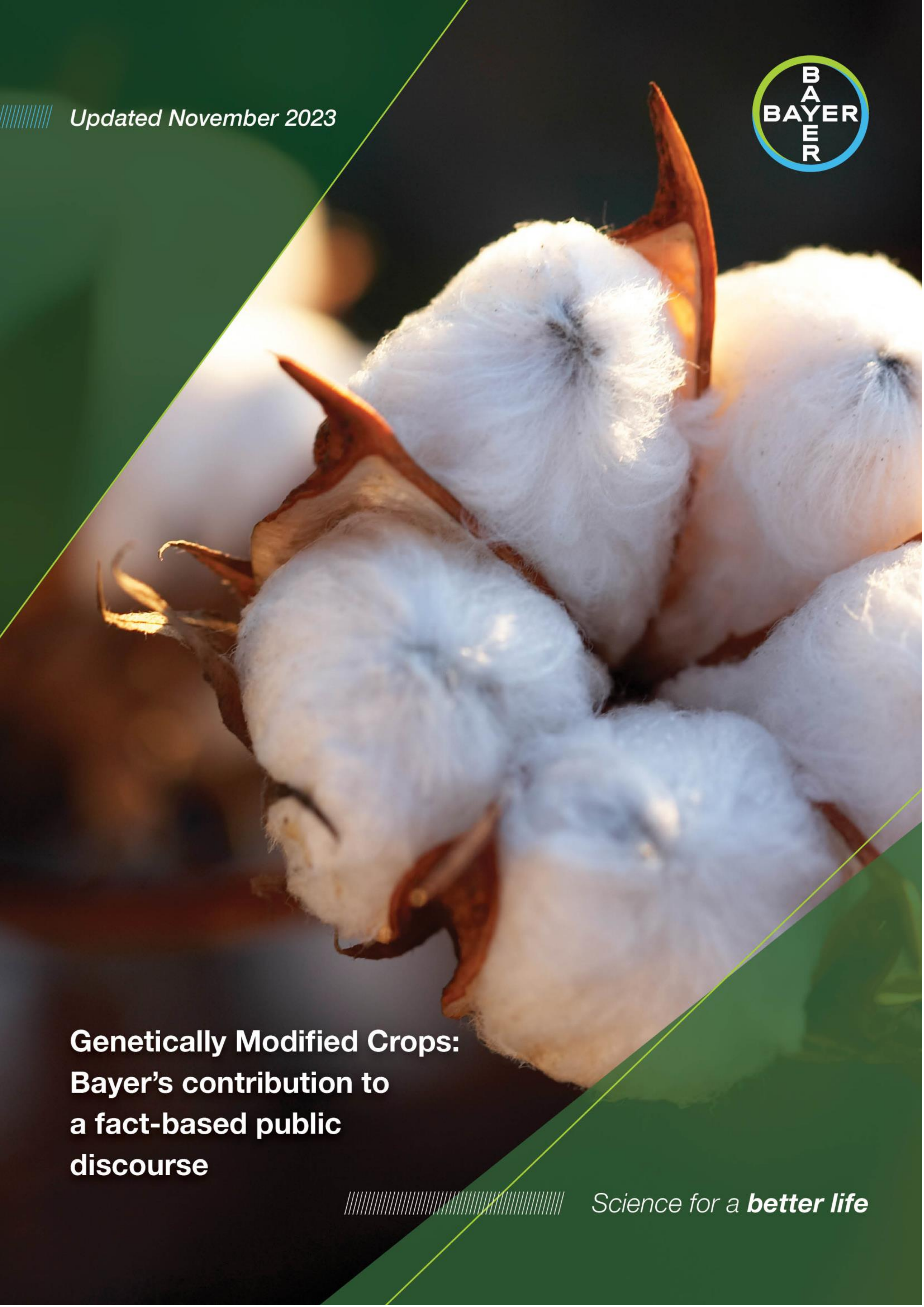
Updated November 2023



Genetically Modified Crops: Bayer's contribution to a fact-based public discourse

Science for a ***better life***

Foreword

This is the second edition of the report, following the original published in 2022. The 2023 edition has been updated with new data, as available. It should be noted that the report uses data from several sources. Unfortunately, as of November 2023, there was not one comprehensive source of information about GM crops that captures all varieties and regions of the world. References to third-party reports or research papers have also been updated in the instances when a new edition became available. In addition, the report includes some clarifications and modifications made in response to feedback to the first edition.

Executive Summary

Report Goal

When GMOs (genetically modified organisms) in agriculture were launched commercially, there was no blueprint for bringing such a disruptive food technology to market. Based on market realities at the time, Monsanto, which was acquired by Bayer in 2018, focused on marketing GM (genetically modified) crops to farmers and engaging primarily with agriculture organizations and regulatory authorities. Over time, it became clear that this was not sufficient to foster technology acceptance and it would be beneficial to engage in broader discussions about GMOs among various societal stakeholders. The intent of this report is to provide information about the role of GM crops in sustainable agriculture and the global food system and shed light on our efforts toward minimizing the impact on the environment and biodiversity.

This report is intended to add to our transparency efforts. We have taken this report as an opportunity to revise our way of explaining GM crops in our portfolio, while recognizing that this technology still carries acceptance issues and that disruptive technologies require additional engagement with critical voices.

The Executive Summary and full report will cover:

- What are GMOs?
- GMOs in Today's Food System
- The Controversy Around GMOs: Impact Versus Benefits
- GMO Regulations
- Bayer's Transparency Commitments
- Can GM Crops Make Agriculture More Sustainable?
- Conclusion

What Are GMOs?

For as long as people have been growing crops, they have been crossbreeding them to achieve improvements in taste, appearance, and resistance to plant diseases, among other things. Advances in plant science enable companies like Bayer or crop breeders at academic institutions to develop crops with urgently needed properties more efficiently than conventional breeding could, or to add properties that cannot be achieved through traditional breeding methods.

GM crops are plants that have been developed using genetic engineering, a method that allows plant breeders to take a desirable characteristic (i.e., a trait) found in nature and transfer it from a plant or another organism to the plant they want to improve. During this process, scientists transfer a specific gene(s) from one organism to another to achieve a range of desired characteristics e.g., resistance to drought, insects, or tolerance to herbicides.

GMO (genetically modified organism) / genetic engineering (GE) / genetically modified (GM) / biotech seed or crop are terms often used synonymously.

The process of bringing a GM seed trait or variety from product concept to market launch is rigorous and complex, lasting approximately 16.5 years and costing $115 million.[1] It involves comprehensive scientific testing and regulatory reviews. Regulatory agencies review and approve individual traits developed through genetic engineering; and certain agencies also review and approve combined or stacked traits, which is a GM crop with a combination of different traits (e.g., targeted pest insect control and herbicide tolerance). GMOs are tested for human, animal and environmental safety, grown and/or imported in more than 75 countries and are part of the systemic process of agriculture for farmers today.

GMOs in Today's Food System[a]

Since their commercial introduction in 1996, GM crops have been extensively adopted by farmers around the world, becoming an essential component of the global food system and contributing to food security and the resilience of food supply chains. GM crops are considered the fastest adopted technology in recent times – the GM crop area accounted for 202.2 million hectares (ha) world-wide in 2022.[2] In 2022, GM crops represented 53% of the overall seed market ($23,793 million of GM seeds versus $20,793 million of conventional seeds)[3] and were cultivated – in commercially significant quantities – in 27 countries, with the largest GM planted areas in the US, followed by Brazil and India.[4] In 2022, the global planted area increased by 3.3.%, with the largest increases in Brazil, Australia, India, Paraguay and South Africa.[5]

As of 2019, there were 14 GM crops commercialized, including corn, soybean, cotton, canola, alfalfa, sugarbeets, sugarcane, papaya, safflower, potatoes, eggplant, squash, apples, and pineapple.[6]

Corn (51.7%), soybean (33.6%), and cotton (9.4%) compose a total of 95% of the total GM market[7], for which the most important GM crop-growing countries are reaching market saturation in GM adoption rates[b] (US: 95%; Brazil: 94%; India: 94%; Argentina: 100%; Canada: 90%).[8]

In 2022, soybean was the GM crop with the largest crop area (98.92 million ha), followed by corn (66.23 million ha), cotton (25.363,8 million ha), canola (9,92 million ha), and sugarbeet (0,49 million ha).[9]

184.98 million of a total of 202.10 million ha, i.e., 91.5% of all GM crop area, is concentrated in 5 countries: US (74.69 million ha), Brazil (63.2 million ha), India (12.35 million ha), Argentina (23.41 million ha), and Canada (11.32 million ha).[10]

Today, Bayer is one of more than 30 GM crop developers, ranging from commercial to government entities. Table 2 in the appendix shows all developers of GM crops.

The Controversy Around GMOs: Impact Versus Benefits

GMOs are one of the most intensely debated topics when it comes to food production. Perspectives range from considering GM crops one of the most significant breakthroughs in modern agriculture to concerns about their impact on the environment and on human and animal safety. Questions have been raised about the negative impact on biodiversity, especially for the use of herbicide-tolerant (HT) GM seeds in combination with broad-spectrum herbicides, the contamination of non-GM crop fields caused by gene flow from genetically modified crops, and a decline of local and indigenous varieties.

GMOs and Biodiversity

Perhaps the most debated aspect of GMOs has been their impact on the environment, in particular biodiversity. For example, the decline in monarch butterfly populations has been attributed to the use of herbicides on HT GM crops. Indeed, declines in the monarch population have been documented since the 1990s. Many factors are thought to contribute to the problem: habitat loss in the Mexican forests, climate change, weather events and the loss of milkweed in cultivated fields. Milkweed is a weed that farmers can control effectively with HT GM crops but that also constitutes the monarch larvae's main source of food and habitat. Bayer takes action to build and maintain monarch-friendly habitats. We collaborate with conservation groups, academic experts, farmers, and government agencies to find meaningful and proactive ways to help the monarch butterfly and other pollinators thrive. Read more about Bayer's efforts in Chapter 2.

Pollinators, such as honey bees, play an important role in food production. They also depend on natural habitats for their nutrition and to thrive and grow. When more land is dedicated to crop cultivation, biodiversity and natural habitats are negatively impacted.[11] Therefore, intensive agriculture, which enables the production of more food and fiber on the same area, can impact natural habitats, which are essential for preserving biodiversity. According to Brookes, in 2020 alone, due to the planting of GM

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[a] This report uses data from several sources. Unfortunately, as of November 2023, there is not one comprehensive source of information about GM crops that captures all varieties and regions of the world. All used sources are referenced in the Endnotes section.
[b] Considering adoption rate for corn, soybean, and cotton, which represent over 95% of total GM crops.

crops, 23.4 million ha of land were saved from cultivation, equivalent to the combined agricultural area of Philippines and Vietnam.[12]

Critics of GM crops have argued that insect-resistant (IR) crops that contain *Bacillus thuringiensis* (Bt) are harmful to bees, but there is no evidence to support this claim. Bayer takes into account pollinator safety when developing all new products. All GM crops are thoroughly tested in the early product development stages to assess their effects on honey bees. GM crops with IR traits do not have any biologically relevant effects on honey bees.

Honey bees and other pollinators could be indirectly impacted when herbicides applied to crops inadvertently reach pollinator habitats. To mitigate the potential impact of spray drift onto off-crop pollinator food sources, product labels require farmers to use spray drift reduction equipment and/or downwind no-spray buffer zones as measures for ensuring that foliar herbicide applications do not impact to natural habitats honey bees depend on and that serve as refuges for biodiversity. Insect-protected GM crops reduce the need for conventional insecticides, thereby reducing the potential for beneficial insects to be exposed to insecticides.

Coexistence of GM and Non-GM Crops

The impact of GM crops on local and indigenous crops has received significant attention. Farmers are accustomed to growing different crops next to each other, and experience shows that various cropping systems (conventional, organic, GM) can coexist successfully. Farmers select the type of cropping system and the types of crops they grow based on market needs and demand. Bayer firmly believes that farmers should be able to choose the cropping system that best helps them meet their needs.

MSCI ESG Research has raised the topic of claims and even litigation involving the cross-pollination of GM and conventional crops. It is important to know that inadvertent cross-pollination is preventable by allowing sufficient distance between fields and timing planting to prevent simultaneous pollination in two adjacent fields. Therefore, these events are extremely rare. Contrary to some claims, there is no evidence to suggest that local or native plants are reduced in the unlikely event of inadvertent cross-pollination between GM and non-GM crops. Moreover, only plants of the same species that are sexually compatible can cross-pollinate. For example, GM canola would have no impact on an adjacent field of organic corn. This topic is explored in more detail in Chapter 2 of this report. We are not aware of any open litigation claiming cross-pollination or contamination of non-GM crops. An explanation of allegations on coexistence and open litigation is included in Appendix 4 of this report.

Bayer is committed to providing continuous support to farmers by co-designing sustainable farming practices and undertaking stewardship activities and training programs to ensure successful coexistence. In agriculture, coexistence also depends on communication, cooperation, and mutual respect among farmers. Awareness of a neighbor's planting intentions helps farmers decide which Best Management Practices (BMP) to deploy. Our belief in the successful coexistence of various cropping systems is underscored by our recent entry into the organic vegetable seed segment.[13]

Impact on Indigenous Crops

Over the past century, there has been a decline of local seed varieties in the US and Europe. This happened because farmers have opted in favor of seeds with higher yield potential developed professionally by breeding companies.

GMOs and Smallholder Farmers

Patent protection for GM seed has come under scrutiny, especially in instances where smallholder farmers have used GM seed for subsistence needs. As an agriculture company, we are committed to providing smallholder farmers with access to the full spectrum of sustainable agricultural solutions and empowering them to reach their growth potential. Like any publicly traded company that invests heavily in innovation, Bayer values the protection of intellectual property. However, we recognize that smallholder farmers face unique socioeconomic challenges, and therefore we have expressed our commitment in our Intellectual Property Rights, which encompass GM crops. First and foremost, our approach to Intellectual Property Rights is guided by societal benefits. This means that Bayer does not intend to enforce its Intellectual Property Rights against smallholder farmers for private and noncommercial use of farm-saved seed to escape extreme poverty and will work collaboratively to integrate these smallholder farmers into the world of commercial farming to improve their livelihood. It is worth noting that, in 2021, Bayer was ranked 1st in the Access to Seeds Index for Africa[14] and 3rd for South and South-East Asia[15] by the World Benchmarking Alliance, an organization that seeks to increase the private sector's impact toward a sustainable future for all and assesses seed companies on their efforts to make quality seeds accessible to smallholder farmers.

GMO Regulations

GM seeds need regulatory approval (i.e., registration or authorization) before they can be commercialized and be made available to farmers for planting. Whilst GM crops remain highly regulated, several large countries have been revising their regulations to acknowledge the history of safe use and trait familiarity, amongst other efficiency measures. As such, some GM regulations have been simplified to support workflow and improve timelines for regulators, especially in Canada and Australia. Today, GM crops are grown in 27 countries.[16] The established consensus among regulatory agencies globally is that foods and feeds derived from GMOs are as safe and nutritious as those derived by conventional breeding techniques. Bayer applies consistent and transparent product characterization and safety standards globally, resulting in one global data set for each GM crop. In addition, there can be region-specific data that may only be applicable to the specific region. All study results are available to all authorities, even if they are not part of the official submission dossier in a specific country. Nevertheless, some countries, including much of the European Union, do not allow GM crop cultivation. However, most countries, including those in the European Union, approve imports of GM crops such as corn and soybeans to be used primarily as animal feed – and therefore as a basis of protein-based food like meat, milk, and eggs.[17] The discrepancies in the scope of how GM crops are authorized point to the fact that the topic of GMOs is as divisive within governmental bodies as it is in society, calling for more engagement and information exchanges on the topic. Read more in Chapters 3 through 5.

Bayer's Transparency Commitments

We have come to recognize that there is an information gap about food production and the technologies used to produce food. We understand that consumers deserve to know where their food comes from and how it is grown. As a result, Bayer has expanded its transparency commitments to engage in more conversations about science and food production with internal and external stakeholders. We have formalized our continued dialogue by establishing a transparency-focused platform, which provides interested consumers and the scientific community access to summarized test results and evaluations on the human and environmental safety of active substances used in our crop protection products as well as on the safety of GM crops. We also have provided access to full in-depth study reports evaluated by regulators for the authorization of our products, alongside informational materials to help put regulatory science results into context. You can learn more about our transparency platform and commitments in Chapter 5 of this report or by visiting our transparency website.

The introduction of GM crops has offered a valuable lesson on building acceptance for disruptive food technologies, not just for Bayer but for the entire agriculture value chain. The societal debate around GMOs has prompted a reassessment of how we interact with critical perspectives. We've learned that engagement with different groups and intentional listening are critical in identifying gaps in understanding and building consensus based on shared values. Communication needs to happen at all levels, starting with our executive leaders, and input gathering needs to be institutionalized. To achieve our vision for enhanced stakeholder engagement, Bayer has taken the following steps:

- We have established an external advisory body – the Bioethics Council – to ensure a broad independent perspective and guidance on complex ethical questions related to emerging life science technologies. The Bioethics Council consists of a diverse group of independent thought leaders in the field of bioethics who engage in regular dialogue with Bayer executives and scientists.
- We have established an independent external Sustainability Council that advises the Board of Management and other functions on sustainability initiatives, provides guidance on the contribution that Bayer can make with its research and development, and independently examines the progress made by Bayer in the implementation of its sustainability targets.

- // Bayer's Supervisory Board, the highest internal governance board of the company, has established a dedicated ESG (Environmental, Social, and Corporate Governance) Committee, which focuses on corporate social responsibility and the environmental, social, and corporate governance elements of the company's business activities.
- // At Bayer, sustainability and business strategy are fully integrated. We see sustainability as a growth driver and an essential component of our corporate strategy, our corporate values, and the way in which we operate our businesses. Our strategy is aligned to the global Sustainable Development Goals (SDGs) of the United Nations, the attainment of which is targeted for 2030.

In the case of GM crops, we've learned that leading with science and farmer benefits is not enough – we need to describe the benefits of new technologies for all sectors of society rather than our farmer customers alone.

Can GM Crops Make Agriculture More Sustainable?

GM crops deliver a range of benefits to large and small farmers: improved protection from weeds, insects, diseases, and extreme weather, which results in increased yield, reduced pesticide use, and reduced greenhouse gas emissions. According to a recent study, "Over the 24 year period examined to 2020, the widespread use of GM insect resistant and herbicide tolerant crops has reduced pesticide application by 748.6 million kg (-7.2%) of active ingredient and, as a result, decreased the environmental impact associated with herbicide and insecticide use on these crops (as measured by the indicator, the Environmental Impact Quotient (EIQ)) by 17.3% between 1996 and 2020."[18] Modern agriculture technologies – of which GM crops are an essential component – make it possible to grow food more efficiently, without expanding the surface area of cultivated land to meet growing global demand.

The world's population is expected to grow to around 10 billion people by 2050 – an increase of around two billion people relative to 2020. In addition, both the Food and Agriculture Organization (FAO) of the United Nations and the World Resources Institute (WRI) expect a 50% increase in the demand for food and animal feed by 2050. Intensive agriculture, made possible by advances in breeding technologies, along with fertilization, irrigation and the use of crop protection products, is the only time-tested way to grow food without turning more natural habitats into farmland. In the U.S., between 1948 and 2017, labor and land inputs declined by 76% and 28%, respectively, while farm production nearly tripled.[19] While subsistence agriculture and organic farming are viable production options, they cannot scale up to meet existing demand and maintain the resilience of the modern food systems.[20] For example, biotechnology has made it possible to sustainably increase global production levels of soybeans by 330 million tons and of maize by 595 million tons since the introduction of the technology in the mid-1990s.[21]

When objections to modern agriculture technologies are raised, we need to ask ourselves if it is possible to produce enough food to meet the needs of the entire global population with zero impact on the environment. Without adopting new and efficient technologies, including GMOs, natural habitats would be sacrificed for crop cultivation at an increased rate. Technology makes it possible to limit the amount of agricultural land, which can allow more land to be set aside for biodiversity. However, trade-offs are inevitable to ensure food systems are resilient and food supplies are ample and affordable. Bayer's vision for the future of global agriculture is focused on regenerative agricultural practices with nature positive outcomes. By this we mean an outcome-based production model that also preserves soil health, strengthens seed and crop resilience, mitigates the effect of climate change and protects natural resources. Our portfolio of solutions, including biotechnology alongside crop protection and digital solutions, serves as the foundation for regenerative agriculture. This report describes Bayer's responsible business conduct with regard to GM seed production and our efforts to communicate transparently about GM crops and other technologies.

Bayer, along with many experts, believes that GM crops, as a component of intensive agriculture, contribute to sustainable and resilient food production.

Conclusion

Since their introduction in 1996, GM crops have provided incontestable benefits to farmers, resulting in their broad adoption in the main agricultural producing countries. They became systemic to the global food supply, contributing to its efficiency and resiliency. Even countries that don't allow the cultivation of GM crops rely on imports of GM crops to meet their needs for animal feed. Today, Bayer is one of many companies that develop GM crops. Studies have documented the benefits of GM technology in helping to protect crops from weeds, pests, and disease, reducing the use of crop protection products and cutting greenhouse gas emissions. While every agricultural technology has some impact on biodiversity, more intensive, efficient agriculture – including GM crops – makes it possible to grow as much food as needed on existing agricultural land without further expanding into natural habitats. Bayer has learned a lot from the introduction of GM crops, and we have embraced the power of transparency in addressing controversial topics and questions. This report has been developed in the spirit of dialogue and information sharing.

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[1] https://croplife.org/plant-biotechnology/regulatory-2/cost-of-bringing-a-biotech-crop-to-market/
[2] https://gm.agbioinvestor.com/
[3] https://agbioinvestor.com/analytical-reports/the-seed-market-report/seed-market-overview-contents/global-seed-market-summary/
[4] https://gm.agbioinvestor.com/
[5] Ibidem
[6] https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp
[7] https://agbioinvestor.com/analytical-reports/the-seed-market-report/gm-seed-market-contents/gm-crops/
[8] https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp
[9] https://gm.agbioinvestor.com/gm-production
[10] Ibidem
[11] https://ipbes.net/global-assessment
[12] https://www.tandfonline.com/doi/full/10.1080/21645698.2022.2105626
[13] https://www.vegetables.bayer.com/us/en-us/products/organics.html
[14] https://www.worldbenchmarkingalliance.org/publication/access-to-seeds-index/wca/rankings/
[15] Ibidem
[16] https://gm.agbioinvestor.com/
[17] https://geneticliteracyproject.org/gmo-faq/where-are-gmo-crops-and-animals-approved-and-banned/
[18] https://www.tandfonline.com/doi/full/10.1080/21645698.2022.2118497?src=
[19] https://www.usda.gov/media/blog/2020/03/05/look-agricultural-productivity-growth-united-states-1948-2017
[20] https://www.tandfonline.com/doi/full/10.1080/21645698.2022.2105626
[21] Ibidem

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1. GM Crops – Definition and Role in the Global Food Production System

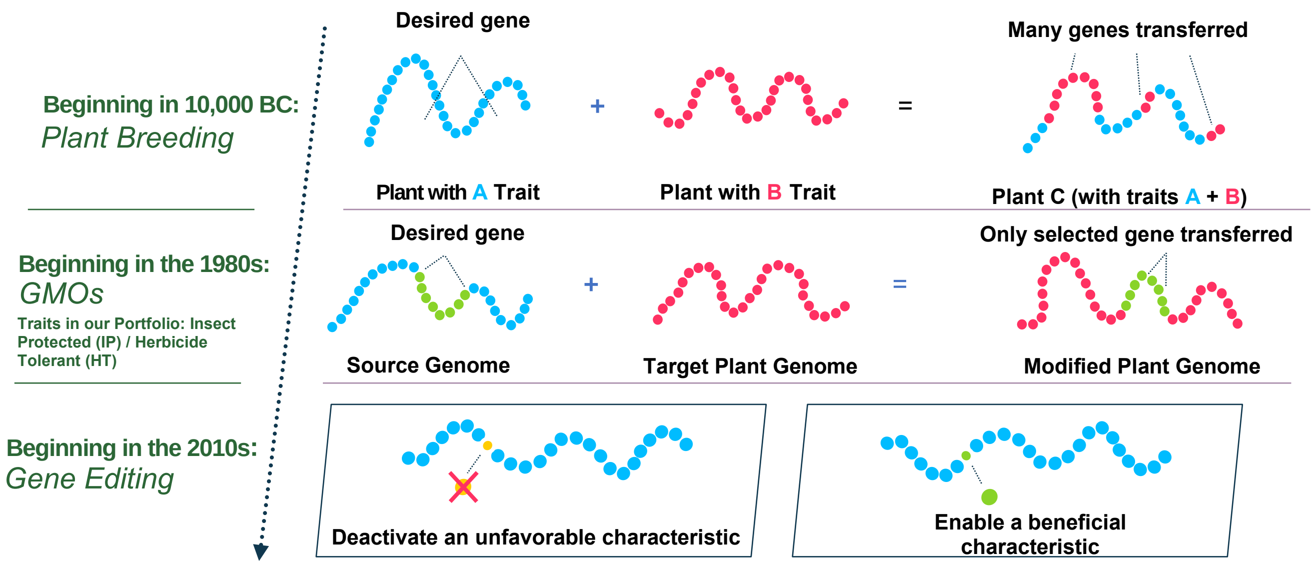
- Due to their adoption by farmers around the world, GM crops play a systemic role in today's agriculture and contribute to the resilience of the global food value chain.
- Bayer is one of many companies and organizations around the world that develops GM crops.
- GM crops contribute to the sustainable intensification of agriculture and to an increase in productivity and yield, thereby limiting the need to expand farmlands into natural habitats.

What Are GM Crops?

Farmers from industrialized and developing countries alike have experienced the benefits of genetically modified (GM) crops for the past 27 years. GM crops provide substantial agronomic, economic and ecological benefits. They help farmers increase productivity by protecting harvests from insect pests, weeds and adverse climate conditions while consuming fewer natural resources.

GM crops are also referred to as GMOs (genetically modified organisms), genetically engineered crops (GE) or biotech crops. These terms, often used interchangeably, refer to a process that allows plant scientists to take desirable genetic material from one organism found in nature, such as a bacterium, and transfer it to a plant they want to improve. Some examples of desirable characteristics or traits commonly transferred to crop plants include resistance to targeted insects or disease and tolerance to herbicides that allow farmers to better control weeds.

Plant breeders leverage the genetic diversity of plants to generate new and unique plant varieties and hybrids for farmers using several other methods in addition to genetic modification. The efficiency and accuracy with which plant traits can be improved has been increasing.



Plant breeding techniques have been used nearly as long as agriculture has existed. Plant breeding is the science of crossing two plants to produce a new plant that shares the best characteristics of its parents. Researchers continuously use their knowledge of plant genetics combined with innovative breeding tools to develop better crops that make farming more efficient, cost effective and environmentally sustainable.

GM crops are improved by plant scientists using genetic engineering, most often to introduce a beneficial characteristic to the plant that does not occur naturally in the species (e.g., resistance to pests and diseases, adaptability to environmental conditions). These improved seeds provide farmers with options to increase or protect their harvest while also reducing their farms' impact on the environment.

Gene editing is the latest innovation in a long line of plant breeding tools used by public, private, small and large breeders to improve crops. Gene editing tools help scientists find and improve a specific part of a plant's DNA responsible for important plant functions. Conventional plant breeding takes several generations of crops to enable or remove a plant characteristic. Gene editing is highly targeted approach that can bring about improvements in a single generation of a crop.

Modern Agriculture Imperatives

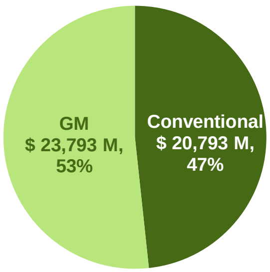
As the world population increases, the resiliency of food systems is challenged by climate change and supply chain disruptions caused by several challenges, including the Covid-19 pandemic and wars. Expanding farmland to meet the growing demand for food and feed is not an option, since available farmland has been and will continue to decline due to climate change, water challenges, soil erosion, and other factors. Intensive agriculture with high yields per hectare of farmland is a crucial factor in ensuring the continued availability of high-quality and affordable food. Faced with the task of providing food security for the global population, it is not feasible to increase food production with zero impact on the environment. The question is how to ensure a reliable, resilient, and cost-effective food supply without expanding farmland area and continuing to preserve biodiversity. While some trade-offs are unavoidable, Bayer sees innovation, accompanied by sustainable practices, product stewardship, and responsible business conduct as a way to sustainably maximize the potential of existing farmland.

GM crops are one of many innovative agriculture tools that contribute to improved productivity, strengthen the resiliency of the global food supply, and optimise the use of farmland. With each generation, agricultural technologies have become more precise, effective, and sustainable, lowering the input requirements to produce the same amount of food. For example, recent advances in digital farming make it possible to use the right amount of fertilizer, water, and crop protection inputs and select the right seed variety that will perform best in given conditions.

The Role of GM Crops in the Global Food Production System

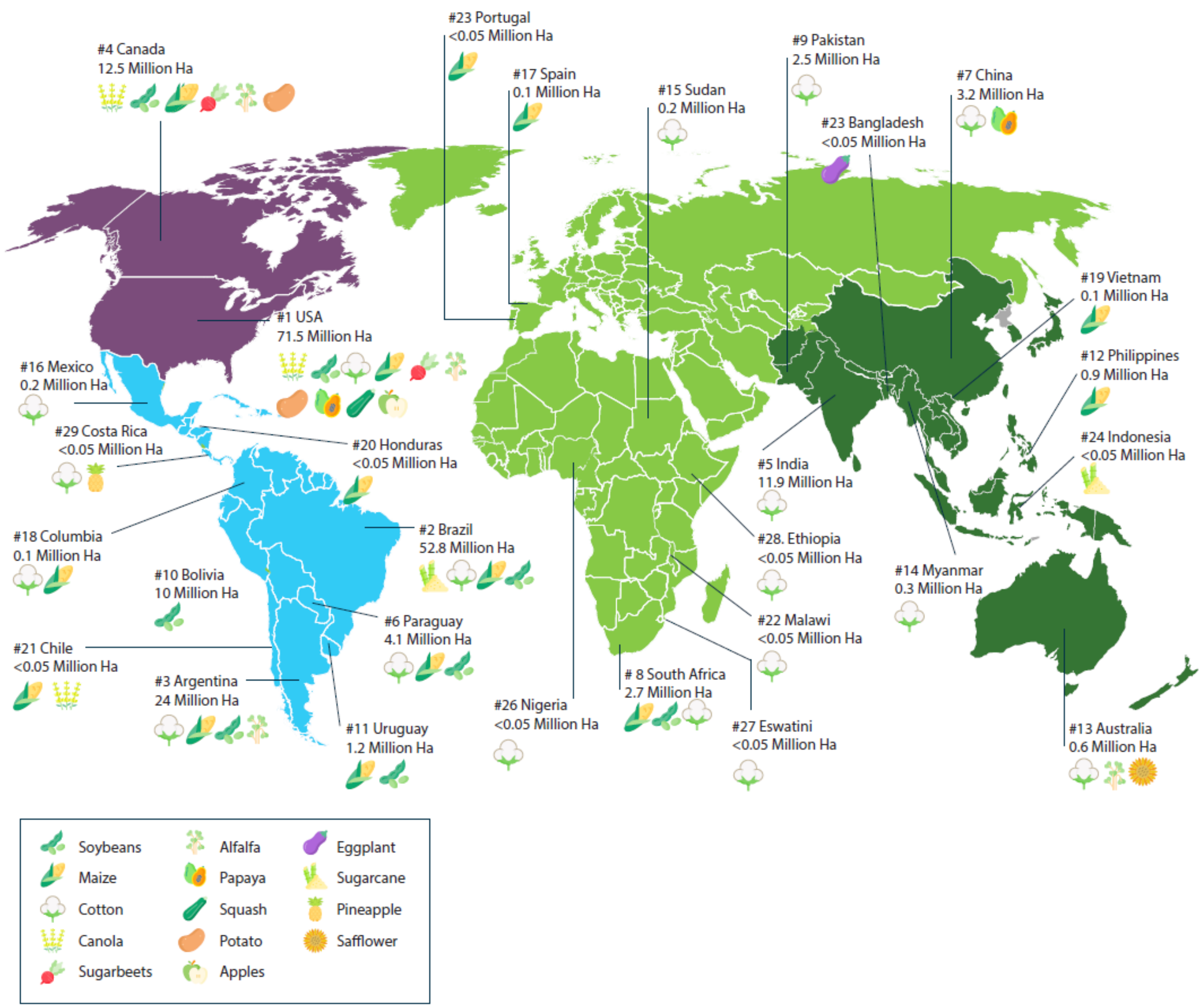
Adoption and Cultivation of GM Crops

Since the start of their commercialization in 1996, GM crops have been widely adopted by farmers around the world and are now a key component of the global food system. According to information from the news service AgbioInvestor,[c] the GM crop area accounts for 202.2 million ha worldwide (a 3.3% increase in 2022). In 2022, GM crops represented 53% of the overall seed market ($23,793 million of GM seeds versus $20,793 million of conventional seeds).[22] and were cultivated – in commercially significant quantities – in 27 countries, with the largest GM planted areas in the US, followed by Brazil and India.[23]



[c] Some of the AgbioInvestor data included in the report is only available to subscribers. All links are included in Endnotes.

Cultivation of GM Crops Around the World

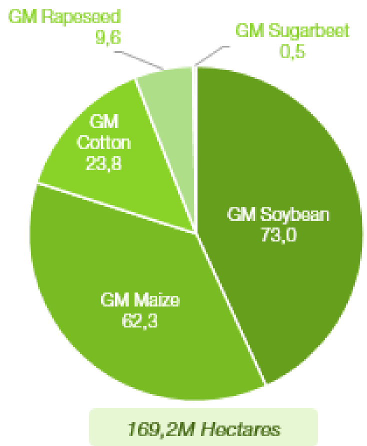


Source: ISAAA 2019 Global Status of Commercialized Biotech/GM Crops in 2019 Brief No.55ISAAA_Ithaca, NY

Corn (51.7%), soybean (33.6%), and cotton (9.4%) compose a total of 95% of the total ($23,793 million GM market.[24] The global area of biotech crops increased approximately 112-fold from 1.7 million ha in 1996 to 190.4 million ha in 2019, making GM crops the fastest adopted crop technology in recent times.[25]

GM crop cultivation is concentrated in 5 countries: US (74.69 million ha), Brazil (63.2 million ha), India (12.35 million ha), Argentina (23.41 million ha), and Canada (11.32 million ha).[26]

Share of Commercially Significant GM Crops



In 2022, soybean was the GM crop with the most crop area (98.92 million hectares), followed by corn (66.23 million ha), cotton (25.36 million ha), canola (9.92 million ha), and sugarbeet (0.49 million ha).[27]

Source: adapted from AgbioInvestor – 2020 Seed Market Review & Global Planted Areas & GM Seed Market: GM Crops

Imports of GM Commodities to the EU

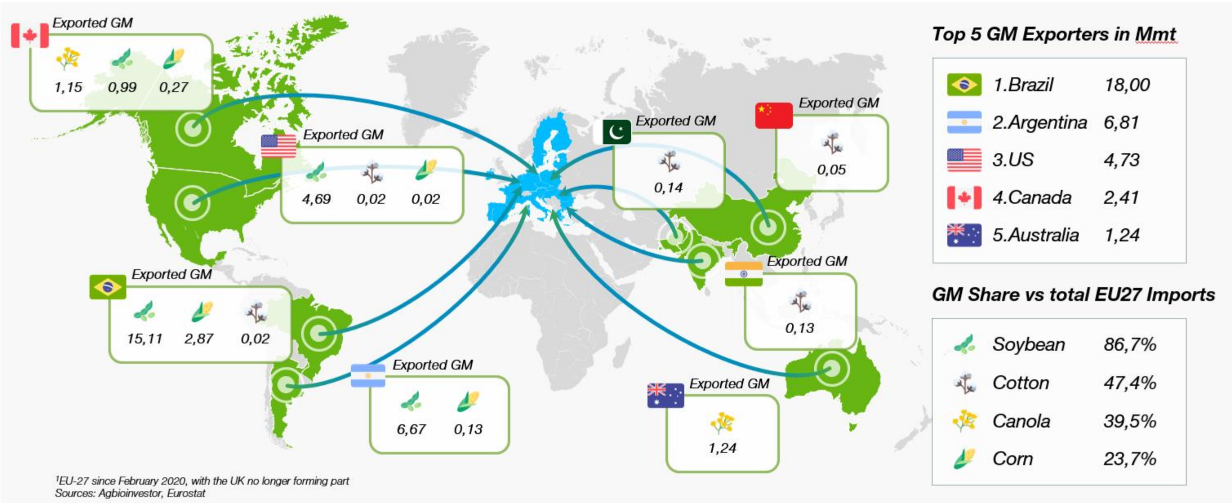
Although most EU countries have banned GM crop cultivation, they still rely heavily on GM crop imports. European farmers depend on imported GM crops to feed animals that produce their meat, dairy products, and eggs. Europe is not self-sufficient in producing the vegetable oils and protein it needs to sustain its food production and livestock. Significant volumes of GM crop commodities grown in the Americas, primarily soybean, are imported annually into the EU to meet the demands of local livestock producers and the food industry value chains.[28] Only 29% of the high protein feeds needed to balance animal diets originates from the EU[29]. In 2021, 2.7 million MT of soybean were harvested from the 939,620 ha of soybean grown in the EU and 14.6 million MT had to be imported. This did not satisfy the protein gap in food and feed value chains as the EU also imported additionally 16.3 million MT of soybean cakes in 2021.[30] The EU livestock sector's competitiveness is enabled by the availability of protein-rich livestock feed from GM corn and soy grown in the Americas. This feed enables European farmers to produce animal-derived products, such as meats, cheeses and eggs, that are in demand by consumers across Europe and worldwide, as part of EU agricultural exports. This makes a positive contribution to Europe's value-added food producers, boosts regional economies and highlights the importance of global trade in meeting the EU's agricultural and food supply needs.

In 2021, the main exporters of GM crops to the EU27 by volume were:[31]

- // Brazil: 18 million MT, primarily corn and soybean
- // Argentina: 6,81 million MT, primarily soybean
- // US: 4,73 million MT, primarily soybean
- // Canada: 2,41 million MT, (Soybean and Canola) and Australia (Canola)

Based on 2021 data, GM soybeans were the most significant GM commodity imported into the EU27 countries – more than 85% of EU27 imported soybean is GM. Other GM crops with significant share in total imports to EU27 were: cotton (over 45% of imported cotton), canola (almost 40% imported canola) and corn (23% of imported corn). While GM cotton imports into the EU27 countries are smaller compared to GM soybeans, they still constitute a significant portion of GM commodity imports, especially if we consider them in value terms. They represent 1% of the imports volume-wise (metric tons) but 8% of the € imported, right above canola and corn. The imports of GM cotton from countries like India, Pakistan and China contribute to the EU's textile industry, providing a sustainable source of raw materials for the production of textiles and garments.[32]

Imported GM crop commodities used in European countries' food production value chains make a positive contribution to protecting Europe's natural habitats. These imports reduce the need to significantly expand European farming areas for food and feed production. Adoption of GM crops in cultivation countries has contributed to increased yields, optimization of inputs on the crop and reduced the need for continual land expansion that would otherwise be needed for agricultural production if they were not adopted. Increased land use either in the cultivation countries or within the EU to compensate for this production gap would result in a loss of biodiversity, but also in increased greenhouse gas emissions.[33]



2021 EU27 (with the UK no longer forming part as of February 2020) imports of GM commodities in Mmt

GM Crop Development and Production

GM Crops at Bayer

According to the FAO, every year, 20-40% of global food production is lost to pests.[34] Plant diseases cost the global economy around $220 billion annually, and invasive insects cost around $70 billion.[35] FAO estimates that losses caused by weeds may account for 5-10% of agricultural production in developed countries and up to 20-30% in developing countries.[36] Plant scientists at Bayer have developed GM crops with ground-breaking traits that offer strengthened resistance to targeted insect pests and tolerance to selected herbicides for more effective weed management, and resilience to environmental stresses, such as drought. Farmers value these properties because they protect their crops from significant damage and enable them to achieve desired yields. Overall, GM traits contribute to increased yields and strengthen the resilience of global food production systems. In addition, HT crops help promote conservation or no-till farming practices, which improve soil health and keep more carbon in the ground.[37]

The most widely commercialized traits by Bayer confer herbicide tolerance and targeted pest resistance. See Appendix 3 for more information:

- Tolerance to herbicides makes it possible to spray crops with herbicides to manage broad-spectrum weeds while leaving the crops intact. Today, Bayer sells corn, cotton, canola, soybean, and alfalfa that have been engineered to be tolerant to the following herbicides: glyphosate, glufosinate, and dicamba.
- IR plants are protected against specific insect pests, such as stem and stalk borers, armyworms, earworms, cutworms, and rootworm in corn; bollworm/budworm and lygus in cotton; and spybean looper caterpillars in soybeans.[38]
- The biggest markets for these products are North and South America. [39]

Bayer's Research & Development (R&D) Pipeline

Bayer's Research & Development (R&D) efforts are focused on developing new solutions geared to support farmers in their need to meet the growing global demand for food, feed, fiber, and fuel while also advancing a climate-smart and sustainable future for the industry. Our pipeline is ensuring that the benefits of our GM products continue to stay impactful and effective. Many of the GM products in our pipeline include stacked traits, which means that these GM plants are produced through conventional breeding between plants expressing independent GM traits. The "stacking" allows the farmer to have the value of multiple GM traits in the same crop (e.g., insect protection and HT traits), such as in our Trecepta® Corn, VT Double PRO®, and VT Triple PRO® corn products.

GM Crop Competitor Landscape

Agriculture is a competitive and heterogeneous industry with a mix of small, medium, and large seed developers. Just as GM adoption around the globe shows a diverse picture, so does the competitive landscape. Table 2 in the appendix shows the developers of GM crops, confirming that Bayer is not the only player in these areas. This information is based on the GM Approval Database (GMAD) from ISAAA, compiling all available information about GM crops that have been approved for planting.

Bayer offers licenses for broad access to its technologies to large and small companies. We derive most of >2bn EUR of licensing revenue in Crop Science from our seed and trait business, and only about 10% of this is from licenses to multinationals. The remaining 90% is from licenses to small and mid-sized seed companies.[40]

2. Controversies Over GM Crops

Bayer acknowledges that agriculture, including GM crops, has an impact on biodiversity and that this topic is seen as controversial.

- On the one hand, GM crops enable optimal land use (i.e., producing more food on the same land area), which reduces the footprint of agriculture and thereby reduces the impact on biodiversity globally. On the other hand, cultivation of GM HT crops, like conventional tillage, can reduce biodiversity in the field by eliminating flowering weeds and reducing habitats for some insects.
- These impacts can be mitigated through habitat restoration measures and best management practices to achieve the full benefits of intensive agriculture and meet the global demand for food and feed.

GMOs' Impact on Biodiversity

Farming, like many other activities, has an impact on biodiversity, yet it is not a zero-sum game. The world population is growing as are its demands for protein-rich food. The traditional way of growing more food requires expanding farmland area. However, farmland is a limited resource, and farmland expansion would require sacrificing natural habitats where biodiversity flourishes. Therefore, to meet the social, environmental, and economic needs of a population that is growing in numbers and wealth, we need to further optimize agricultural production systems by using existing farmland more efficiently to produce higher yields. The drive to achieve efficiency at scale has led to the emergence of large farms, which use sophisticated machinery and are capable of achieving high profitability. On the one hand, large farms, which focus on only a few crops, are not hospitable to biodiversity. On the other hand, these farms have become the backbone of the global food supply and a guarantee of resilience in the face of war, pandemics and other disruptions. Globally, GM crops are an important tool that farmers can use to improve the efficiency of agriculture – producing more food on the same land area. This slows the expansion of farmland to meet society's increasing food needs while contributing to nature conservation and preserving biodiversity. Intensive agriculture has made it possible to increase yields by 60% over the past 40 years, while increasing agricultural land by only 5%.[41] Under current food consumption patterns, if GM crops were banned globally, crop productivity would decrease in existing farming areas, requiring the conversion of vast areas of pasture and forest lands for agricultural production. Between 1996 and 2018, productivity gains through the cultivation of GM crops saved a cumulative 231 million ha of land from ploughing and cultivation.[42] "In 2020, the extra global production of the four main crops in which GM technology is widely used (85 million tons), would have, if conventional production systems been used, required an additional 23.4 million ha of land to be planted to maintain production levels."[43] This is the equivalent of the combined agricultural areas of the Philippines and Vietnam.

By importing GM crops, especially for food, animal feed or clothes production, even countries that don't cultivate GM crops can limit the expansion of farmland in their countries. For example, in 2021, 2.7 million MT of soybean were harvested from the 939,620 ha of soybean grown in the EU and 14.6 million MT had to be imported.[44] This did not satisfy the protein gap in food and feed value chains as EU also imported additionally 16.3 million tons of soybean cakes in 2021.[45] Under the assumption that soybean meal is about 80% of the soybean content and considering the average yield of soybean crops in the EU, if all the needed soybean and soybean meals were produced in the EU today, 12 million more ha (ha) of productive EU farmland would be needed to meet this supply. Considering the arable land of EU countries (excluding permanent grasslands and crops), this is roughly equivalent to use all the current arable land area of a relatively big country like Germany or a combination of all the current arable land area in Poland and Austria.[d]

[d] Estimated from arable land of EU countries in Eurostat database "Main farm land use by NUTS 2 regions (ef_lus_main)" at https://ec.europa.eu/eurostat/data/database. Accessed in February 2023.

In 2010, a European Commission assessment modelled the effect of discontinuing soybean imports from the US, Brazil and Argentina. It revealed that local production to meet total European soybean demand will require an increase in productive farmland.[46] An assessment of farmland needs for EU production of all soybean needs, estimates that this will likely take place by converting forest and pasture land into agricultural production.[47] In addition to the impact on biodiversity, one of the main problems with land use conversion to cropland is that much of the carbon that has been sequestered over the years is released into the atmosphere.

Other commodities like corn and canola are as well imported into the EU from countries cultivating GM crops. In 2021 EU imported 14.1 million MT of corn as well or 16% of its total use and 5.1 million MT of canola or 23% of its total use.[48] Thus, the additional area that would be required in EU to compensate the deficit between production and internal needs would be equivalent to 1.8 million ha of arable land for corn production plus 1.6 million ha of arable land for canola production.

EXAMPLE: GM Crops Are Instrumental to Preventing Deforestation in and increasing production on the current farmland in Brazil:
Brazil provides an example of how GM crops can contribute to a "sustainable intensification" of agriculture production, allowing productivity and production to be increased on the current farmland, thereby saving forests and biodiversity (ISAAA, 2018). Deforestation, a process by which Amazon forests were cut down to free upland for food cultivation, has resulted in significant biodiversity losses in South America.

Forests play a vital role in mitigating climate change, protecting biodiversity, and enabling water availability and soil conservation. Millions of people rely on forests for food security, livelihoods, and energy sources.[49] While the rate of forest loss and degradation has slowed globally since 2000, it still contributes to challenges like climate change and biodiversity loss. Deforestation and forest degradation are complex processes, with multiple causes that differ from region to region, but agriculture has historically been among the major drivers. Overall, deforestation is driven by the need to provide food, feed, energy, lumber, and housing for a global population steadily growing in numbers and wealth. To meet the growing demand for food and feed without increasing the pressure for deforestation, crop yield gains need to be improved around the globe through the adoption of modern agriculture practices. Thus, fulfilling the demand in one region should not occur at the cost of deforestation in another region.

In the example of Brazil, improvements in agricultural productivity over the past three decades increased crop yields by nearly 400% while the farmland area needed for this yield increment increased by only 33%. This could not have been possible without the incorporation of innovation like GM crops and the adoption of modern agronomic practices.

A recent study shows that the continuation of current trends in soybean yield and area would lead to the conversion of an additional 5.7 Mha of forests and savannahs during the next 15 years, with an associated 1,955 Mt of CO_2 released into the atmosphere. In contrast, the acceleration of yield improvement, coupled with the expansion of soybean area only in areas currently used for livestock production, would allow Brazil to produce 162 Mt of soybean without deforestation and with 58% lower global climate warming relative to that derived from the continuation of current trends.

To avoid that the replacement of pasture with soybean production isn't simply pushing pastures into other areas and causing more deforestation for livestock, a "dual intensification" of crop and livestock systems, coupled with strong institutions and policies that prevent deforestation in frontier agricultural areas is needed.

Based on the assumptions made in the study (instead of based on these facts), Brazilian farmers could expand soybean production by increasing yields of current soybean producing areas with available and future technology, and by reclaiming and occupying vast areas of degraded pastures. This type of intensification might have negative impacts on the biodiversity of degraded pasturelands, but this impact should be substantially smaller than that associated with the conversion of native habitats.

In addition, the authors emphasize that intensification would benefit from a cropping-system perspective to optimize the productivity of the whole crop sequence. This can be achieved by agricultural practices such as appropriate choices of sowing dates and cultivars, improved nutrient management including eco-friendly technologies like biological nitrogen fixation, integrated pest and disease management, improved soil and water management including no till and the use of cover crops.[50]

Grain production, land use and yield

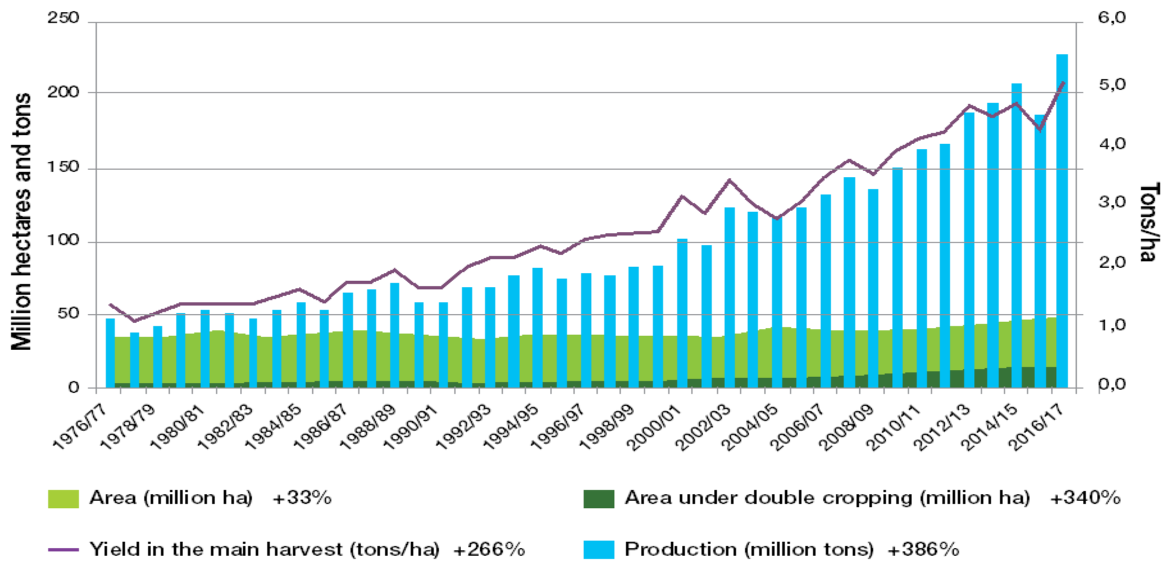


Figure 1. Agro + Investments: Investing in Brazilian agribusiness is a great deal. Ministry of Agriculture, Livestock and Food Supply

Figure 1 shows the significant increase in production that occurred in the early 2000s when GM crops expanded in Brazil. Evolution in productivity based on innovation, of which GM crops are an important part, has reduced deforestation pressure in the past and will continue to be a key driver in the future. Bayer works with our farmer customers and within our supply chain to address the drivers of deforestation and forest degradation. We want to make a significant contribution – not only protecting existing forests, but also helping to restore lost forest land. We do not have all the solutions to challenges as big as deforestation. However, we continuously expand our collaborations with relevant local and regional organizations that complement our technologies with their knowledge and networks. We also participate in coalitions across the value chain with the objective to achieve net-zero deforestation. That also includes, for example, driving forward the sustainable intensification of agriculture in Brazil to prevent further deforestation and be able to meet population food, fiber, and energy demands. A case in point is Bayer's "PRO Carbono Commodities" program, which helps farmers with the adoption of sustainable agricultural practices. For the first time, Bayer offers soybeans with a measured, tracked and deforestation-free carbon footprint grown in Brazil. The program guarantees that production comes from an area free of deforestation and that farmers have not converted areas of natural vegetation into agricultural fields in the past 10 years.[51]

The Facets of Sustainable Intensification of Agriculture

Farmers face a lot of pressures protecting their crops from pests, disease, and weeds in order to preserve yields. To achieve efficient and sustainable management of agroecosystems, effective weed control is required.[52] Among various crops, weeds are responsible for the highest potential yield loss, with losses due to animal pests and pathogens being about half of what is caused by competition with weeds, and thus weed control is a major factor affecting land use efficiency. Weeds are the most important disservice to agriculture, and thus their control is essential for reducing competition for natural resources, such as water, nutrients, space, and light, and also for ensuring the quality and purity of the harvested commodity.[53] Farmers use a number of agronomic practices to combat weeds, such as manual weeding, mechanical tilling, burning and herbicide use. Since some weeds are a source of food for some beneficial insects, one could see a dilemma between the need to increase yield to meet the rising need for food and the desire to preserve some aspects of biodiversity.

HT GM crops are an important technology that help farmers manage weeds and therefore achieve higher crop yields. Where GM HT crops are not available, farmers have to rely on tillage or hand weeding, complicated herbicide application schemes or accept that some weeds would not be controlled. Full weed control is essential because weeds multiply fast, depleting crops of nutrients and compromising yields. While some biodiversity losses in the field can be attributed to the use of crop protection products (herbicides) on HT crops, studies show that the overall volume of herbicides used to manage weeds has been reduced thanks to GM crops.[54]

In some countries, as referenced by Graham Brookes of PG Economics Limited,[55] both the volume of herbicides used (in terms of weight of active ingredient applied) and the associated Environmental Impact Quotient (EIQ) values were reduced compared with usage on conventional (non-GM) crops. The EIQ was developed by Cornell University scientists in 1992 as a method to provide growers with a means to compare potential environmental and health impacts of their pesticide options. It is acknowledged that the EIQ has methodological limitations, and its assessment capability is limited. However, it has utility as a comparative screening tool to help inform the use of one product over another. Collaborations are ongoing to convert to a more holistic assessment approach in the near future. In the meantime, EIQ will continue to be used by some researchers as an indicator to estimate changes of pesticide environmental impact. Even in countries where the average amount of active ingredient applied to GM HT crops represents a net increase relative to usage on conventional crops, in terms of associated environmental impact (measured by the EIQ indicator), the environmental profile for the GM HT crop has commonly been better than its conventional equivalent.[56]

It is worth noting that weed resistance has developed as a result of widespread use of certain herbicides on GM crops, such as glyphosate, although similar resistance has been observed to herbicides used on conventional crops and to mechanical weeding.[57] We recognize that weed resistance needs to be managed and have developed a set of best management practices (BMPs) that can slow the development of weed resistance. To that end, Bayer has developed the Roundup Ready PLUS® Crop Management Solutions program to provide weed management options and economic incentives for soybean, corn and cotton farmers to incorporate additional modes of action into their weed control strategy, such as the overlapping use of residual herbicides. Through industry initiatives such as the Take Action platform, Bayer provides farmers the resources they need to adopt weed management practices.[58]

Bayer is intentional about reducing the impacts of herbicides used in conjunction with GM crops in several ways:

- All herbicide formulations developed for use with HT crops come with label instructions to limit off-site movement from spray applications. These measures are intended to keep the herbicides on-target in the field and away from habitats that are refuges for biodiversity. They include limiting maximum application rates to levels that don't adversely affect biodiversity, restrictions on the timing(s) and number of applications, and the interval between applications. In some cases, herbicide applicators are required to use spray drift reduction technology (e.g., low-drift nozzles and drift-reducing agents added to the spray tank) and wind-directional in-field buffers.
- Precision application technologies (such as drones, among others) allow farmers to use crop protection products in a more targeted way and apply them only when and where needed.

Impact of GM Herbicide-Tolerant Crops on Monarch Butterfly Populations

- The introduction of GM crops and the associated herbicide treatments, especially with glyphosate, were very effective in helping farmers control milkweed in their crop fields – a positive development for intensive agriculture with an unintended indirect consequence for the monarch butterfly. The successful control of milkweed, a weed plant in agricultural areas that serves as habitat for the monarch butterfly, is likely one of many factors that has contributed to the decline in monarch butterfly populations.[59]
- Bayer recognizes that intensive agriculture has had an impact on monarch butterfly habitat, regardless of the exact causes, and has been actively involved in conservation efforts to help restore their natural habitats. This demonstrates how intensive agriculture and conservation efforts can exist side by side to address the trade-offs we face as a global society that depends on modern agriculture for food, fiber and fuel.
- Bayer is working with a diverse set of experts in North America to find meaningful and proactive ways to help the monarch butterfly and other pollinators thrive.

Monarch butterflies have a remarkable life cycle, which for some of the population involves a 10,000-kilometer migration from Canada and the United States to Mexico and back. Over the past 20 years, this insect has faced a number of challenges: losses of breeding and foraging habitats, weather, predators, pathogens, and parasites, and declining overwintering habitats in Mexico. One of these challenges – the loss of breeding and foraging habitats along migration routes – is related to intensive agriculture. Milkweed plants are essential to the monarchs' survival – they lay their eggs on the leaves of the plant, and the butterfly caterpillars eat it as a sole source of nutrition. Milkweed, however, is also a weed that constitutes a problem for farmers in North America. In order to maximize crop yields, farmers strive to keep their fields weed-free.

The decline in North American monarch butterfly populations has received a lot of attention, with much of the responsibility ascribed to agriculture in general and Bayer as a developer and supplier of agricultural inputs and tools for farmers, in particular.

Several studies have concluded that modern farming techniques have led to fewer milkweed plants on agricultural fields[60] and the associated decline in wintering monarchs.[61]

Overall, experts agree that the causes of the long-term monarch population trends are multifactorial and include milkweed decline (due to vegetation management, urbanization, and other factors), climate change and degradation of overwintering habitat in Mexico.[e]

Regardless of the exact causes, Bayer recognizes that intensive agriculture has had an impact on monarch butterflies through changes in milkweed abundance and distribution and has been actively involved since 2014 in conservation efforts to restore their natural habitats. This is, in fact, a perfect example of how intensive agriculture and conservation efforts can exist side by side to address the trade-offs we face as a global society that depends on agriculture for food, fiber and fuel.

Bayer agrees with many other organizations, including the U.S Fish and Wildlife Service (USFWS), that the solution we can impact the most is expanding the monarch butterfly's habitats in North America by planting more milkweed and habitats with plants that bloom throughout the seasons. According to the USFWS, "*Robust conservation efforts are ongoing across the continent, including partnerships with states, tribes, Canada and Mexico, local communities and conservation organizations, to address threats to the monarch and to bolster milkweed abundance and other habitat needs*."[62]

In fact, the USFWS has the goal of adding 1.3 billion milkweed stems by 2038 to the North Core monarch conservation unit, targeted at stabilizing the monarch population. From 2014 to 2023, through targeted

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[e] For more information on herbicide use associated with HT crops as well as other known stressors on the monarch population, please read the blog, "Is the Monarch butterfly threatened with extinction by herbicide resistant GMOs?"

voluntary efforts, around 200 million additional stems[f] have been added to the landscape throughout the United States.[63]

As a part of this habitat initiative, Bayer is collaborating with conservation groups, academic experts, farmers, and government agencies across North America to find meaningful and proactive ways to create additional habitats to help the monarch population thrive. Through these partnerships, Bayer can have a larger impact with on-the-ground habitat projects and more efficiently advance progress on conservation. We've contributed over ten million dollars to a diverse group of organizations, many of which have a multiplier effect by generating matching contributions through additional grants. For instance, our partnership with the National Fish and Wildlife Foundation (NFWF) to date has supported 123 projects and generated more than 142,800 ha of habitat restoration, and over 1,600 workshops and meetings hosted. Working with Monarch Watch and the University of Kansas, we have donated more than 600,000 milkweed plants to provide quality habitat on priority landscapes. Other groups we support, such as Monarch Joint Venture, Pheasants Forever Quail Forever, and the Keystone Monarch Collaborative, also have important initiatives underway. Hundreds of thousands of acres of monarch habitat have already been restored, and we know there's much more to do.[64] These conservation measures benefit not only monarchs, but also many other insects, birds, and mammals that share their habitat.

In 2019, Bayer developed with Iowa State University an app called HabiTally that farmers and landowners can use to easily document the multifunctional habitats they have created for monarch butterflies and track the gains made in milkweed (*Asclepias*) stems per acre across the United States. The app allows for better estimates of how much and where current habitat exists, while also better facilitating analysis of gaps and opportunities for further habitat development. The US Fish and Wildlife Service uses the data to better assess the progress made toward its milkweed stem goal.

Insect-Resistant GM Crops and Pollinators (Bees and Other Nontarget Organisms)

- Insect-resistant GM crops are thoroughly tested and assessed for potential impacts to beneficial species, including bees, as a condition of their registration prior to commercialization.
- Some have expressed concern that IR GM crops containing a toxin that is harmful to the target pest may also be harmful to honey bees. Actually, the highly specific activity of Bt proteins expressed by GM insect-protected crops greatly reduces or eliminates the potential impact on biodiversity, including beneficial insects that are important for biological control of pests.
- In countries where GM insect-protected crops are grown, farmers can minimize the use of conventional synthetic pesticides, which minimizes impact on biodiversity.
- GM IR crops have become an important pillar of Integrated Pest Management (IPM) programs.

Insect pests are one of the main causes of yield loss. To combat insect pests, farmers have had to use a combination of insecticides, which often could not reach insects that attack the plant roots and provide extended control. For example, before GM IR cotton was available, growers in some countries (China and Australia) sprayed their crops 15 – 20 times per year to control insect pests.[65] GM IR crop varieties that produce insecticidal proteins from *Bacillus thuringiensis* (also known as Bt or "Cry proteins") have become one of the tools farmers rely on to increase production by controlling a number of economically and agronomically important insect pests, such as larval lepidopteran (i.e., caterpillars) and coleopteran (i.e., beetles) in corn, cotton, and soybean (Ward et al., 2005; Bacalhau et al., 2020). IR varieties provide a number of benefits, such as monetary savings and improved control that translates to yield increases. For example, the European corn borer and the western corn rootworm are common pests that attack corn plants, with each pest having the potential to cause an estimated $1 billion in annual losses in the US. Research has shown cumulative benefits of $3.2 billion for both Bt- and non-Bt corn growers over 14 years since the adoption of Bt corn (1996–2010) in Illinois, Minnesota, and Wisconsin.[66] Plants modified with traits that protect roots from insect damage also provide higher yields since they use water more efficiently than those

[f] Milkweed stem count progress only accounts for additional stems in the North Core monarch management unit, and also takes into account the stems lost due to retired CRP acres since 2014 (i.e. net loss of 250k CRP acres in the North Core unit).

with damaged roots and are less likely to lodge (i.e., fall over) after strong wind events, which keeps the crop from being harvested. Even growers who plant non-Bt crops benefit because the general pest populations are reduced by Bt crops.
As with any insect pest-control practice, there is concern that using GM IR crops may cause adverse effects to biodiversity in agroecosystems. Over the past 25 years, extensive environmental testing has been done on Bt proteins expressed by GM insect-protected crop varieties, and the weight of evidence shows no adverse or unintended effects to wildlife.[67] Lack of adverse and unintended effects to nontarget organisms reflect the narrow spectrum of activity of Bt proteins in commercialized GM insect-protected crop varieties. The highly specific activity of Bt proteins greatly reduces or eliminates the potential for impact on wildlife, including beneficial insects, which don't feed on crop leaves or roots and, which are important for biological control of pests (Romeis et al., 2019).[68] Consequently, GM IR crops have become an important pillar of Integrated Pest Management (IPM).[69] IPM is an ecosystem-based strategy that focuses on long-term prevention of pests that damage crops through a combination of techniques, which include the use of resistant varieties, such as GM insect-protected crops, to maximize control mechanisms of insect pests. A recent systematic review of the literature and meta-analysis, provides further evidence that Bt corn presents a highly selective pest control technology and further support the conclusion that there are no unacceptable risks to non-target organisms and biodiversity.[70]

GM IR crops have greatly reduced or replaced conventional chemical insecticides to control pest species in corn, cotton, and soybean. In countries where GM insect-protected crops are cultivated, farmers using these GM crops make optimal use of conventional insecticides only when necessary to control crop pests, which reduces the impact of direct and indirect effects of farming practices on biodiversity. The potential for indirect effects is *de minimis* because potential effects to the food web are minimized. Since 1996, when the first GM insect-protected corn and cotton were commercially introduced, globally, insecticide use for cotton has been reduced by 339 million kg of active ingredient (30% reduction) and for corn by 85.4 million kg of active ingredient (41% reduction).[71] For cotton and corn, this represents a 34% and 45% reduction in the Environmental Impact Quotient (EIQ), respectively. GM insect-protected soybeans became available for commercial use in South America in 2013. Over this period, the reduction of conventional insecticide use on soybeans was estimated to be 23.9 million kg (9.8% of total soybean insecticide use), with an associated environmental benefit as measured by the EIQ of 17.8%.[72] According to the US Department of Agriculture (USDA), insecticide use on corn farms declined most years and had an overall drop from 0.21 pound per corn planted acre of corn in 1995 (the year before Bt corn was commercially introduced) to 0.06 pound in 2005 and 0.02 pound in 2010. Insecticide use has declined for both Bt adopters and nonadopters in recent years. According to ARMS data, only 9% of all US corn farmers applied insecticides in 2010.[73]

Bees and other pollinators are hugely important for sustainable food production, and we also depend on healthy pollinators for our seed production. GM crop traits are stringently regulated and undergo thorough environmental testing and ecological risk assessments to make sure they do not adversely impact beneficial organisms, including pollinators. These types of analyses have principally focused on GM crops with insect-control traits because these traits exhibit a toxic mode of action against target pests. In contrast, herbicide-tolerance traits do not exhibit toxic modes of action, and therefore inherently pose negligible risk to pollinators and other beneficial organisms.

To minimize potential risks posed to pollinators by GM crops, initial tests are carried out in early product development stages to assess the potential for acute and chronic effects to larval and adult honey bees. These highly conservative assays screen for potential effects throughout the honey bee life cycle. Only products that pose negligible risk to honey bees and other pollinator populations have been registered for commercial cultivation. In confirmation of this, an analysis of multiple independent studies conducted on GM plants that produce insect-control proteins from the soil bacterium Bt did not identify any biologically relevant effects on honey bees (Duan et al., 2008).[74]

In addition to honey bees and other pollinators, GM crops are thoroughly tested for potential effects on beneficial organisms that perform important functions in agricultural ecosystems. These functions include biological control of crop pests as well as nutrient cycling and soil health. Following a well-established and internationally accepted framework, comprehensive laboratory and field testing have demonstrated that insect control traits in commercially developed GM crops do not harm beneficial organisms.[75] This is, in part, due to the specificity and relatively narrow spectrum of activity observed with commercially developed insect-control traits. Several studies have shown that the activities of *Bt* proteins depend, in part, on the presence of one or more specific receptors, which are not present in non-target insects and mammals.[76] Extensive testing has also demonstrated that the proteins produced by insect-control traits in GM crops do not persist and rapidly degrade in the environment, thereby minimizing potential exposure, and therefore risk, to beneficial species. In addition to beneficial organisms, the results of these studies and assessments support the conclusion that all commercialized GM crops to date do not pose an unacceptable risk under intended use to non-target organisms, including beneficial and listed threatened and endangered species.

GMOs and Plant Genetic Diversity

Some questions have emerged regarding the impact of GM crops on the genetic diversity of plants. Genetic diversity is vital for plant breeders to develop new crop varieties regardless of the addition of a GM trait. There is no evidence that genetic diversity has decreased because of the introduction of genetically modified crops. After reviewing more than 900 studies, the National Academies of Sciences, Engineering, and Medicine[77] stated that researchers did not find any indication that the genetic diversity of major seed varieties in countries like the United States had declined due to the introduction of genetically modified seeds. The number of available seed varieties had, however, declined during the 20th century due to farmers' preference and strong demand for high-yielding seeds.

Genetic diversity is defined as the variety of genes within a particular population, species, variety or breed.

Coexistence of GM and Non-GM Crops

- Coexistence in agricultural production systems and supply chains is well established and well understood by farmers and the agricultural value chain.
- In practice, coexistence is something farmers manage at farm level.
- Bayer is committed to providing continuous, collaborative support to farmers, co-designing sustainable farming practices, stewardship, quality management activities, and training programs.
- Bayer's Technology Use Guide for all of its GM seed offerings includes agricultural practice requirements and clear guidelines in place for our own sites and those of our seed producers that must be followed to prevent inadvertent pollination and ensure successful coexistence.
- There are no lawsuits claiming cross-pollination filed against Bayer. Therefore, we cannot settle any litigation – as requested by ESG rating agencies – because there are no lawsuits.

Concerns have been raised about the possibility of GM and non-GM cropping systems coexisting in proximity, prompted by fears of gene flow from GM crops to conventional crops. In fact, reality has shown that GM cropping systems can be implemented close to conventional or organic fields with no adverse effects.

Coexistence in agricultural production systems and supply chains is well established and well understood by growers, who are responsible for implementing best practices to satisfy specific marketing or certification standards that, in many cases, earn them a premium. Growers employ appropriate practices to ensure the integrity and marketability of their crops and communicate with their neighbors to be aware of their planting intentions.

A variety of agricultural systems around the world have coexisted successfully for many years. Standards and best practices were established decades ago and have continually evolved to deliver high-purity seed and grain to support production, distribution, and trade of products from various agricultural systems. For example, production of similar commodities, such as field corn, sweet corn, and popcorn, or canola varieties with low erucic acid content for food use and high erucic acid content for industrial uses, has occurred successfully in proximity for many years.

The introduction of GM crops generated renewed discussion focused on coexistence of GM cropping systems with conventional cropping systems and organic production. These conversations have primarily focused on the potential marketing impact of the introduction of GM products on other systems. Considerations about the suitability of a crop for a particular market, as opposed to the health and safety of GM products, are the focus of concern because the food, feed, and environmental safety of GM products are demonstrated before they are allowed to enter the agricultural production system and supply chain. The coexistence of conventional, organic, and GM crops has been the subject of several studies and reports[78] that conclude coexistence among GM and non-GM crops is readily achievable and is successfully occurring.

In general, successful coexistence of all agricultural systems depends on communication, cooperation, flexibility, and mutual respect for each system among growers. Agriculture has a history of innovation and change, and growers have generally adapted to new approaches or challenges by utilizing appropriate strategies, farm management practices, and new technologies. While growers are ultimately responsible for ensuring coexistence, Bayer is committed to providing continuous, collaborative support to farmers, co-designing sustainable farming practices, stewardship activities, and training programs such as BayG.A.P.[79] or Better Life Farming.[80] Furthermore, our entry into the organic vegetable seed segment reflects our belief in the coexistence of agricultural systems. We are supporting this commitment with various initiatives around the globe. We provide a Technology Use Guide (TUG) to all grower customers using our technology, available on our website.[81] Among other information, the guide contains provisions for planting at a prescribed distance to other fields of the same crop type or planting at different times to prevent simultaneous pollination in two fields.

Coexistence works when practices are in place during cultivation, harvest, transport, storage, and processing of GM and non-GM crops. Some important concepts relevant to understanding coexistence are:

- Crops will only pollinate other varieties of the same crop. Thus, for example, GM canola would have no influence on a farmer's ability to grow organic corn in adjacent fields.
- Cross-pollination will only occur to a significant degree if the crops are sufficiently close, the flowering periods are the same, and the receiving crop has not already self-pollinated.
- Scientific studies show that for all crops, the majority of cross-pollination occurs at the edge of the fields, with a rapid decrease as the distance from the pollen source increases.[82]
- The potential for cross-pollination is only present in certain well-defined cases. Good communication between nearby farmers can ensure problem-free coexistence through agreement to separate crops of the same type.

At the moment of this report's completion, we are unaware of any open litigation claiming cross-pollination/contamination. In the United States, previous legal cases involving cross-pollination were in fact allegations that the US government needed to regulate or assess GM crops more closely or allegations that related to intellectual property concerns rather than cross contamination. Therefore, we cannot settle any litigation – as requested by ESG rating agencies – because there are no lawsuits.

Intellectual Property and GM Crop Accessibility for Farmers

- There is a perception that smallholder farmers don't have access to GM crops because of intellectual property (IP) protection.
- Bayer recognizes the importance of smallholder farmers for the global food production system, does not assert intellectual property rights against smallholder farmers who save seeds to escape extreme

poverty, and works to introduce them to the world of commercial farming as a way to improve their livelihoods.

GM crops are grown by over 18 million farmers annually, with over 95% of whom are small farmers. Intellectual property rights for GM crops include patents and plant variety protection which serve to safeguard the significant investments in improving them and bringing them to market. Patents and plant variety protection protect different types of innovations and are therefore both necessary. Patents together with fair licences do not block access but rather stimulate innovation while enabling the dissemination of innovation to many plant breeders, ultimately providing more choice and value-added solutions for farmers. As a research driven company relying on intellectual property protection, Bayer is open to help explain how patents can stimulate plant-based innovation for the benefit of society.

Bayer does not assert intellectual property rights against smallholder farmers who save seeds on their farms for private and noncommercial use in order to escape extreme poverty. Instead, we want to work together with these smallholder farmers to introduce them to the world of commercial farming and enable them to improve their livelihoods.[83]

Bayer recognizes the importance of smallholder farmers for the global food production system. An estimated 550 million smallholder farmers feed more than half of the population in low- and middle-income countries.[84] Owning small plots of land where they can typically only harvest one or two crops, smallholders can lack the resources needed to support their families and communities. These farmers face unique challenges that require tailored solutions. At Bayer, we want to enable 100 million smallholder farmers[85] in such countries around the world by providing more access to agricultural solutions that are sustainable, including GM crops, and we support a number of IP-related initiatives to help. We aim to support them through collaborative partnerships and innovative solutions that expand agricultural know-how to address their most challenging issues. In 2022, together with our partners, we supported 52 million smallholder farmers in LMICs with our products and services – three million more than in the previous year. We achieved this by significantly expanding business activities, especially in Asia/Pacific. We are successively expanding our product and service portfolio for smallholder farmers, including innovative business models and digital solutions across the entire crop system. This includes solutions from the areas of digital farming and market access, a differentiated product portfolio, biotechnological solutions and the formation of partnerships along the value chain. In 2021, Bayer ranked first (out of 32 companies) within the Access to Seeds Indexes in Eastern and Southern Africa and in Western and Central Africa.[86] Access to Seeds[87] is an independent ranking of companies active in the seed industry, both in field crops and vegetable seeds. This index is a viable tool for Bayer and other companies to benchmark and better focus on initiatives that will help improve farmers' access to seeds, including GMOs.

There are claims that restrictions on the use, exchange, and sale of farm-saved seeds could lead to farmers becoming increasingly dependent on the formal seed sector by requiring more inputs compared with local varieties, pushing up production costs and, thus, posing a burden for cash-strapped farmers. We consider that the cost of seed is only one part of the overall production process that a farmer must consider, representing only 20%-30% of the total production costs. A complete cost-benefit analysis should include all inputs, crop yields, market prices and resultant income. We believe in the freedom of choice of farmers and support their ability to choose which seeds are best suited for their individual production schemes. In 2020, for each extra dollar invested in GM crop seeds, farmers in developing countries received $5.22, whereas farmers in developed countries received $3.00.[88] Today, smallholder farmers, mainly from India and Asia, buy our GM corn, cotton, hybrid rice, mustard and vegetable seeds because they rely on the results of our products and expertise to provide a better overall financial return.

3. Ensuring Product Safety and Responsible Use

- Bayer is committed to Product Stewardship for the life cycle of its products and services globally, participates in industry programs, such as Excellence Through Stewardship, and endorses CropLife International's Plant Biotechnology Code of Conduct.
- Newly developed GM crops undergo a robust, science-based safety assessment prior to commercialization to ensure safety for the use as food and animal feed as well as for the environment.
- GM crops undergo rigorous testing for allergens and also a comparative assessment with their non-GMO counterparts.

Excellence Through Stewardship and the Technology User Guides

Stewardship is a life cycle approach to product management. It is the responsible way to manage GM crops from their discovery and development to their use and eventual discontinuation. Bayer is highly committed to the responsible management of its products and continues to invest in stewardship practices and quality management systems globally where GM crops are developed, grown, and used. Maintaining excellence in stewardship is key to preserving license to operate (LTO) across the value chain and to protecting the responsible use of the technology so its benefits are sustained.

Bayer endorses the CropLife International Plant Biotechnology Code of Conduct[89] and the Universal Declaration of Human Rights. These guidance documents, together with participation in industry initiatives – such as Excellence Through Stewardship® (ETS)[90] – and in conjunction with regulatory considerations, provide the basis for our regulation, the Bayer Product Stewardship Commitments, Principles and Key Requirements.[91]

Bayer is committed to product stewardship throughout the life cycle for all products and services worldwide. Our responsible use is clearly demonstrated in our active membership in ETS, internal stewardship activities and processes, as well as our efforts to share product use information with growers and encourage sustainable use of Bayer products.

ETS is a global program that promotes the responsible management of GM crops through the universal adoption of stewardship programs and quality management systems for the full product life cycle – from discovery and development to their use and eventual discontinuation. ETS helps its members by establishing principles and best management practices, developing high-quality technical resources and facilitating a Global Stewardship Audit Process. Part of the objectives of the ETS programs are to:

- Promote responsible use of GM crops for food, feed and environmental safety
- Support full compliance with applicable regulatory requirements
- Maximize technology benefits
- Drive continuous improvement
- Share best practices
- Actively engage with the food value chain to evaluate and promote appropriate stewardship approaches

Bayer is a founding member of ETS, and our employees are active in ETS committees and programs and on the board of directors. ETS is important to Bayer because third-party audit certification provides the framework to e.g.

- Achieve consistent cross-geography internal operational standards
- Provide LTO needed to deliver our regulatory and commercial timelines
- Enable market and regulatory confidence

ETS guides that address stewardship, Insect Resistance Management,[92] and Maintaining Plant Product Integrity[93] provide operational standards for organizations across the industry. ETS audit verifications are used to verify that appropriate systems have been implemented. Bayer currently has all world regions certified and received ETS re-certification in the US in 2021. Independent third-party auditors verified that Bayer successfully completed current ETS audit requirements and have in place stewardship programs and quality management systems consistent with the ETS initiative.

As part of its life cycle approach that addresses all major aspects of responsible product management, Bayer created a Product Stewardship Commitment, Principles and Key Requirements regulation, which captures its requirements to define and meet the highest stewardship standards in the industry. The regulation addresses the product life cycle for all for our agricultural products and services worldwide, including all seeds and traits, biologics, and crop protection products, as well as services in the Bayer portfolio.

Internally, Bayer uses a Life Cycle Stewardship Activities Management Process (LCStAMP) to identify key stewardship activities across the product life cycle. LCStAMP provides for stewardship planning and review sessions by monitoring progress and planning for upcoming milestones. Stewardship activities are organized into Stewardship categories and recorded at product and country level using digital tools.

Additionally, Bayer has made available Technology Use Guides (TUGs)[94] – concise sources of technical information about Bayer's current portfolio of GM crops and crop protection products/technology products. The purpose of TUGs are to educate growers and encourage sustainable use of Bayer products. TUGs are available for each GM crop, setting forth the requirements and guidelines for the use of these products. Content includes a detailed overview of stewardship:

- Importance of stewardship
- Insect resistance management (IRM) requirements
- Integrated pest management (IPM) recommendations
- Weed resistance management/weed management
- Identity preserved production
- Coexistence of biotech cropping systems with other ag production systems
- Refuge requirements
- Employment of integrated pest management practices
- Treated seed best management practices
- Guide to responsible planting
- Honey bee health information

Through TUGs, Bayer instructs growers to report any incidence of repeated non-performance of Bayer products to the appropriate company representative, local retailer, or extension agent.

Other resources are implemented at a local level, including training.

Overview of GMOs and Human/Animal Health and Environmental Safety

- After 30 years of research and assessments, the safety of GM crops for human, animal health and the environment[95] is strongly supported by the global scientific community. The prevailing scientific consensus is that foods and feeds derived from GMOs are as safe and nutritious as those derived by conventional breeding techniques. Yet even though the safety of GMOs has been established, the topic of safety remains an important point of discussion.
- This section will explore the safety studies and regulatory assessments performed to ensure the safety of GM crops prior to their commercialization. The global scientific evidence supporting the safety of GMOs will also be discussed.

Since 1992, when the first GM crops were being developed for commercialization, at least 72 different countries have granted over 4,400 commercial use approvals on over 400 different GM crop products in 29 crops.[96] Pre-market safety reviews have been validated by more than 400 million cumulative ha of GM crops cultivated worldwide. Regulatory authorities responsible for the assessment and authorization of GM crops have developed an approach whereby new GM crops are compared with conventional crops that have a known history of safe use. Based upon hundreds of studies using that approach, regulatory authorities have determined that their use in food, animal feed, and the environment is just as safe as that of their conventional crop counterparts that have been grown and consumed for generations. According to the FAO, "We can be rest assured that GM crops that are approved are safe and continuous monitoring is undertaken."[97] The evidence on the safety of GM crops could not be more conclusive. For each new GM crop product intended for commercialization, Bayer conducts years of field trials and comprehensive testing over a series of coordinated phases of product development, from early discovery to commercialization, to be scientifically certain that the genetic modification and new trait(s) are efficacious to meet growers' needs and will not affect the food, feed, and environmental safety of the crop. Only products that meet Bayer's high technical and safety standards are approved for advancement to the next phase of development. As result of a rigorous development process, developing and bringing a new GM HT or insect-protected crop to the commercial market can take an average of more than 16.5 years from product concept to product launch.[98]

In order to appreciate the rigor of testing GM products undergo before commercialization, it is important to remember that GM traits are governed by the plant's genetic makeup. For context, genes (the blueprint of a plant) are made up of DNA, which is transcribed by RNA, resulting in proteins and the combination of these expressed proteins, in turn, results in specific traits (e.g., plants with modified oil profiles or insect resistance). Most plants have 30,000 – 100,000 genes. With GM trait development, 1- 2 genes are introduced to the plant genome.

Early Discovery Safety Assessments of GMOs

During the early R&D process, scientists determine which traits are capable of conferring specific benefits of interest to growers. After a desired trait is identified, the gene(s) associated with it goes through a safety screening process before it is inserted into the plant.

Bioinformatics screening is performed to determine if the newly expressed protein is a known allergen, or if the amino acid sequence of the newly expressed protein has structural similarity to known allergenic proteins. Likewise, the amino acid sequence is compared with a comprehensive database of known toxins. These determinations can be done without ever generating a GM plant. Thus, scientists know very early in the development phase whether a proposed GM trait would contain an allergenic or toxic protein. Eventually, the new GM protein is tested for abundance in the plant and digestibility. These tests of the new protein – required by regulatory authorities globally – are conducted to ensure that the application of a transgenic method to a plant does not result in a new crop allergen.

It is important to reiterate that no single GM-based protein in a food has been found to cause an allergic reaction. However, there is one documented example of a protein intended for a GM crop having allergenicity concerns, which was a soybean being developed for animal feed that was to express a protein from the Brazil nut. (This was not a product developed by Bayer.) Since the researchers determined that the inserted protein was associated with a Brazil nut food allergic reaction, the product was not developed.[99] Bayer halts the R&D process if testing shows a likely allergic reaction.

Some allergenic proteins are present naturally in conventional crops, and their concentrations are highly variable; however, GM techniques have not changed the amounts of these natural allergenic proteins. A recent study[100] explored if GM products (e.g., corn, wheat, rice, soy, etc.) are more allergenic than their conventional counterparts. The authors identified 83 studies published in peer-reviewed literature addressing this question. The conclusion from this analysis was that no animal or human study was identified that demonstrated that a GM food item was more allergenic than its conventional counterpart. The same review[101] indicated that there is no evidence that consumption of GM products by individuals who are not allergic to conventional forms of those items would result in allergy or increase the risk of developing an allergy to that item.

Regulatory Safety Evaluations

In order to receive regulatory approval, Bayer, as well as other companies that produce GM crops, must collect safety data that is required by regulatory agencies around the world. Regulatory authorities follow scientific principles and standards established over the course of several decades by international organizations, such as the World Health Organization (WHO), the FAO, the Organization for Economic Cooperation and Development (OECD), and the Codex Alimentarius International Food Standards. Bayer's safety studies are conducted in compliance with all applicable laws and regulations and in adherence to strict standards of data quality and integrity. Safety data must support the food, feed and environmental safety of the product and be conducted in compliance with recognized Good Laboratory Practices (GLPs) or other quality management systems set by International Standards Organizations (ISO) to ensure the data is defensible and reproducible, regardless of which entity collects it. For more information about safety studies on GM crops, please visit our Transparency page.[102]

Regulatory authorities require the following types of studies to assess the safety of GM products:

- Studies to characterise each gene (DNA) added to the GM crop are performed to confirm that only one copy of the desired gene is inserted into the plant genome and that the genetic material is stable.
- Studies to evaluate the protein(s) expressed by the introduced gene include acute toxicity studies that feed amounts of protein that are 100% times more than humans or animals would be exposed to, simulated digestibility studies to ensure the protein readily breaks down in the digestive system, heat stability testing and bioinformatics evaluations to confirm that the protein is not a known allergen or

toxin. Tests are also performed to determine the levels of protein in GM plants people or other organisms might be exposed to when eating the plants.

- Studies that look at the whole GM plant (how it is growing in the field, its characteristics as food and feed):

Comparative Composition Assessment

Crop compositional evaluations are comparative safety assessments between the GM crop and its conventional counterpart. Conventional crops have a long history of safe use and serve as the baseline in the evaluation. This is often referred to as the concept of substantial equivalence. The purpose of this approach is to recognize that most crops naturally contain some anti-nutritional component, which is unchanged. All Bayer GM crop products undergo a comparative safety assessment process that requires evaluation of the composition of the GM crop relative to that of a conventional comparator to determine if significant and biologically relevant compositional changes are induced by the insertion of a gene.[103] Crop composition studies come from replicated field trials in multiple geographic locations. Assessment includes crop-specific lists of well-defined nutrients, anti-nutrients, and toxins as defined by the OECD[104], including levels of protein, carbohydrate, fat, amino acids, fiber, vitamins, and a variety of other components. As an example, the results of a compositional analysis of GM soybean demonstrated that the harvested seed of the GM soybean are comparable to those of the conventional soybean comparator and the commercially available soybean varieties. In fact, studies have demonstrated that crop composition is mostly affected by geography and genetics rather than the insertion of a gene. To date, studies on the composition of GM foods currently on the market reveal no differences that would implicate a higher risk to human health and safety than from eating their non-GM counterparts. By this comparative assessment approach, GM crops have been considered as safe as their conventional counterparts that have a long history of safe use.

Toxicology Studies

Animal feeding studies are conducted to confirm the wholesomeness of the grain and to detect unintended changes:

- During a 42-day study, broiler chicken, which are very sensitive to changes in their nutrition, are fed diets with the greatest practical amount of the GM crop (e.g., 60-70% of GM corn) to determine any changes in their growth and health and differences between chicken fed conventional grain.
- During a 56-day study, catfish fed a diet high in GM grain are compared to a group fed conventional grain.
- Bayer performs 90-day animal toxicity studies (adapted from the OECD Test Guideline 408) using a harvested component (e.g., grain) of the GM crop, which is then fed to animals, and submits the findings to regulatory agencies around the world. The purpose is to identify potential toxicologically significant diet-related differences relative to the conventional comparator using standard toxicity endpoints. To date, 90-day feeding studies have revealed no diet-related toxicological hazards, including cancer, in animals fed GM crops.

Environmental Assessment

Bayer GM crops also undergo rigorous testing and assessment to evaluate the environmental safety of the GM crop and the introduced trait(s) (e.g., herbicide tolerance or insect resistance) under its intended use. A variety of field, laboratory, and greenhouse studies are conducted to evaluate whether the agronomic, growth, and development characteristics of the GM crop and its interactions with various biotic and abiotic environmental stressors (e.g., insect pests, diseases, drought, wind) are fundamentally unchanged from the conventional crop, except for the introduced trait(s). These comparative crop characterization data, along with the nature of the crop and introduced trait(s) as well as gene flow information, are used to assess whether the GM crop or any sexually compatible related species growing nearby have the potential to become more weedy or persistent in the environment or adversely impact the environment or biodiversity in the agro-ecosystem relative to the conventional crop. For GM crops designed to control targeted pests, additional environmental fate and ecotoxicity studies are conducted to assess the risk of potential impacts on non-target organisms (NTOs) and the services they provide (e.g., honey bees for pollination services and other beneficial NTOs important for soil services and biological control).

Global Regulatory Review and Approval

Types of Safety Studies Required by Regulatory Authorities

Protein Safety	Food & Feed Safety	Environmental Risk Assessment
Bioinformatics	Crop Composition	Crop Characterization and Exposure
Protein Toxicity		Ecotoxicology Testing
Allergenicity	Animal Studies: Toxicology & Nutrition	Non-target Organism Effects Endangered Species

Once Bayer has completed the required safety studies and met applicable regulatory requirements for the new GM crop, the data are submitted to regulatory authorities around the world for review both in countries where the GM crop will be cultivated and in countries that may import the derived crops. These regulatory authorities are equipped with functional regulatory systems and expertise for GM crop assessment. After conducting a thorough, independent review of Bayer's data, the regulatory authorities will approve the product if they determine it to be safe for farmers to grow in the environment and safe to consume as food and feed. Once commercialized and throughout its life cycle, Bayer continues to evaluate product safety and durability-related information to ensure appropriate stewardship of the product and compliance with post-market monitoring requirements (e.g., insect resistance monitoring) in product registrations to support product re-authorizations and ongoing commercial use.

Weight of Scientific Evidence on the Safety of GM Crops

The safety of GM crops has been validated by numerous third-party organizations among various governing bodies all over the world (see full list in appendix). A range of in-depth studies and reviews on GM crops by the science communities in Europe and the United States confirm a track record of safe use, including:

- World Health Organization (WHO)[105]
- the European Food Safety Authority (EFSA)[106]
- In 2016, the National Academies of Sciences, Engineering, and Medicine examined all available research studies for evidence of adverse health effects directly attributable to consumption of foods derived from GM crops but found none. As part of this review, a panel of more than 20 scientists, researchers, and agricultural and industry experts reviewed over 20 years of data and based on approximately 900 studies and tests as well as health data from Europe and North America; this select panel concluded that "no substantiated evidence of a difference in risks to human health between currently commercially genetically engineered (GE) crops and conventionally bred crops, nor did it find conclusive cause-and-effect evidence of environmental problems from the GE crops."[107]
- The European Commission funded 50 studies on GM crop safety, involving 400 independent European research groups, covering 10 years of GM crop safety research and more than 1,700 peer-reviewed,

scientific studies. They confirmed the findings of regulatory agencies, concluding that GM crops on the market are as safe as conventional crops.[108]

- Two independent EU-funded studies support the safety of GM corn, but more importantly, they evaluated the rodent studies used in these assessments. These studies conducted research on the scientific value, design, procedures, analysis, and interpretation of animal feeding studies for the risk assessment of genetically modified food and feed. First, the GMO Risk Assessment and Communication of Evidence (GRACE) project[109] was performed to provide input to the European Commission on the need for 90-day animal feeding trials as part of the authorization of GM food and feed. Additionally, the Two-Year Safety Testing (G-TwYST)[110] was initiated in this context but also to address concerns about possible health impacts of GM corn. Neither the 90-day nor the 2-year toxicology studies revealed any health risks of the GM corn tested. The authors also concluded that longer studies are not more informative for this application.[111]
- Another study, GMO90+,[112] was funded by the French government and was designed to identify biomarkers of exposure or health effects in Wistar Han RCC rats fed diets composed of GM corn grains either with or without glyphosate treatment as compared with a corresponding near-isogenic control. No biomarkers of adverse health effect could be attributed to the consumption of GMO diets in comparison with the consumption of their near-isogenic non-GMO controls.

GMOs and Livestock

GM crops like alfalfa, cotton, corn, soybean, sugarbeets, and canola are significant sources of feed for animal agriculture. Even countries that don't allow the cultivation of GM crops (e.g., the majority of EU countries), rely on GM crops as feed to sustain their meat, milk and egg production. GM crops are nutritionally the same as their non-GM counterparts when they are digested and there is no way to test the meat, milk, or eggs to determine if they were from an animal fed GM crops.[113] Regulatory authorities around the world have confirmed the safety of GM crops used for feed. Researchers Van Eenennaam and Young[114] demonstrated through publicly available data that since the adoption of GM crops in the United States, there has not been an apparent change in productivity (production of meat, milk, and eggs), for a total of more than 100 billion broiler and layer chickens, beef cattle, dairy cows, and hogs.

4. Lessons Learned – Modern Agriculture Technologies and Sustainability

// The introduction of GM crops has provided many lessons on how to engage with critical voices.
// Bayer remains committed to continued dialogue.

GM crops were a disruptive technology when they were introduced by industry, and Bayer had to learn the hard way what works and what doesn't when commercializing a novel food technology. The key lesson we've learned as a company is that engagement, especially with critics, matters. We've also learned how to improve our listening and find common ground with those who hold different positions than ours.

While farmers, especially in the Americas, turned out to be extremely receptive to a new technology that enabled them to increase yields, manage weeds and pests, and switch to no-till practices, communication with mainstream society – and even with some NGOs – was hampered by several societal trends:

// Food is an emotional topic

It is no secret that food is one of the most important social symbols and also one that is deeply connected to one's identity. This explains why any information related to food or food safety triggers strong emotions and has contributed to a heightened perception of risk associated with GMOs. In retrospect, we did not fully acknowledge the emotional dimension of the stakeholders who expressed concerns about the safety of GM crops. As a result of this oversight, we have now enhanced our transparency efforts to build up and strengthen trust by making information accessible. (See Chapter 5 for more information.)

// Increased interest in transparency and food origins

The commercialization of GM crops has overlapped with an increased level of consumer awareness of food, its health, and nutritional benefits. This has led to concerns about the safety of GMOs, a scientific subject that was difficult to explain. During initial commercialization of GM crops in the 1990s and early 2000s, Monsanto and others in the industry undertook significant efforts to communicate about GM crops, which were effective at the time. However, as consumer trends leaned further and further in the direction of what was perceived to be a "natural" way of growing food (with no GM crops or crop protection products, such as herbicides and insecticides), often conflated with organic agriculture, the industry stopped engaging in conversations, naively believing that the scientific and regulatory consensus on the safety of GMO would be clear to consumers. This was not effective, and, looking back, additional engagement with consumers and other stakeholders was warranted. With this in mind, we understand that consumers might have questions about where their food comes from and how it is produced.

// Consumers' decreased connection to farming

While on the one hand there is an increased interest in transparency, on the other hand many people have lost touch with agriculture. Consumers in the developed world are used to uniform, fresh, and affordable produce and have little to no insights into the pressures farmers face, including the need to manage weeds, pests, and plant disease. This has led to a growing information gap when it comes to food production and the benefits that science and innovation can deliver in agriculture. Over the past decades, we've come to appreciate the importance of explaining product benefits not just to our direct customers but explaining their implications for society at large in conversations with broader circles of stakeholders. We've learned that when we begin conversations by establishing areas of shared interest and common ground, we can more easily explain the need for GM crops.

After reflecting on the lessons learned, Bayer has enhanced and expanded it outreach and transparency efforts, as described in the following chapter.

5. Transparent Engagement

- Bayer has made a commitment to enhancing our corporate transparency efforts by supplying detailed disclosures on materials, project expenses, research activities, regulatory study reports and collaborations.
- Advisory bodies have been established for guidance and perspective on sustainability efforts, such as the Bioethics Council, Sustainability Council and ESG Committee.
- Dialogue that is regular, constructive, and transparent with customers and stakeholders helps us recognize important trends and developments in society and our markets at an early stage and take this information into account in how we conduct business.

Trust and Transparency

Science and innovation have transformed health and nutrition around the world. In our work, science has allowed us to develop products that can support farmers as they seek to provide enough food for the world. While the science behind modern agriculture is held to rigorous standards, information about how companies test and develop new products has not typically been accessible to the public.

As such, Bayer has made a commitment to continually enhance our corporate transparency efforts[115] throughout many facets of our business, including:

- We make available submissions on our GM crop products that have been assessed by regulators in the United States the US Department of Agriculture (USDA), the Food and Drug Administration (FDA), and the Environmental Protection Agency (EPA). Data to support every GM Crop product that Bayer has commercialized, in any country, has been submitted to the relevant US agencies. The submissions to US regulators are often the basis for submissions to other countries and contain the key safety studies that have been performed on the products and submitted to regulatory authorities around the world. Submissions by product can be found here.[116]
- We increase transparency and visibility of Bayer's innovative research activities within the external scientific community through our Science in Spotlight platform, listing peer-reviewed scientific publications authored by Bayer employees.
- To generate more transparency around our scientific collaborations, we launched the Bayer Science Collaboration Explorer in 2021. In this publicly accessible database, we disclose information on new contract-based scientific collaborations with universities, public institutions, and individuals. The database is currently launched in Germany and the US, with more countries to follow.
- We make detailed disclosures on material and project expenses and headcount of the essential political liaison offices in the transparency registers of the European institutions and the US Congress. We also report data for countries in which there is no legal disclosure obligation.

Innovation is at the core of our purpose: "Science for a better life." Emerging life science technologies are advancing rapidly and deliver the opportunity for disruptive positive impact on society, people, and the environment. Bayer is committed to using emerging technologies in an ethically responsible way within our business and R&D activities. We seek to actively take part in the development of bioethical standards, to engage with society and relevant stakeholders, and to address potential concerns.

Bayer Crop Science Transparency Commitments

As one of the leading life-science companies, we aim to foster an informed and open science-based dialogue on our agricultural innovations. Our transparency commitments are meant to establish a conversation around science, which means listening and responding to questions and concerns from our internal and external stakeholders. We also aim to foster an open and informed dialogue on agricultural innovations by enhancing public access to the process used to assess the safety of our products, so that everyone can see the integrity of our results for themselves. That's why we were the first industry player to launch a dedicated transparency platform in 2017 to enable access to the information behind our science. Through our transparency-focused platform,[117] both interested consumers and the scientific community can access the insights of our work and connect with us and our science. Visitors to our platform can download summarized test results and evaluations that provide information on the human and environmental safety of active substances used in our crop protection products as well as on the safety of GM crops:

- We have made safety study data available[118] for download for 32 active substances used in our crop protection products. This data has been submitted to the European Food Safety Authority (EFSA) for substance approval in the European Union.
- We've enabled online access to key submission documents[119] for 16 traits of our GM crops that have been assessed by regulators in the United States – the US Department of Agriculture (USDA) and the Food and Drug Administration (FDA). We also provide the Study Index, the list of studies provided to the Environmental Protection Agency (EPA) where applicable.
- Upon request, we provide access to full in-depth study reports evaluated by regulators for the authorization of our marketed crop protection and GM crop products.
- In addition to providing downloadable and requestable regulatory safety study documents, our transparency platform also includes large amounts of educational materials[120] that help put regulatory science into context. Our goal is to transform the way we communicate about science so that we can cultivate trust about our products, practices, and innovations.
- Through the OpenLabs program[121] initiated in 2020, we offer the public the opportunity to observe our scientists carry out a safety study in our labs and in the field. One can experience what it means to strictly follow OECD test guidelines and Good Laboratory Practices (GLPs), as well as the procedures that make the Bayer studies reliable, verifiable and reproducible. In addition, one can connect with scientists and experts live and learn more. Dates and registration links are available here.[122]
- We provide access to Bayer's safety standards for our crop protection products starting with our Operator Safety Standards[123] and soon also Bayer's dietary and environmental safety standards.

Advisory Bodies

In the spirit of improved two-way communication, Bayer seeks guidance and perspective on our R&D and sustainability efforts from these advisory bodies:

- We have established an external advisory body – the Bioethics Council – to ensure a broad independent perspective and guidance on complex ethical questions related to emerging life science technologies. The Bioethics Council consists of a diverse group of thought leaders in the field of bioethics, from both medical sciences and agricultural backgrounds, who engage in regular dialogue with Bayer executives and scientists.
- We have established an independent external Sustainability Council[124] that advises the Board of Management and performs other functions on sustainability initiatives, provides guidance on the contribution that Bayer can make with its research and development, and independently examines the progress made by Bayer in the implementation of its sustainability targets.
- Additionally, Bayer's Supervisory Board, the highest internal governance board of the company, has established a dedicated ESG (Environmental, Social, and Corporate Governance) Committee,[125] which focuses on corporate social responsibility and the environmental, social, and corporate governance elements of the company's business activities.

Engagement with Critical Stakeholders

We seek common ground with critical stakeholders and listen carefully to diverse points of view and engage in thoughtful dialogue. This requires that all engagements and communications be truthful and transparent. We respect the independence of journalists and media representatives. Our interactions with media are governed by Bayer's Societal Engagement (BASE) principles. set out in a publicly available Board of management-approved Group regulation, which establishes how we interact worldwide not just with our employees but also with patients, customers, consumers, business partners, political stakeholders, scientists, critics and our stockholders. In this way, we want to live up to our social responsibility as a sustainably acting and transparent company that is respected for its contribution to progress in healthcare and agriculture. We want to listen, understand, take concerns seriously and engage in respectful dialogue – especially where this is difficult or uncomfortable.[126] This means that we engage openly and transparently with media and provide accurate information. Sometimes a scientific article makes claims or provides new information that merits a response or further enquiries, or it may be the origin of a media report where journalists approach Bayer for comment. They have often raised their concerns about different aspects related to GMOs and potential for negative impacts on the environment, farmers, and consumers.

GMOs have been and continue to be intensively studied, with hundreds of scientific papers and media articles published every year. Some critics continue to repeat broad claims without additional substantiation. Although we cannot provide comprehensive responses to all unsubstantiated claims, we try to engage in a scientific and constructive dialogue whenever we can. Our scientists assess new studies and reports and their methodologies thoroughly on their scientific merit, and we aim to provide science-based answers to the questions they raise.

In the past consumers didn't have access to safety studies and had questions about the safety of GM crops. In 2013, companies representing the GM seed industry – at the time, BASF, Bayer, Dow AgroSciences, DuPont, Monsanto, and Syngenta – launched the website and associated campaign GMO Answers.[127] The initiative committed to responding to questions from consumers about how food is grown, with a goal of making information about GMOs in food and agriculture easier to access and understand. Questions could be posed to the website and answered by experts in the field, including experts from academic institutions, NGOs, farmers, physicians, and industry groups. Between 2013 – 2018, when the site was active, over 1,200 questions were posed and answers and are now archived on the website. All questions that were submitted were answered except for repetitive or offensive questions. Questions included those about food and environmental safety, business practices, herbicides, GM food labeling, and GM crops basics. There are also informational videos, infographics, and other educational resources available. As of 2020, GMO Answers is a program managed by CropLife International.

Engagement with Customers

Bayer is proud of its role and contributions to society and public life over and above its investment and developments of innovations in pursuit of our mission of health for all and hunger for none. Ongoing dialogue with our customers, the farmers in the case of the Crop Science division, and related value chain stakeholders is vitally important to us. After all, their needs, expectations, and viewpoints affect our credibility, reputation, and public acceptance and thus our commercial success.

Dialogue that is regular, constructive, and transparent with customers and stakeholders helps us to recognize important trends and developments in society and our markets at an early stage and take this information into account when shaping our business. We launched the Bayer Societal Engagement (BASE) principles[128] in 2019 and gave them status of a corporate policy for implementation by all Bayer employees. These principles serve to codify our standards and values.

In strategic decision-making processes that demonstrate our commitment to governance, stewardship, and responsible use practices regarding new GMO product launches and new precision breeding technology innovations, for example, Bayer proactively approaches our customers and key social and political players right from the start of a new project. Such open dialogue modeled on industry leadership and transparency enables us to identify opportunities and address any perceived risks early on. This process is in line with our Stakeholder Engagement Guideline and is supplemented by an internal information platform.

Through a multi-stakeholder dialogue and the coalition Bayer formed in 2021 with organizations such as the World Bank, the Global Economic Forum, and Grow Asia, we significantly raised societal awareness about the challenges faced by smallholder farmers. For example, we conveyed to governmental organizations the need to enable smallholder farmers, many of whom are in countries with fast-growing populations, to access technology and innovations to measurably improve their living conditions and food security.

The TELA Corn project is an example of our dedicated decade-long work with a public-private partnership to introduce GM corn seed with drought tolerance and insect resistance to smallholder farmers through African seed companies. Drought is a frequent problem in Africa, making farming challenging for farmers whose harvests are dependent on rainfall. Insects present an additional pressure to farmers with limited resources to manage pests. African smallholder farmers often don't have access to affordable quality seed and are highly vulnerable to predatory sales of counterfeit seeds, ultimately jeopardizing their food production quality and quantity. Bayer is working with multiple stakeholders familiar with the seed systems in Africa to lend our expertise and know-how to initiatives to develop more robust and sustainable seed systems in Africa. We also work with the National Agricultural Services of seven African governments plus several non-governmental development organizations to effectively engage with African smallholder farmers to deeply understand their needs and transfer our scientific knowledge to dramatically improve their agronomic practices and productivity.

6. How GM Crops Contribute to Sustainability

- Sustainable agriculture is built on three pillars: it is capable of feeding a growing population while conserving natural resources; it emits fewer greenhouse gases and instead contributes to capturing CO2; and protects biodiversity and helps farmers deal with the effects of climate change. GM technology supports all the pillars of sustainable agriculture.
- Thanks to GM technology, farmland use is more efficient, resulting in the preservation of natural habitats.
- GM technology has contributed to a significant reduction in the negative environmental impact associated with insecticide and herbicide use on the areas devoted to GM crops.
- GM crops allow farmers to use conservation tillage and other conservation agriculture methods as well as have less greenhouse gas emissions to make their farms more sustainable and environmentally friendly.

In addition to contributing to yield increases, which result in more efficient farmland use and therefore less pressure on natural habitats to be converted into farmland, impacting biodiversity, GM crops present a number of other positive impacts, which make food production more sustainable. These benefits need to be understood/viewed under the pressure to produce sufficient food for a growing world population.

Environmental Benefits of GM Herbicide-Tolerant (HT) Crops

In addition to combatting weeds, one of the main causes of yield loss, the adoption of GM HT crops has resulted in environmental benefits, which have been thoroughly documented by Graham Brookes of PG Economics Limited in a series of research studies, as well as by other researchers. A global analysis conducted by Graham Brookes concluded that GM HT crops have resulted in aggregate reductions in both the volume of herbicides used (in terms of weight of active ingredient applied) and the associated field EIQ values[129] when compared with usage on conventional (non-GM) crops in countries like the US, Canada and South Africa, indicating net improvements to the environment. In other countries, primarily in South America, while the net amount of herbicide active ingredient applied to GM HT crops increased, the overall environmental impact, as measured by the EIQ indicator, improved.[130]

At the global level, GM technology has contributed to a significant reduction in the negative environmental impact associated with insecticide and herbicide use on areas devoted to GM crops. Since 1996, the use of pesticides on GM crop areas has fallen by 748.6 million kg (7.2%) of active ingredient relative to the amount reasonably expected if this crop area had been planted with conventional crops. The environmental impact associated with herbicide and insecticide use on these crops, as measured by the EIQ indicator, decreased by 17.3% between 1996 and 2020.[131]

For example, the adoption of GM HT corn has resulted in a reduction in the volume of herbicide active ingredient usage 224 million kg of active ingredient (-6.2%) and an improvement of 7.8% in the associated environmental impact, as measured by the EIQ indicator, between 1996 and 2020.[132] GM cotton delivered a net reduction in herbicide active ingredient use of 38.6 million kg relative to the conventional alternative between 1997-2020 in all GM-adopting countries, except South Africa. This represents a 8.4% reduction in aggregate usage, and, in terms of the EIQ indicator, a 6.9% net environmental improvement.[133]

Benefits of Conservation Tillage

In the last 150 years, 50% of the Earth's topsoil has been lost due to erosion. Historically, plowing or tilling was the tool used by farmers to control weeds. This common method of weed control disturbs the top layer of soil, which is rich in nutrients that are essential for growing plants. HT crops offer the opportunity to introduce weed management strategies without tillage. This allows the soils to more efficiently store nutrients and water and results in better soil moisture, lower carbon emissions,[134] and reduction of soil erosion. The practice can leave some crop residue on the soil's surface to lessen the opportunity for the soil to erode. Because of its positive implications for operating costs and environmental stewardship, conservation tillage is increasing on farms around the globe.[135] Conservation tillage leads to increased carbon sequestration, soil and water conservation, improved soil biodiversity, decreased soil erosion, improved water quality, habitat provision for biodiversity, and enabling the use of cover crops that benefit biodiversity between crop cycles.[136] GM HT crops enable farmers to reduce or eliminate conventional tillage as a method of weed management and instead use techniques such as conservation agriculture (CA), which is applied worldwide in more than 79 countries on a total of more than 180M ha.[137]

Environmental Benefits of GM Insect-Resistant Crops

Between 1996 and 2020, GM IR technology has effectively replaced the insecticides used to control important crop pests. This was particularly prevalent in cotton, which used to be treated extensively with insecticide to manage bollworm/budworm pests.[138] The global insecticide savings from using GM IR corn and cotton in 2018 were 8.3 million kg (–82% of insecticides typically targeted at corn stalk boring and rootworm pests) and 20.9 million kg (–55% of all insecticides used on cotton), respectively, of active ingredient use relative to the amounts reasonably expected if these crop areas had been planted to conventional corn and cotton. In EIQ indicator terms, the respective environmental improvements in 2018 were 88% associated with insecticide use targeted at corn stalk boring and rootworm pests and 59% associated with cotton insecticides. Cumulatively since 1996, the gains have been a 85.4 million kg reduction (41%) in corn insecticide active ingredient use and a 331 million kg reduction in cotton insecticide active ingredient use.[139]

Improved Soil Quality and Soil Biodiversity

Soil management practices can impact soil quality and subsequently soil biodiversity.[140] Soil structure is compromised, as deeper cultivations, like tillage, destroy natural cracks and worm burrows, leading to water logging and surface erosion, especially on sloping fields.[141]

Conservation tillage restabilizes food webs that biodiversity depends on by benefitting soil microorganisms, soil mesofauna, and burrowing animals, and enhancing the diversity of soil organism communities due to the creation of a more favorable habitat.[142] Conservation tillage increases the abundance of beneficial insects and numbers of earthworms and earthworm biodiversity.[143] The significant positive impact of conservation tillage on the abundance of macro fauna groups has been widely documented.[144]

Increasing crop residue in conservation tillage systems increases wildlife cover, and the general rule is that the greater the amount of crop residue a tillage practice leaves on the surface, the better the practice is for birds and small mammals.[145] Therefore, fields employing conservation tillage have a greater biodiversity density of birds and nests for ground-nesting birds than conventionally tilled fields, resulting from improved dietary resources within conservation tillage fields.[146] Increases in crop residues on the soil surface also tend to increase the diversity of small mammals in crop fields.[147]

Reducing Greenhouse Gas Emissions

The ecological footprint of agriculture currently accounts for about 25 percent of greenhouse gas emissions worldwide.[148] The sources of greenhouse gas emissions include cultivation, decomposition of applied fertilizers and organic matter, and irrigation.

At Bayer, we strive to advance a carbon-zero future for agriculture in close collaboration with farmers and global and local players. This applies for the highest greenhouse gas emitting crop systems and in the regions Bayer serves with its products. Therefore, our focus lies on soy and corn in the United States, Brazil, and Argentina; paddy rice in India; and wheat, cotton, and canola in various geographies. To achieve our target, we foster the adoption of climate smart practices and technologies by our farming customers. These include high-yielding crop genetics, crop protection products, precision irrigation systems, soil management tactics through no-till and cover crops, crop rotation, root health, fertilization management, microorganisms and inoculants, a switch to dry-seeded rice, and digital and precision farming tools. GM crops are an essential element of this strategy.

In addition to our commitments to carbon neutrality for our own operations, we aim to enable our farming customers to reduce their greenhouse gas emissions per kilogram of crop produced by 30% through 2030. From 1996 to 2020, the cumulative permanent reduction in fuel use in countries where GM crops have been cultivated has been about 39,147 million kg of carbon dioxide, arising from reduced fuel use of 14,662 million liters. In terms of car equivalents, this is equal to taking 25.9 million cars off the road for a year.[149] GM crops have reduced greenhouse gas emissions by helping farmers adopt more sustainable practices such as reduced tillage, which decreases the burning of fossil fuels and retains more carbon in the soil.

Improved Water Conservation and Erosion Reduction

Growing GM crops helps farmers address water conservation, especially via improved water use efficiency of the GM crop. Improved crop varieties bring farmers better yields per ha planted – producing more "crop per drop" of water used, with the GM crop more efficient at using the water available. Drought-resistant crop varieties, such as Bayer's Droughtgard® hybrid corn, allow farmers to manage the risk of water stress on crops. Where IR varieties are planted, less water is needed.[150]

Where pest-resistant Bt maize is grown in the EU (Spain and Portugal), studies calculate that these crops save some 94.7 million cubic meters of water per year by reducing the volumes of insecticide sprayed and improving the crop-water efficiency of maize production.[151]

Tillage-induced soil erosion was one of the earliest major soil threats faced in agriculture and has a direct impact on water quality and aquatic biodiversity. The success of conservation tillage extensively enabled by GM HT crops, to increase infiltration, reduce runoff, and reduce erosion, is due to less soil compaction, increased crop residue, and increased surface organic matter.[152]

Contribution of GM Crops to Food Production

The estimated net economic farm-level benefit of planting GM crops was $18.8 billion in 2020. For farmers using the technology, farm incomes increase by $261.3 billion for the 1996–2020 period thanks to more productive harvests (72%) and cost savings (28%).[153] This equates to an average farm income gain across all GM crops grown in this period of about $112/ha. The benefits of GM crops are distributed to farmers in developing countries by 52% and to farmers in developed countries by 48%. In the EU, an analysis of 21 years of growing GM IR corn in Spain and Portugal estimates an increase of farmer income of €285.4 million, based on gross margin increases reported by farmers.[154]

In low- and middle-income countries, farmers growing GM crops benefit from productive harvests that bring higher profits.[155]

The importance of agricultural production to rural economies and communities in these countries means that more productive farming can bring less dependence on imports, and potential for increased export revenues. This is likely to have a positive impact on national economies and GDP. For example:

- Indian farmers growing GM IR cotton have helped transform the country from a net importer to a net exporter of cotton.[156]

- An impact analysis of GM IR cotton on farming communities in India shows that growing this crop variety ultimately increased household living standards among smallholder farmers.[157]
- In Sub-Saharan Africa, half of women are employed in agriculture[158] and hand-weeding falls primarily on women. A study showed that in 2007-2008, women in households that grew GM corn spent 10 weeding days (72h) less in their corn fields than their counterparts who planted conventional corn. This freed up smallholder farmer women to pursue other activities at home or in their communities. Compared to their male counterparts, women devote a significant amount of time to other on-the-farm and household responsibilities, which is why they value the time savings provided by the cultivation of GM crops.[159]

A significant portion of farmers worldwide are smallholders living in low- and middle-income countries. GM crops are an important component of the farming "toolbox" that contributes to better livelihoods for these smallholder communities. As the world's leading agriculture company, Bayer committed to support a total of 100 million smallholder farmers in low- and middle-income countries by 2030 by improving their access to agricultural products, services, and partnerships. To achieve this, we are increasing the range of our commercial efforts and strategic initiatives tailored to the needs of smallholder farmers. Our strategy to strengthen smallholder farmers is embedded in our regional commercial strategies.

Crop biotechnology has contributed to global food security. GM crops have improved yields through better control of pests and weeds. For example, between 1996 and 2020, IR crop technology used in cotton and corn has, across all users of this technology worldwide, increased yields by an average of 17.7% for IR corn and 14.5% for IR cotton relative to conventional production systems. Farmers who grow IR soybeans commercially in South America have seen an average 9.4% increase in yields since 2013.[160]

During the period of 1996-2020, crop biotechnology has been responsible for the additional global production of 330 million tons of soybeans and 595 million tons of corn.

Conclusion

Since their introduction, GM crops have had a significant impact on global food production. Farmers around the world have embraced them for their agronomic and economic benefits, and they are now a significant contributor to the resilience of global food supply chains. As importantly, GM crops are one of the key agricultural innovations over the past several decades that contribute to the sustainable intensification of agriculture. By increasing yields on existing farmland surfaces, GM crops reduce the need to expand crop production areas into natural habitats, such as woodlands and forests. GM crop cultivation requires lower inputs of land, water, energy, and crop protection resources. We recognize that GM crops have raised questions among various societal stakeholders and that proactive engagement and transparent communication are necessary to achieve acceptance. We are committed to continuing the dialogue with various groups, understanding gaps and building consensus based on shared values.

Driven by our vision of “health for all, hunger for none”, we believe we can work together to ensure food production while addressing climate change, preserving biodiversity and tackling the interrelated challenges of deforestation. GM crops, as part of our tailored solutions, is one way Bayer is helping people and the planet.

Appendices

Appendix 1: Global Area of Biotech Crops in 2019 by Country

*19 biotech mega-countries growing 50,000 hectares, or more, of biotech crops
**Rounded-off to the nearest hundred thousand. (https://www.isaaa.org/resources/publications/briefs/55/executivesummary/default.asp)

Table 1. Global Area of Biotech Crops in 2019: by Country (Million Hectares)**

Rank	Country	Area (Million Has)	Biotech Crops
1	USA*	72	Corn, soybeans, cotton, alfalfa, canola, sugar beets, potatoes, papaya, squash, apples
2	Brazil*	53	Soybeans, corn, cotton, sugarcane
3	Argentina*	24	Soybean, corn, cotton, alfalfa
4	Canada*	13	Canola, soybeans, corn sugar beets, alfalfa, potatoes
5	India*	12	Cotton
6	Paraguay*	4	Soybeans, corn, cotton
7	China*	3	Cotton, papaya
8	South Africa*	3	Corn, soybeans, cotton
9	Pakistan*	3	Cotton
10	Bolivia*	1	Soybeans,
11	Uruguay*	1	Soybeans, corn
12	Philippines*	1	Corn
13	Australia*	1	Cotton, canola, safflower
14	Myanmar*	0	Cotton
15	Sudan*	0	Cotton
16	Mexico*	0	Cotton
17	Spain*	0	Corn
18	Colombia*	0	Corn, cotton
19	Vietnam*	0	Corn
20	Honduras	<0.1	Corn
21	Chile	<0.1	Corn, canola
22	Malawi	<0.1	Cotton
23	Portugal	<0.1	Corn
24	Indonesia	<0.1	Sugarcane
25	Bangladesh	<0.1	Brinjal/Eggplant
26	Nigeria	<0.1	Cotton
27	Eswatini	<0.1	Cotton
28	Ethiopia	<0.1	Cotton
29	Costa Rica	<0.1	Cotton, pineapple
	Total	**190**	

Appendix 2: List of All GM Developers

Table 2: list of all GM developers
African Agricultural Technology Foundation (AATF)
Agricultural Biotech Research Institute (Iran)
Agritope Inc. (USA)
Agrivida, Inc.
BASF
BASF and Bayer CropScience (including fully and partly owned companies)
Bayer Australia
Bayer CropScience (including fully and partly owned companies)
Beijing DaBeiNong Biotechnology Co. Ltd. (DBNBC)
Beijing University
Bejo Zaden BV (Netherlands)
Central Institute for Cotton Research and University of Agricultural Sciences Dharwad (India)
Centre Bioengineering, Russian Academy of Sciences
Centro de Tecnologia Canavieira (CTC)
Chinese Academy of Agricultural Sciences
Cornell University and University of Hawaii
Cotton and Sericulture Department (Myanmar)
Del Monte Fresh Produce Company
DNA Plant Technology Corporation (USA)
Dow AgroSciences LLC
Dow AgroSciences LLC and DuPont (Pioneer Hi-Bred International Inc.)
DuPont (Pioneer Hi-Bred International Inc.)
EMBRAPA (Brazil)
Florigene Pty Ltd. (Australia)
FuturaGene Group
Genective S.A.
Go Resources Pty Ltd
Huazhong Agricultural University (China)
ICABIOGRAD
INDEAR
Institute of Microbiology, CAS (China)
International Rice Research Institute
J.R. Simplot Co.
JK Agri Genetics Ltd (India)
Maharashtra Hybrid Seed Company (MAHYCO)
Metahelix Life Sciences Pvt. Ltd (India)
Monsanto Company (including fully and partly owned companies)
Monsanto Company and BASF
Monsanto Company and Bayer CropScience
Monsanto Company and Dow AgroSciences LLC
Monsanto Company and Dupont (Pioneer Hi-Bred International Inc.)
Monsanto Company and Forage Genetics International
Monsanto Company and Scotts Seeds
Nath Seeds/Global Transgenes Ltd (India)
National Institute of Agrobiological Sciences (Japan)
Novartis Seeds and Monsanto Company
Nuseed Pty Ltd
Okanagan Specialty Fruits Incorporated
Origin Agritech (China)
PT Perkebunan Nusantara XI (Persero)
Renessen LLC (Netherlands)
Renessen LLC (Netherlands) and Monsanto Company
Research Institute of Forestry (China)
SEITA S.A. (France)
Seminis Vegetable Seeds (Canada) and Monsanto Company (Asgrow)
South China Agricultural University
Stine Seed Farm, Inc (USA)
Suntory Limited (Japan)
Syngenta
Syngenta and Monsanto Company
Technoplant Argentina
Texas A&M AgriLife Research University
United States Department of Agriculture - Agricultural Research Service
University of Florida
University of Saskatchewan
Vector Tobacco Inc. (USA)
Verdeca
Westhoff Vertriebsgesellschaft mbH
Zeneca Plant Science and Petoseed Company

https://www.isaaa.org/gmapprovaldatabase/developerlist/default.asp

Note: A number of these companies are no longer in business or have been acquired by other entities.

Appendix 3: The Most Widely Commercialized Traits by Bayer Confer Herbicide Tolerance and Pest Resistance

Key proprietary GM seed traits

Maize	Soybean	Cotton	Canola	Sugarbeet
SmartStax	Roundup Ready	Bollgard II	Roundup Ready	Roundup Ready
VT Double Pro	Roundup Ready 2 Yield	Bollgard III	TruFlex	
VT Triple Pro	Intacta RR2 Pro	Roundup Ready Flex		
Trecepta	Roundup Ready 2 Xtend	Roundup Ready XtendFlex		
Roundup Ready 2				
DroughtGard				

Appendix 4: Explanation of Allegations on Coexistence and Open Litigation

// At the time of this report's completion, we are unaware of any open litigation claiming cross-pollination/contamination. In the United States, previous legal cases involving cross-pollination were in fact allegations that the US government needed to regulate or assess GM crops more closely or allegations that related to intellectual property concerns rather than cross-contamination. Therefore, we cannot settle any litigation – as requested by rating agencies – because there are no lawsuits.

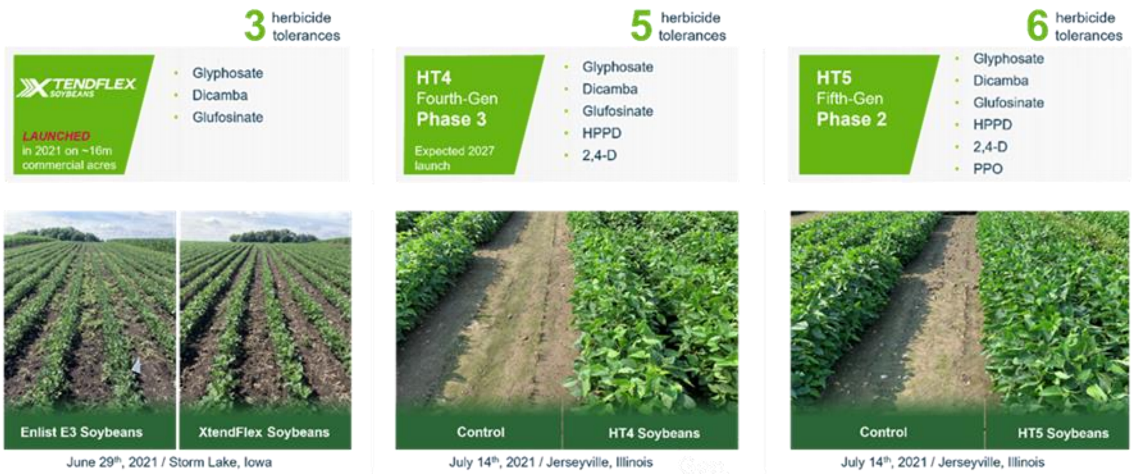
// There have been two court cases alleging an actual or potential failure in coexistence; however, in both cases the complaining party failed to identify a harm that warranted mitigation or compensation.

// The legal cases in North America that actually concern intellectual property (patent) rights (involving saved seed) have at times been misrepresented as failures in coexistence – the practice of growing crops with different quality characteristics or intended for different markets in the same vicinity without becoming commingled and thereby possibly compromising the economic value of both.

Appendix 5: Bayer Next-Generation Traits

Three Generations of Soybean Herbicide Tolerance Traits

Technologies Provide Solutions to Address Farmer's Needs, Herbicide Resistance Challenges



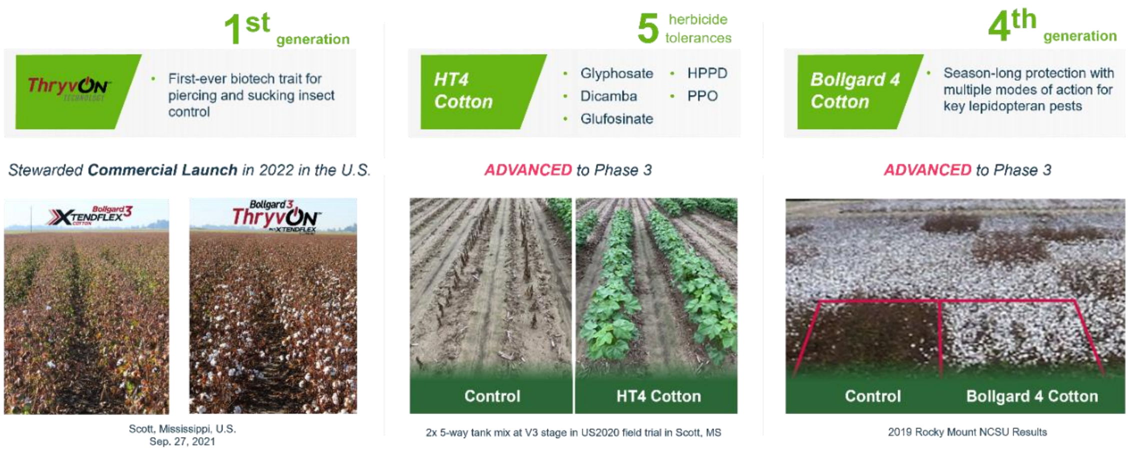
Next-Gen Intacta Traits to Sustain Leading Franchise in Brazil

Intacta 2 Xtend Launched; IP3 Currently in Phase 3, IP4 Advanced to Phase 1

Multiple Traits in Late-Stage Development for Cotton Farmers

Leading Innovations for Cotton Growers Driving Growth in >€500m[1] Cotton S&T Business

[1] 2020 cotton seed & trait sales for Bayer Crop Science



Appendix 6: Human/Animal Health

The American Medical Association, the Society of Toxicology, the International Life Sciences Institute, the National Academy of Sciences in the United States, the Royal Society of the United Kingdom, the World Health Organization, the French Academy of Medicine, the FAO, and the European Union Commission. Is GM food safe? https://axismundionline.wordpress.com/2014/11/18/the-new-is-gm-food-safe-meme/

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