truly resistant and genetically diverse varieties may take decades.

Another question regards costs. In Germany, a vineyard renovation costs about €30,000 per ha. That might be lower in other countries, but even at total planting costs of €5 per vine plant, a 100% conversion to different varieties would cost €40-64 billion throughout the EU. Wine production and income in that conversion time would go down dramatically because each vine needs about three years after planting to have a full harvest. And, what happens if the pathogens "outsmart" the resistance afterwards? Or if other, perhaps more severe, pathogens appear? Are gene editing companies going to have insurance systems to cover the lost investment?

[7] By volume and treatment frequency.

[8] Please note that "mildew" is not a specific species. There are numerous genera in two large taxonomic families: Peronosporaceae & Erysiphaceae.

[9] In the 19th century it was already known that varieties from specific origins are resistant to certain pests/diseases. (see solution to Phylloxera)

[10] https://euroseeds.eu/app/uploads/2020/06/20.0278.1-Innovation-to-preserve-tradition-fungi-resistant-grape-vine.pdf

[11] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Vineyards_in_the_EU_-_statistics#:~:text=The%20European%20Union%20(EU)%20had,the%20world's%20wine%2Dgrowing%20areas.

[12] A somatic mutation is not a mutation in the seeds, but in the vegetative material (e.g. a branch). Cuttings from these branches form new varieties, but these varieties usually share the same genetics as the original variety.

4. WILL GROWING OF GENETICALLY ENGINEERED CROPS LEAD TO THE DISPOSSESSION AND DISEMPOWERMENT OF FARMERS?

With patented genetically engineered fruit and vegetable crops potentially entering the market there is **a certain risk that patent holders will promote these varieties with "leasing" models and that farmers' dependency on the patent companies increases.**

In commercial apple cultivation, it is now common to grow "club varieties". The protected varieties are licensed to the grower, and he/she must manage them according to specific rules. Producers who want to be part of "the exclusive club" must agree to a contract with the patent/brand owner for the cultivation and purchase of the fruit and pay license fees[13]. The owner of the variety has the right to reject or exclude growers from the "club".

The contract obliges the grower to certain quality criteria (shape, size, colour), and controls the destination and the marketing of the product. The grower is not allowed to sell directly to consumers or any other third party not included in the contract. The grower is also not allowed to reproduce patented trees or extent the cultivated area. The growers are only allowed to manage the trees according to the contract. He/she is basically not the owner of the tree, he/she "leases" the trees. The model of production basically leads to dispossession and disempowerment. The grower has no rights on the harvest, the patent/brand owner organises the marketing and the grower has little influence over the price. He/she is only a servant to the patent/brand owner.

Patenting of crop varieties and/or trademarks are not an exclusive problem associated with genetically engineered crops. It is a general trend. However, **with genome editing this trend may accelerate and create even stronger dependencies.** A recent report by Friends of the Earth Europe (FoEE) et al. (2022) showed that pesticide trader and seed seller Corteva already applied for 1430 "NGT patents". The authors conclude: ***"This increased use of patents, in combination with genetic modifications, is likely to result in a significant increase in the number of seeds and food with properties that are covered by a patent. This reduces access to biological diversity for plant breeders and farmers, and creates legal uncertainties around the use of seeds."***

Other dependencies will occur regarding the use of seed material from the harvest for the next crop. Many crops are pollinated by wind or insect pollinators. In the case that different traits of GMO crops are grown in a certain proximity genetic material will be exchanged by wind and/or pollinators. The next generation from these cross-pollinated seeds may have a mixture of unknown and maybe unwanted properties. This means that growers have to buy "clean" seed material for every season.

[13] See: https://provarmanagement.com/pink-lady/questions-answers/

5. WILL THERE BE PESTICIDE REDUCTION WHEN PLANTING GENETICALLY EDITED CROPS?

Research on genome editing in the European Union is financially supported with millions of public money[14]. However, there are no numbers published about the pesticide reduction potential in the European Union. None of the current research reviews (by Modrzejewski et al. 2019; EC 2021; JRC 2021; Touzdjian Pinheiro Kohlrausch Távora et al. 2022) published data on how many pesticides treatments could be potentially saved in a particular modified crop.

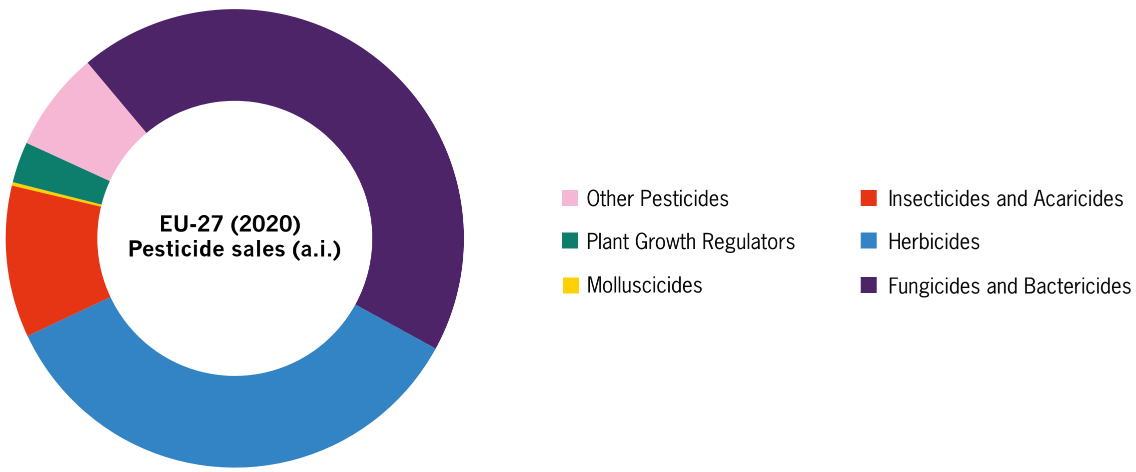
Almost 80% of the EU's pesticide use comprises herbicide and fungicide use (see next Figure 2), and there are currently no genetically engineered solutions available (or in development) which could substantially reduce these uses.

Modrzejewski et al. (2019) compiled a list of research on genome-editing in plants for increased resistance to biotic stress (pathogens [fungi, viruses, bacteria]). The following table shows the list of crops and pathogens from Modrzejewski et al. (2019) with an own evaluation on the EU pesticide use reduction potential. The targeted indications (crop-pathogen combinations) are not major "pesticide consumers" in Europe: either the cultivated area has a small share (cucumber, tomato, spring wheat, citrus) and/or the pathogen is not the major cause of pesticide use in this crop. Viruses and bacteria for example are usually not controlled with pesticides[15]. In citrus crops, the main pests are arthropods (mites and insects), and in vineyards, the mildews (see above).

[14] https://www.euractiv.com/section/agriculture-food/news/meps-demand-eu-funding-for-research-into-gene-editing-surveillance/

[15] Sometimes, the vectors (often aphids) are controlled using insecticides.

Figure 2:
PESTICIDE USE IN THE EU-27 BY USE TYPE IN 2020



CROP	CY*	TRAIT	PATHOGEN RESISTANCE, IMMUNITY TO:	EU PESTICIDE REDUCTION POTENIAL
Cacao	USA	FR	Phytophthora tropicalis	Low, no EU crop.
Cucumber	Israel	VR	Cucumber vein yellowing virus (Ipomovirus); the potyviruses, Zucchini yellow mosaic virus; Papaya ring spot mosaic virus-W	Low, small area under cultivation. Not the primary pathogens treated with pesticides.
Grapefruit	USA	BR	Citrus canker	Low, small area under cultivation. Not the primary pathogen treated with pesticides.
Grapevine	China	FR	Botrytis cinerea	Low, small area under cultivation. Not the primary pathogen treated with pesticides.
Maize	USA	FR	Northern Leaf Blight (NLB)	Not a primary pathogen treated with pesticides.
Orange	China	BR	Citrus canker	Low, small area under cultivation. Not the primary pathogens treated with pesticides.
Rice	USA, France, China, Philippines	FR	Rice blast	Low, small area under cultivation.
Rice		BR	Bacterial blight	Low, small area under cultivation.
Rice		FR	Resistance to powdery mildew	Low, small area under cultivation.
Rice		BR	Pathogen Xoc RS105	Low, small area under cultivation.
Rice		BR/ FR	Bacterial blight and rice blight	Low, small area under cultivation.
Rice		VR	Rice tungro disease (RTD)	Low, small area under cultivation.
Tomato	Germany, UK	FR	Powdery mildew	Low, small area under cultivation.
Tomato	Saudi Arabia	VR	Tomato yellow leaf virus	Low, small area under cultivation.
Tomato	USA	BR	Different pathogens including P. syringae, P. capsici and Xanthomonas spp.	Low, small area under cultivation.
Spring wheat	China, USA	FR	Powdery mildew	Low, small area (<1%) under cultivation.

FR: Fungal resistance;
VR: Virus resistance;
BR: Bacteria resistance
CY: Countries where research/development is carried out.

In addition, **most of the pathogens**, such as powdery mildew[16] **in spring wheat**[17,18] developed by Calyxt for the US market, **can be avoided through simple agronomic measures** (see question 1). The compilation of Modrzejewski et al. (2019) does not contain a single NGT plant with resistance against arthropods (insect pests and spider mites), a reduction of insecticides/acaricides through NGTs is therefore not foreseeable.

When it comes to pesticide reduction in the European Union, the potential of these genetic engineering-technologies seems to be currently nearly zero.

[16] There are 172 known genomes of Blumeria graminis f. sp. tritici which evolve rapidly through hybridization (see Sotiropoulous et al. 2022)

[17] https://calyxt.com/calyxt-launches-u-s-field-trials-with-university-of-minnesota-for-powdery-mildew-resistant-spring-wheat-variety/

[18] In Europe winter wheat is the most common wheat grown.

6. WOULD GENETIC ENGINEERING ACCELERATE THE "RACE TO THE BOTTOM"?

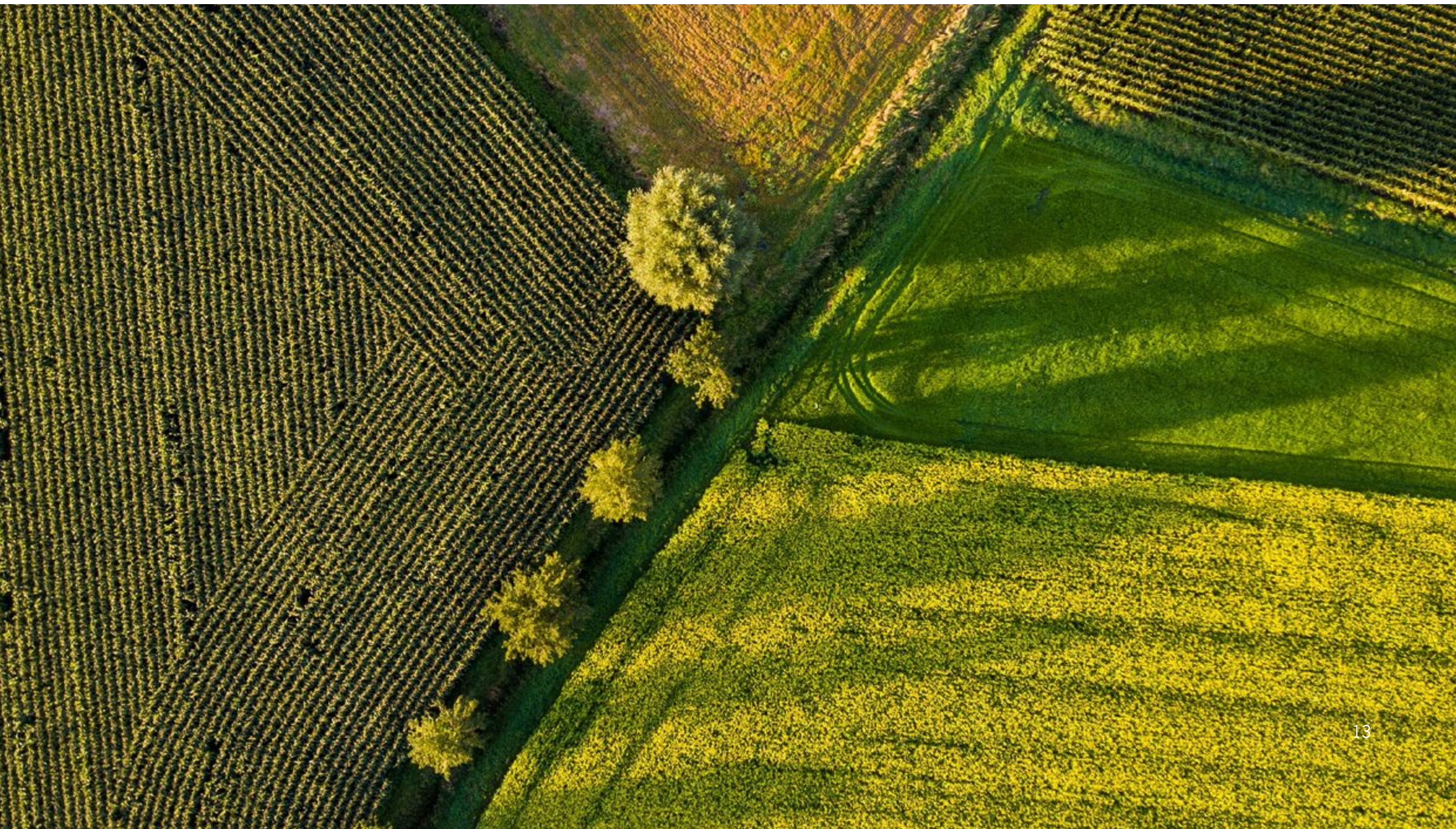
So far, farmers in the European Union can for some crops achieve higher prices, because they are certified GMO free. This advantage would be lost, when genetically modified crops are widely planted.

As thoroughly described in the chapter "The race to the bottom" in the foodwatch report "Locked-in pesticides" most farmers have no control over the prices they can achieve. This means they need to either reduce costs per produced unit or increase volume at the same costs. However, because all farmers (globally) try to do this, prices have been generally declining. That is the reason why farming is highly subsidized in most industrial countries.

The promise of the GMO promoters is that EU farmers growing new genetically engineered crops might be able to produce at lower costs per unit or more units at lower costs than non-GE adopters. But if all farmers planted genetically modified crops, then all would have equal conditions. The result of this would be a further decline in farm incomes (Jordan 2002).

A widespread use of GMOs on conventional farms could endanger organic farming, because genetically edited material will be distributed via wind, pollinators or during transport of seeds. So far, organic agriculture has rightfully (see Wickson et al. 2016[19]) rejected the use of genetically modified crops and ensures that produce is GMO-free. Future Organic farming might be at risk, as no GMO free products could be guaranteed.

[19] "Unless NPBTs (new plant breeding techniques – note by foodwatch) can offer empirical evidence of benefits sustainable over the long-term and move beyond the same type of hypothetical promises of technoscientific fixes for complex political and socio-ecological problems, which have been perpetuated for decades without delivery, then they will not be awarded a place in organic agriculture."



7. IS IT POSSIBLE AT ALL, THAT GENETICALLY ENGINEERED RESISTANCE WORKS ON THE LONG TERM?

So far, weeds, insect and pathogens have always rather quickly developed new populations which can survive pesticide spraying and overcome plants resistance. Evolution usually "outsmarts" human technology. Even if scientists could develop for example a permanent late blight resistant potato, how can it be certain that not another pathogen will enter the open ecological niche? After all, a monoculture of a well fertilised crop is an available energy source, and it seems rather unlikely that no pest and/or pathogen will attempt to utilise this resource. Just to hope that no other pathogen, pest will take the opportunity is not enough. **Long-term field testing must be required before any GMO can enter the market**.

Long-term testing is also needed because:

"Breeding alone won't achieve anything. Breeding must go hand-in-hand with research of the environment we are breeding for. A growing environment differs between regions, [which have] different soils with different water-holding capacity, and climates [that may be] warmer or cooler, wetter or dryer. We also need to consider that the climate is changing. (...)" Asseng (2022).[20]

[20] https://www.foodnavigator.com/article/2022/08/18/meet-the-scientists-unlocking-the-genetic-potential-of-wheat-to-boost-global-food-security

CONCLUSION

NGTs so far only seems to be an empty promise. Genetically modified crops suitable to achieve the "Farm to Fork" objectives are not available. It seems, they won't be available within the next 10-15 years. Contrary to what proponents claim, under the current circumstances crops created by NGTs should be considered a high-risk technology as they pose a number of risks, as outlined below:

- large corporations will use NGTs to control seed material via patents/branding and to make farmers to 100% dependent on the companies;
- NGTs under control of these companies may result in higher genetic uniformity causing higher pesticide use, a business model which would serve companies like BayerCropScience, Corteva, Syngenta and BASF, which sell seeds and pesticides;
- low diversity is a real threat to food safety, because the risk that biotic or abiotic stressor cause a total loss is higher in monocultures.

A high diversity, and locally adjusted, robust varieties are needed to cope with the effects climate change and invasives species.

The fundamental question is whether society wants to rely on new, high-risk technologies to solve crises caused by human-made technologies? Do we want to force farmers to become locked in further by the same or similar interest groups that control the pesticides, when low tech, low risk solutions to most pest and disease problems already exist?

For many decades, the pesticide and biotech corporations have used their economic power to install positive narratives about new technologies into the minds of the public and decision makers. As demonstrated with the "old" gene technology or with synthetic pesticides, they have created utopian narratives and sought to use their power to create technological lock-ins with a high degree of farmer dependency (Clapp & Ruder 2020). To believe that "genome editing" will be an exception is more than naive.

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