Agrochemicals
& commercial seeds

Agrochemicals/Pesticides: Companies in the agrochemical sector manufacture and sell pesticides used in agriculture. ETC Group uses the word "pesticide" as a synonym for "agrochemical." The words "herbicide," "insecticide" and "fungicide" refer to different types of agrochemical products (weed killers, insect killers and chemicals used to destroy fungus, respectively). In the wake of recent mega-mergers, at least five of the leading pesticide companies also dominate the world market for commercial seeds and traits. With the commercialization of molecular biotechnologies in the mid-1990s (e.g., herbicide-tolerant genetically modified plants), the pesticide and seed sectors became inextricably linked. Today they are being further linked by Big Data strategies.

Leading Companies by Agrochemical Sales, 2020

Ranking	Company /Headquarters	Agrochem Sales $US millions	% Global Market Share
1.	ChemChina + SinoChem[1] (China) *pro forma* (Syngenta Group)	15,336 11,208 (Syngenta Group) + 4,128 (ADAMA)	24.6
2.	Bayer[2] (Germany)	9,976	16.0
3.	BASF[3] (Germany)	7,030	11.3
4.	Corteva[4] (USA)	6,461	10.4
	TOTAL TOP 4	**38,803**	**62.3**
5.	UPL[5] (India)	4,900	7.9
6.	FMC[6] (USA)	4,642	7.4
	TOTAL TOP 6	**48,345**	**77.6**
7.	Sumitomo Chemicals[7] (Japan)	4,010	6.4
8.	Nufarm[8] (Australia)	3,491	5.6
9.	Jiangsu Yangnon Chemical Co., Ltd.[9] (China)	1,413	2.3
10.	Shandong Weifang Rainbow Chemicals Co.,Ltd.[10] (China)	1,048	1.7
	TOTAL WORLD MARKET	**62,400**	**100%**

Source: ETC Group

The global market for agrochemical products was US$62,400 million in 2020.[11]

- ChemChina accounts for one-quarter of the global pesticide market – a share that is likely to expand rapidly following the 2021 merger of ChemChina + SinoChem (see below).
- Top 2 global pesticide market = 41%
- Top 4 global pesticide market = 62%
- Top 6 global pesticide market = 78%

Commercial Seeds & Traits: The seed sector refers to crop seeds (primarily proprietary field crop and vegetable seeds) sold via the commercial market and genetically modified crop traits. However, ETC Group's definition excludes farmer-saved seed and seed supplied by governments/public institutions. Despite the astonishing level of corporate concentration in the global commercial seed sector, the vast majority of the world's farmers are self-provisioning in seeds, and farmer-controlled seed networks still account for an estimated 80-90% of seeds and planting material globally.[12] Over the past 40 years, the world's largest agrochemical firms have used intellectual property laws, mergers and acquisitions (M&As) and new technologies to take control of the commercial seed sector. Today, pesticides and commercial seeds are no longer distinct links of the industrial food chain. However, ETC Group continues to provide corporate rankings and market share for seeds and agrochemicals as *separate* sectors. The 'pure-play' seed company (that is, a company that focuses primarily on seeds) is a rarity among the leading companies. Vilmorin (#5) and KWS (#6) are exceptions.

Leading Companies by Seeds & Trait Sales, 2020

Ranking	Company /Headquarters	Seeds & Trait Sales $US millions	% Global Market Share
1.	Bayer[13] (Germany)	10,286	23
2.	Corteva Agriscience[14] (USA)	7,756	17
3.	ChemChina/ Syngenta[15] (China)	3,193	7
4.	BASF[16] (Germany)	1,705	4
5.	Groupe Limagrain/ Vilmorin & Cie[17] (France)	1,684	4
6.	KWS[18] (Germany)	1,494	3
	TOTAL TOP 6	**26,118**	**58**
7.	DLF Seeds[19] (Denmark)	1,153	3
8.	Sakata Seeds[20] (Japan)	648	1.0
9.	Kaneko Seeds[21] (Japan)	570	1.0
	Total World Market	**45,000**	**100**

Source: ETC Group

According to Jonathan Shoham, Senior Analyst, IHS Markit, the global market for seeds and traits reached $45,000 million in 2020.[22]

- The top 2 companies control 40% of the global seed market.
- The top 6 companies control 58% of the global seed market.

Trends: chew on this

The global pesticide economy is undergoing tectonic shifts. The world's largest agrochemical/seed firms are racing to fortify their oligopoly power with ongoing consolidation, and feverish investments in high tech and digital platform technologies that are designed to extend their market share. Here ETC examines four, inter-related trends:

- **SuperSized Consolidation: ChemChina + SinoChem = Industrial Ag's Newest Input Empire**
- **Post-Patent & Generics Drive Pesticide Proliferation**
- **Big Ag's Digital Turf Grab**
- **New Techno-Fixes: 1) Gene Editing; 2) RNA Pesticide Sprays**

Supersized Consolidation: Chemchina + Sinochem = Industrial Ag's Newest Input Empire

The long-expected merger of **SinoChem** and **ChemChina** (both state-owned) was finalized in early 2021. The colossal Chinese merger creates not only the world's largest chemical conglomerate, but also the leading industrial farm input business (seeds, pesticides and fertilizer assets) — all under the umbrella of the newly formed Syngenta Group. As a result of the merger, annual sales of the new Syngenta Group (which consolidates all of ChemChina and SinoChem's ag input assets), will approach an estimated US$27 billion.[23] The mega-merger is likely to spur even greater industry consolidation both within China and beyond.

In response to a surging demand for food (especially animal protein), a rapidly expanding middle class, and a diminishing pool of farm labour (80% of China's population will live in cities by 2050[24]), China is revving up domestic food production with a full-throttle embrace of high-tech, industrial agriculture and chemical-intensive inputs.[25] With the acquisition of Swiss-based Syngenta in 2017, the Chinese state aims to ensure that a greater proportion of its industrial farm inputs, agribusiness technologies and intellectual property are China-owned and sourced, while simultaneously expanding export markets with a global reach.[26]

Over the past 20 years, China has become the economic center for global pesticide production, use and export.[27] Since 2008, Chinese pesticide exports grew 14% per year. Today, China manufactures more pesticide active ingredients than the U.S. or the E.U..[28] Chinese companies have traditionally focused on cheaper ways to manufacture off-patent ag chemicals, rather than invest in costly R&D to develop new active ingredients. **But now, China is leading on all fronts. In addition to being the world's leading manufacturer of off-patent and generic pesticides, the Chinese state owns a multinational ag input powerhouse (Syngenta) with R&D muscle and a global presence.**

China's Ag Input Empire: The union of **SinoChem** and **ChemChina** creates the world's largest industrial chemicals group, with estimated revenues of about US$153 billion per annum[29] and 200,000 employees.[30] The state-owned conglomerate operates oil and gas exploration and production, oil refining, trading and marketing, agricultural inputs, chemicals, real estate, and financial services business. Guided by its company motto, "in science we trust,"[31] SinoChem's agriculture division focuses on fertilizer (Sinofert Holdings Co.), and seeds (China National Seed Group Co.) and a rapidly expanding pesticide portfolio.[32] SinoChem already owns two national level pesticide R&D centers, Shenyang Research Institute of Chemical Industry (SYRICI) and Zhejiang Institute.[33] In February 2021 Syngenta announced plans to build a US$230 million R&D centre in the eastern Chinese city of Nanjing that will focus on digital agriculture, chemical pesticides and biologicals.[34] As a result of the merger, annual sales of the new Syngenta Group (which consolidates all of ChemChina and SinoChem's ag input assets), will approach an estimated US$27 billion.[35] Following a series of mergers and acquisitions, the newly-created Syngenta Group is straining under a heavy debt load.[36] To raise money, ChemChina announced plans to sell a 20% stake in Syngenta Group in an initial public offering (IPO) on Shanghai's STAR Market in late 2021,[37] but the IPO was temporarily suspended.[38]

Post-Patent & Generics Drive Pesticide Proliferation

Among the most significant trends in industrial farm inputs: the meteoric rise of off-patent and generic pesticides, especially in the global South.[39] The explosive growth of generic pesticides was fueled by the expiration of patents on best-selling pesticides (especially Monsanto's glyphosate herbicide, in 2000).

During the same time period (2000-2020), multinational agrochem giants have been slower to develop new active ingredients for proprietary, high-value chemical products.[40] The lag in innovation by multinational agrochem/seed giants is, in large part, explained by the spiraling costs of bringing a new active ingredient to market.[41] But economists also note that giant corporations operating in highly concentrated markets may have less incentive to innovate and invest in R&D.[42] Moreover, with breakthroughs in ag biotech in the late 1980s and 1990s, the agrochem/seed giants pursued a *different* innovation pathway – opting to invest R&D in the genetic engineering of proprietary seeds that obliged farmers to buy more of the company's agrochemicals.[43] Herbicide tolerance, the trait found in the vast majority of all genetically engineered crops worldwide – is a classic "technological lock-in" that is designed to entrench chemical dependence in agriculture and amplify market power.

With adoption of herbicide tolerant crops and massive use of chemical weedkillers (on both genetically engineered [GE] and non-GE crops), more than 250 weed species across 70 countries have evolved resistance to at least one herbicide formula,[44] leading farmers to spray more frequently or use multiple weedkillers. Taking just one example: in 1990, U.S. farmers applied an average of 1.8 herbicide sprays to each acre of corn. By 2018, farmers sprayed 3.4 herbicides, on average, per acre of corn.[45] In 2021 Bayer introduced XtendFlex soybeans that are engineered with triple chemical tolerance (to glufosinate, glyphosate, and dicamba herbicides).[46] And if that genetic arsenal doesn't pack a lethal punch, Bayer plans to develop six-way herbicide tolerant crops by 2030.[47]

Over the past 25 years, as patents on blockbuster proprietary products began to expire, more nimble pesticide manufacturers – especially in China and India – have created huge markets by churning out cheaper formulations of post-patent products. Generic agrochemicals overtook proprietary and off-patent pesticides for the first time in 2002, and the cheaper off-patent and generic products have dominated the global market ever since.[48] By the end of 2013, off-patent products accounted for more than 77% of the total pesticide market, and that share has continued to grow an average 2% to 3% each year.[49] Today, China supplies almost half of all herbicide global exports, with glyphosate chief among them.[50] India's herbicide exports (largely glyphosate) grew 19% per year between 2003 and 2015.[51] Notably, the world's fifth largest agrochemical firm, UPL Ltd. (India), derives 71% of its 2021 FY revenues from generic pesticides.[52]

According to industry analysts, between 2017 and 2023, patents will expire on more than 100 agrochemical products – valued at US$11 billion.[53] Although multinational pesticide giants have been slower to innovate with new active ingredients, they've managed to bolster their oligopoly market power, in part, by reformulating existing active ingredients into "profitable agrochemical cocktails."[54] The multinational giants also rely on negotiating strategic licensing deals, including access to registration data, for their products that will soon go off-patent.[55]

The bottom line: In recent years, hundreds of generic manufacturers, especially in China and India, have produced a global glut of pesticides that has helped to drive down the price of many agrochemicals.[56] Indiana University professor Annie Shattuck offers a profoundly disturbing but vital assessment of today's on-the-ground (and in-the-soil) reality: "The structure of global trade and underlying transformations in agrarian life have every bit as much to do with creating a toxic agriculture as any single corporation. The post-millennial global pesticide regime is one in which pesticide use is ubiquitous and its impacts are broadly illegible. As capitalist farming continues to expand around the globe, agrichemicals are traveling with it…Agriculture is becoming even more dependent on pesticides, not less, especially in the Global South." – Annie Shattuck, 2021[57]

Bayer's Remorse Continues: Monsanto may be history, but its legacy of contaminating human health and the environment lives on.[58] Bayer acquired Monsanto for a whopping US$63 billion in 2018, and continues to pay the price. Bayer has been forced to commit US$11.6 billion – plus another US$4.5 billion[59] toward future claims – to settle around 125,000 existing claims and lawsuits by users of Roundup (generic name: glyphosate) who allege that the Monsanto products caused their non-Hodgkin's lymphoma.[60] The tragedy, of course, is that due to generic knock-offs, glyphosate exports and use have proliferated throughout the global South. However, numerous local jurisdictions and countries (e.g., Mexico, Vietnam, Germany) have initiated plans to restrict, phase out or ban glyphosate products.[61]

Big Ag's Digital Turf Grab

The world's largest agrochemical/seed firms have fortified their market control via consolidation and mega-mergers; now they are feverishly investing in high-tech and digital technologies that can further expand their already-solid oligopoly. They are not alone; other corporate titans, sitting atop their own sectors – fertilizer giants, ag equipment manufacturers, big tech – are muscling their way into the digital ag arena.

In the past half-decade, the biggest players in global agriculture consolidated to produce the Fat Four (Bayer, Corteva Agriscience, Syngenta Group/ChemChina, BASF) amid a dramatic onslaught of digital technologies that invite – almost require – cross-sectoral convergence. **"Data is the new soil"** – now a common metaphor to suggest digital information's ubiquitous and foundational role – also points to the reality that Big Data is becoming the prerequisite, the milieu and the means of producing agricultural commodities. The world's biggest data companies – Apple, Alibaba, Amazon, IBM, Google, Baidu, Microsoft, among others – are now tightly entangled with industrial food production.

The reach of digital food and ag is rapidly expanding to peasant and smallholder agriculture in the global South.[62] Digital technologies offer new forms of control and value extraction that threaten to further usurp farmer autonomy and decision making while facilitating and expediting a new era of land grabbing.[63]

Big Data down on the farm can include historical as well as real-time and predicted weather information and crop yields, commodity market information, units of seeds bought and planted, input prices, fertilizer dosage, plot measurements and mapping, soil nutrient levels, soil carbon levels, crop moisture levels, etc. The data is collected, stored, and analyzed with the help of algorithms to make automated on-farm decisions that are touted to improve efficiency and increase profitability. Driverless car technologies, face recognition technologies, robotics and artificial intelligence, machine learning, drone technologies, imaging and sensing technologies, cloud computing, blockchain technologies, mobile apps and more all play a role on the world's biggest industrial farms.

The justifications for using Big Data to advance and ultimately realize "precision agriculture" are already familiar and vary little from the arguments pushing for the acceptance of GMOs more than a generation ago: we are told that food production is inefficient, unpredictable and imprecise and so we must leverage newly-available technologies to produce more food more reliably (i.e., increase yields) for a growing global population – without increasing the need for land and while reducing negative environmental impacts from agriculture.[64] Data-driven decision-making, it is claimed, will allow farmers to increase yields even while reducing herbicide- and fertilizer-use because input-prescriptions will be meticulously accurate, down to the level of the field, the row, and even the individual plant. These automated prescriptions will, ostensibly, save farmers time, money and labour – and the environment wins, too.

Always More Room for Profit: Critics of Big Ag are rightfully dubious that the world's largest input producers are working hard to find ways to sell less product. We can be sure, in any case, the Fat Four won't sacrifice profitability and they will aim to offset reductions in traditional input sales – if, indeed, there are any reductions[65] – with increased sales of other products, which may include 'tailored' or site-specific inputs developed using collected, on-farm data. As Mao Feng, chief brand manager for Syngenta Group's MAP (digital agriculture platform in China, see Table below) explains: "Before, we sold pesticides, seeds and fertiliser. Now we're a farm services company – we sell service and technology…selling individual products, we had hit the ceiling, there was no more room."[66] The new business model is vertical integration under the rubric of farm management services: instead of limiting sales to seed plus a linked-herbicide (Roundup Ready corn seed and Roundup, for example), seed/pesticide firms are now selling (the promise of) high-yielding, weed-free, bug-free fields.[67] To that end, the products for sale may include data-driven input recommendations by a company-linked consultant/agronomist (increasingly referred to as a "trusted advisor"),[68] modelling of potential profits based on predicted weather plus the application of additional proprietary products, soil sampling via in-field sensors and field-scouting via drone on a fee-per-pass basis,[69] etc. The aim is not to profit, necessarily, from the sale of digital tools or app subscriptions – BASF's xarvio Field Manager app, for example, is free to download from the App Store; the aim is to sell data-driven farm management services – including traditional inputs – while collecting valuable on-farm data.

Every leading agrochemical company offers its own digital ag platform marketed to farmers as a way to transform on-farm data into savings that will ultimately increase farm profitability. The Holy Grail, they say, is a **"farm of one,"**[70] where a single farmer/data manager (equipped with many thumbs, perhaps?) can log on to a connected device, watch as the algorithms calculate input prescriptions – based on data collected from in-field sensors and hyperspectral imaging – and then send those prescriptions to a fleet of contracted drones that will dump herbicide, fungicide, fertilizer, growth regulator or other input in a just-right dosage for each plant growing in the field. Post harvest, the farmer can supposedly sit back and enjoy the profits from increased crop sales and reduced labour costs – as well as from payments for 'carbon sequestration' verified by traceability data collected and stored on a blockchain.

However, like varieties of breakfast cereals, there are already a dizzying number of digital ag platform names, tie-ins, co-branding, giveaways and corporate partnerships, blurring the lines between owners and partners.[71] That lack of clarity has added to farmers' already significant wariness about handing over their farm data via digital ag tools.[72] In the context of industrial agriculture, farmers know that competing industrial ag peers, market speculators, commodity traders, landowners/buyers and input developers could all benefit from access to on-farm data related to soil quality, inputs, weeds, pests and yield.[73] If Big Ag companies can't overcome these 'trust challenges,' they will try to sweeten the pot in other ways (see below). The following table presents the biggest seed/agrochemical companies with a sampling from their ever-expanding menu of digital ag services.

Digital Ag Bumper Crop or Data Boosting Product Cross-Fertilization?

Syngenta Group (ChemChina)	
Digital Ag Platform	**AgriEdge**; **Cropio** (E. Europe); **Cropwise** (Brazil); **Modern Agricultural Platform – MAP** (China, developed by SinoChem Agriculture, has on- and off-line components).
Some Components	**Ag Connections** (Syngenta subsidiary, farm management software); **Farm-Shots** (Syngenta subsidiary, satellite imagery); **Land.db** (software for data collection, analysis – USA); **Cropwise Protector** (operations management, data analysis) and **Cropwise Imagery** (satellite remote sensing – both in Brazil); **MAP Zhinong** for field crops and **MAP Huinong** for cash crops (China); **ADAMA** (part of Syngenta Group) **Eagle Eye** (drone analytics platform, **Agremo** technology).
Inter-Operability, Collaborations	**FarmShots** integrated with **Sony's Smart Agricultural Solutions**; **AgriEdge** integrated with **Nutrien's Echelon** (fertilizer) precision ag tool; **Land.db** integrated with **Simplot Grower Solutions** and with **Truterra Insights Engine** (USA); **Ram Trucks** (USA; a new truck = one-year free subscription to **AgriEdge**); **Syngenta MAP** collaborating with **Dole** (and with **Disney** to market two Disney-branded tomato varieties).
Bayer	
Digital Ag Platform	**Climate FieldView** (Monsanto asset) in N. America, S. America, Europe (including Germany, France, Spain, Italy and Ukraine); **Climate FarmRise** (digital app in India).
Some Components	**FieldView Drive**, **Precision Planting 20/20, SeedSense** and **YieldSense** (monitors for data-collection and -sharing); **Digital Mapping** of soil, cloud cover, seed population-to-yield; **Seed Scripts** (seed placement); **Seed Advisor** (corn seed selection and placement); **Disease Risk Modelling**, **Fertility Scripting** (input timing and rate recommendations).
Inter-Operability, Collaborations	**Bayer's** Friends with FieldView web page lists **60+ collaborating companies**, big and small, whose digital services are integrated with or connected to **Climate FieldView:** imaging, sensor, farm management, farm machinery, soil analytics, "profit mapping" (e.g., **Ag-Analytics**) and farm insurance companies; collaboration with **TraceHarvest Network** (**BlockApps** blockchain, China, Brazil and USA) and collaboration with **Ant Financial** (blockchain, China); collaboration with **Biome Makers** (AI virtual assistant in development – input recommendations and yield predictions using soil microbiome and environmental data); research partnership with **XAG** (ag drones) in South East Asia and Pakistan, Japan; part of **AGROS,** collaboration between **Wageningen University & Research and 26 private partners**, including **BASF** and **Kubota** (autonomous growing); strategic partnership with **Rantizo** (drone integration software using **DJI** drones).

BASF	
Digital Ag Platform	**BASF Digital Farming**; **xarvio Digital Farming Solutions**.
Some Components	**xarvio Field Manager** (mobile app, real-time field information, recommendations); **xarvio SCOUTING** (app to identify weeds/diseases)**; GrowSmart Advantage Tool** (USA, uses farm data to estimate the monetary advantage of using BASF products).
Inter-Operability, Collaborations	**Salient Predictions** (long-range weather forecasting) integrated into **xarvio**; **BASF Digital Farming** joint venture with **Bosch** selling two products**: Intelligent Planting Solution (IPS)** (seed, fertilizer prescriptions) and **Smart Spraying** (camera sensor with **xarvio**); collaboration with **Bosch** (Curitiba, Brazil, targeted fertilizer application and seed placement); **BASF Vegetable Seeds**, part of **AGROS,** collaboration between **Wageningen University & Research and 26 private partners**, including **Bayer** and **Kubota** (autonomous growing); partnership with **Hoogendoorn Growth Management** (autonomous growing, software and hardware); collaboration with **Zen-noh,** farmer co-op in Japan (farmer alert system); agreement with **AGvisorPRO** (agronomic advisors for xarvio users, Canada); **xarvio SCOUTING** integrated with **Nutrien Ag Solutions** (fertilizer prescriptions); **xarvio SCOUTING** integrated with **WinField United's ATLAS** digital platform; **xarvio Field Manager** integrated with **senseFly's eBee X** fixed-wing drone platform.
Corteva Agriscience	
Digital Ag Platform	**Granular**
Some Components	**Seed Prescriptions; Directed Scouting; Fertilizer Management; Nitrogen Monitoring; Pioneer seed App**; **Pioneer Yield Pyramid decision tool; Corteva Flight** (stand assessments for corn, sunflower, lettuce; gap analysis, soybeans; **Carbon and Ecosystem Services portfolio** (agronomy support, carbon advisory services and access to carbon markets).
Inter-Operability, Collaborations	**DroneDeploy** (field monitoring software, used in **Corteva**'s 600 drones and by the company's 1000+ drone pilots).
UPL	
Digital Ag Platform	**nurture.farm** (India, pilot projects in the U.S., South Africa, Brazil and Australia).
Some Components	**Cultiv-e platform** (Brazil, info sharing with UPL customers about soybean diseases, highlighting two UPL fungicides).
Inter-Operability, Collaborations	Collaboration with **TeleSense** (AI platform to monitor condition of stored grain – relevant for sale of UPL's fumigant pesticides); collaboration with **Taranis** UAS **FlyUP** (Brazil, aerial mapping of weeds, diseases in sugarcane fields and herd monitoring in pastures).
FMC	
Digital Ag Platform	**Arc farm intelligence**
Some Components	Mobile app action alerts; connection to **FMC** agronomists; uses open API (app interface) that allows **Arc** to work with other companies' digital ag tools; **Pest Pressure Dashboard** (predictive modelling and analytics).
Inter-Operability, Collaborations	Investment in **Scanit Technologies;** partnership with **Scanit** to use its **Spore-Cam** wireless sensor in Brazil to analyze Asian soybean rust; partnership with **Nutrien Ag Solutions** (sending data from **Arc** to **Nutrien's** pest control advisors (California); partnership with AI developer **Shenzhen SenseAgro Technology Co., Ltd**. (China, Fall Armyworm identification and control with **FMC** products).

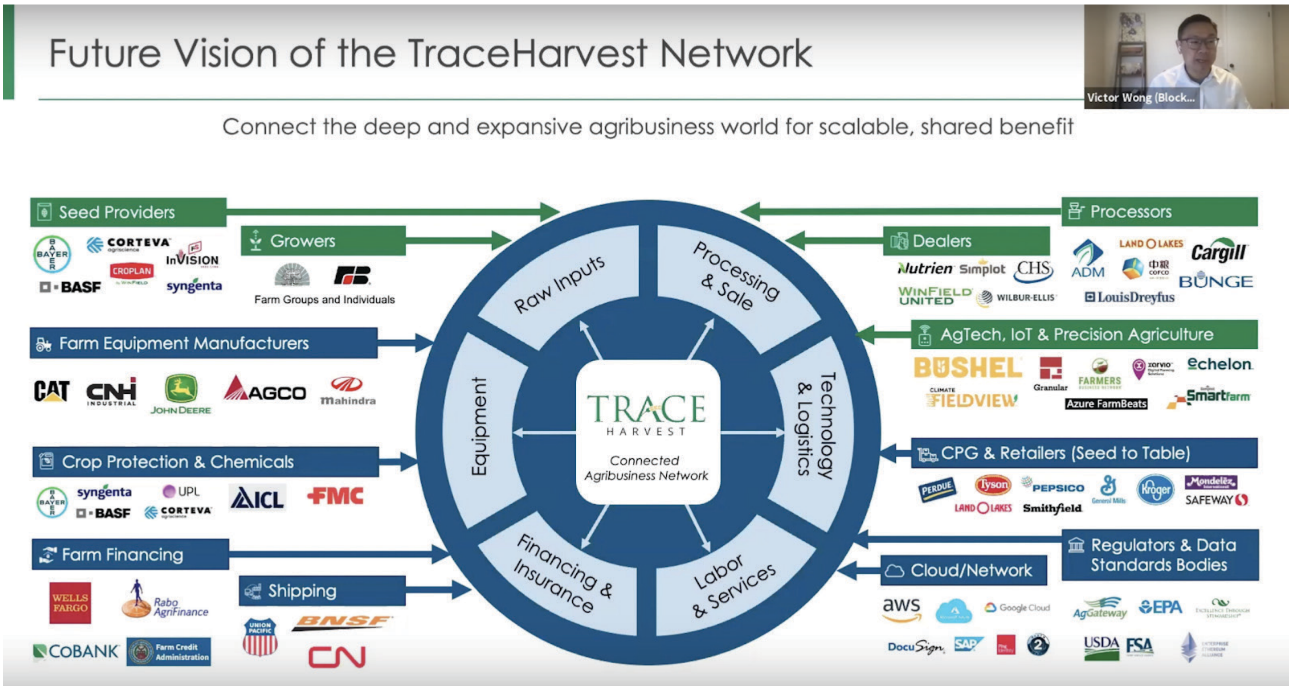
Sources: ETC Group; Yating Jiang, "Rising to Transform Agricultural Production – How Agrochemical Titans Unlock the Potential of Digital Agriculture," 09 March 2021, AgroPages: http://news.agropages.com/News/NewsDetail---38263.htm.

“[Block]Chain, Chain, Chain… You got me where you want me…” When **Bayer** joined forces with blockchain platform company **BlockApps** to create a digital, global replacement for ‘high friction manual tracking’ in the ag sector, they came up with the “highly scalable”[74] **TraceHarvest Network**. The blockchain uses Amazon Web Services (AWS) cloud and computing infrastructure and will follow agricultural products all along the food chain from seed source to grocery shelf (or front door). The advantage of using blockchain’s electronic ledger technology, say its promoters, is that every transactional record (e.g., contract, input purchase, sale, transport, delivery) is secure, time-stamped and authenticated; and it’s impervious to tampering because the blocks are transparent – everyone on the blockchain platform sees each transaction as it happens, in real-time.[75]

The vision for the TraceHarvest Network (see image, below) is to one day bring every big commercial player (and regulatory entity) active in the industrial food system on to one common digital platform – inputs, equipment, technology, processing, retailing, financing, logistics. Why? According to Stan Dotson, who joined BlockApps as a Senior Advisor in early 2021 after 30+ years at Monsanto (plus two years working for Bayer as VP of Digital Strategy and Transformation), Big Ag is under threat from “consumer backlash” due to a “trust crisis.”[76] High-profile food safety recalls have resulted in consumers favouring local and/or known producers. (In the same breath, Dotson also laments the “irrational preferences” of consumers who want their food “free-from-everything.”[77]) He sees blockchain, and TraceHarvest Network in particular, as a way to counter the buy-local, know-your-farmer trends. If blockchains are perceived to be verifiable and tamper-proof – some refer to digital transactions stored as blockchained data the “Single Source of Truth” (SSoT)[78] – then TraceHarvest can help Big Ag overcome its “trust challenges” with consumers. In fact, some blockchains have been breached and are vulnerable to cybercrime.[79]

Big Ag’s Recipe for CarbonEra? Tracing food back to its seed source is just one “use-case” for TraceHarvest, however, on its FAQ page, TraceHarvest claims its blockchain technology “promotes both sustainability and consumer well-being through solutions including carbon offset crediting, outcome-based pricing, and safer, faster food recalls.”[80] The focus on safer food recalls, rather than safer food, reveals a great deal about Big Ag’s thinking. Tracing carbon may turn out to be TraceHarvest’s most useful use-case for the agrochemical/seed company that helped design it. While Bayer piloted its own limited program in 2020 in Brazil and the U.S. – paying farmers to adopt so-called climate smart farming practices (e.g., no till or cover crop) – actually verifying increases in soil carbon wasn’t part of the program. The terms for participation in Bayer’s carbon program were a requirement to plant corn or soybeans, having an active “FieldView Plus” digital ag account and agreeing to share relevant farm data.[81] It was assumed that following Bayer’s recipe would result in increased soil carbon; however, greenhouse gas emissions from energy-hungry blockchains or from data transport, storage and processing are not accounted for.

In tandem with, and under the umbrella of digital ag services, carbon credit schemes for farmers have proliferated in the last half-decade, particularly in Europe and the U.S..[82] So far, carbon market schemes for agriculture are in early stages with both big and small players: startups Nori (U.S.) and Indigo Ag (U.S.), Soil Capital (U.K.) and Soil Heroes (Europe and U.K.) are competing with Bayer, Corteva and Nutrien. The U.S.-based Ecosystem Services Market Consortium (ESMC) will launch a nation-wide carbon market in 2022. Bayer, Syngenta and Corteva were early ESMC partners and have pledged financial support.[83] They are also helping to create the methods "to measure, verify and monetize increases in soil carbon," reductions in greenhouse gas (GHG) emissions, and improved water quality in agriculture. Despite Big Ag's shadow looming over ESMC, it claims to be an independent, non-profit, third-party provider of soil carbon verification. With data-sharing a sticking point for farmers but a crucial need for Big Ag to sustain its new business model, carbon payouts could be the way to bring farmers around and overcome its many "trust challenges."



(Source: BlockApps webinar, 2020[84])

New Techno-Fixes: gene editing and RNA-based pesticide sprays

If the pesticide/seed industry giants can take dominant positions in digital farming platforms and a new generation of gene editing and/or RNA pesticide technologies, they are poised to capture new platforms that could provide new technological 'lock-ins' – obliging farmers and end-users to adopt a new and expanded menu of proprietary ag inputs and digital services.[85]

Faced with expiring patents, herbicide-resistant weeds, the rise of generic pesticides, and efforts by some governments (especially the EU) to rein in chemical toxins, agrochemical/seed giants are looking to fortify their oligopoly power with the rollout of novel, proprietary genetic technologies, most prominently :gene editing and RNA-based pesticide sprays. Although these technologies involve very different techniques, they both seek to concentrate corporate power and reinforce industrial agriculture. There are striking similarities in the way they are being introduced and promoted:

- The biotech industry touts them as tools that will bring faster, precise and highly predictable changes to the genomes of plants, animals and microbes.
- To win consumer acceptance and avoid any association with GMOs, industry insists that neither technology involves the use of genetic engineering (transgenic technology) and therefore must not be subject to GMO regulations.
- In their haste to attract investors and bring to market 21st century techno-fixes, corporate labs and start ups scarcely acknowledge huge knowledge gaps and associated risks.

We look at these in more detail below.

1. Gene editing: Biotech's Silver Bullet for Food & Ag

What is gene editing?

Genome editing techniques are a form of genetic engineering (GE) used to alter the genetic material of an organism, plant or animal (including humans) by inserting, deleting or changing the DNA at a specific target site in the genome. A number of genome-editing technologies are currently being used in food and agriculture. The most well-known among these is the CRISPR-enzyme system (e.g., CRISPR-Cas9, CRISPR-CPF1, etc.) CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, and DNA-cutting enzymes are generally called nucleases. Other gene-editing technologies include TALEN (Transcription activator-like effector nucleases) and ZFN (Zinc finger nucleases). CRISPR-Cas9 made headlines outside scientific circles in 2020 when the scientists who discovered it (Jennifer Doudna and Emmanuelle Charpentier) won the Nobel Prize in Chemistry.

In the food and agriculture arena, Big Ag multinationals and small tech start-ups tout gene editing as a fast, precise and predictable breeding technology that will rapidly deliver "innovative" traits – from non-browning mushrooms to waxy corn to fungus-resistant wheat with fatter grains.[86] Not surprisingly, the first gene-edited crop commercialized in North America was herbicide-tolerant – a canola variety developed by Cibus, which can withstand a dousing of an herbicide manufactured by the Canadian company Rotam. (The product was introduced as an alternative to Roundup Ready canola after Monsanto's herbicide stopped working when weeds became resistant to it.) In an odd about-face the company later claimed their product was not gene-edited at all.[87]

Beyond applications in plants, CRISPR is also being widely developed for gene-editing in livestock (e.g., pigs, cows, sheep, goats and chicken), insects and microbes (to boost productivity, soil fertility, disease resistance, and more).[88] If that extensive tinkering sounds worrisome, headlines like these are designed to demolish any obstacles to public acceptance:

"Crispr Can Help Solve Our Looming Food Crisis" – *Wired* (i.e., transform the food supply to one that can survive the ravages of climate change).[89]
"Can Gene Editing Save the World's Chocolate?" – *National Geographic* (i.e., climate tolerant and disease-resistant cacao)[90]
"Why Gene Editing Is A Climate Change Solution" – *Seed World* (i.e., reduce greenhouse gas emissions, capture carbon, and make crops more resilient to the impacts of climate change)
"Gene Editing Could Protect Your Favorite Foods" – *Innovature* (i.e., will ensure the survival of chocolate, coffee, wine, bananas, oranges, etc., with plants that are higher yielding, climate- and disease-resistant, as well as water- and nutrient-efficient).[91, 92]

Most gene-edited crops are still in the pipeline. A handful are being sold commercially and many more are soon-to-be-released. Calyxt's high oleic, reduced saturated fat soybean oil was commercially launched in the U.S. in 2019.[93] Corteva's waxy corn (used primarily for industrial corn starch and CRISPR-engineered for higher yields) was cleared for release by Canadian regulators in 2020 without a risk assessment, and has already been deemed a category of GMO outside the purview of regulatory oversight in Argentina, Brazil and Chile.[94] Sanatech's CRISPR tomato (engineered to contain heightened levels of an amino acid that reportedly lowers blood pressure) received approval in Japan in early 2021, but its launch will be limited due to an intellectual property (IP) conflict (cultivation will be restricted to home gardeners who will be prohibited from selling or distributing the tomatoes).[95]

Although the basic research on CRISPR and other gene editing tools like TALEN has been conducted primarily in public research institutions,[96] many of the first gene-edited products are coming from tech start-ups that were spawned by academic scientists.[97] Agrochemical and seed giants are conducting in-house R&D, as well as collaborating with and/or licencing technology from smaller companies.

Jennifer Doudna and Emmanuelle Charpentier, the scientists who won the Nobel Prize in Chemistry in 2020 for discovering CRISPR-Cas9, are closely associated with at least three of the start-ups actively commercialising the technology for food and agriculture. Doudna is the co-founder of Caribou Biosciences, which has funding support from food giant Mars, and she sits on the scientific advisory board of Inari Agriculture. Charpentier is the co-founder of

ERS Genomics (the company's sole focus is to maximize commercial licensing of a global patent portfolio related to gene editing owned by University of California Berkeley).[98] Dr. Feng Zhang and other members of the Broad Institute in Boston, U.S.A. also stake key patent claims to CRISPR techniques. They are among the founders of the start-up Pairwise.[99] Since 2016, The Broad Institute (MIT/Harvard) and UC Berkeley have waged a fierce and complicated patent dispute over key IP claims related to CRISPR.[100] Doudna and her colleagues at Caribou have exclusively licensed CRISPR to Corteva for use in corn and soybeans, while Zhang and his colleagues have licensed more liberally to Bayer-Monsanto, Syngenta, BASF, Simplot and Pairwise.

Common(s) Mistake: The Genome Editing Patent Landgrab There's an oft-repeated claim that CRISPR is "a democratizing tool" – suggesting that it is widely utilized and universally accessible.[101,102,103] In reality, the ag biotech industry is scrambling to win monopoly patents on gene-editing technologies, with high-stakes bidding over exclusive and non-exclusive licensing deals. *IPStudies* notes that around 200 patent families are published every month on CRISPR related nucleases, including a growing number of applications from China.[104]

Corteva Agriscience, the world's 2nd largest seed company and 4th ranking pesticide firm, overwhelmingly dominates patent applications related to gene editing nucleases in the crop and seed sector, with more than 70 applications.[105] In 2018, Corteva, the Broad Institute (MIT/Harvard) and other discoverers of CRISPR-Cas9 created a patent pool comprising 48 patents that involve key CRISPR tools for the gene editing of plants.[106] The Munich-based Institute for Independent Impact Assessment in Biotechnology (Testbiotech.org) notes that any plant breeder interested in gaining access to comprehensive use of CRISPR-cas9 will have to obtain licenses from this pool, which is likely to make it costly or prohibitive for many breeders. Testbiotech likens Corteva's control of key patents related to genome editing to a "hidden patent cartel" (the licensing contracts are confidential).[107]

Bayer, the world's top-ranking commercial seed company and 2nd largest pesticide firm, holds international patent applications on approximately 50 nucleases; KWS has around 30 applications, and Cellectis/Calyxt around 20.[108] In the case of granted European patents on site-directed nucleases for application in crops, Corteva holds around 30, while Bayer, Cellectis, BASF and Keygene each hold fewer than 10.

Industry's Quest to De-Regulate Gene Editing in the U.S. and E.U.: Proponents maintain that gene editing and GMOs are distinct because the CRISPR technique does not rely on the insertion of DNA from a different species(although it may include DNA from other species in some instances).[109] And they insist that gene editing techniques achieve the same results as conventional breeding, only much faster and far more efficiently.[110]

Sampling of Genome-Editing Companies Involved in Food and Agriculture

Company (Year founded, Headquarters)	Public / Private	Business Focus in Food and Agriculture	Annual Revenue or Equity Investment Raised US$ million	Food & Ag R&D Collaborators
AgBiome (2012, USA)	Private	Biological and synthetic pesticides; crop traits	~15.68[111] Revenue	The Mosaic Company, Genective [JV: Limagrain and KWS], BASF[112]
Inari (2016, USA)	Private	Crop traits (corn, soy, wheat)	352[113] Investment	Beck's (US seed retailer, corn traits), Mertec (soybean germplasm), M.S. Technologies (trait provider)[114]
Cibus (2001, USA)	Private	Crop traits (canola, rice, soybean, wheat, corn)	~131.3[115] Investment	GDM (soybean genetics), Valley Oils Partners (vegetable oils)[116]
Calyxt (2010, USA) (subsidiary of Cellectis, which owns TALEN)	Public	Crop traits (winter oats, soybeans, hemp, high fibre wheat, alfalfa)	23.9[117] Revenue	NRGene (software), Perdue AgriBusiness (soybean seed), S&W Seed Company (alfalfa)
Caribou Biosciences (2011, USA)	Public (IPO, July 2021)	Licenses its CRISPR/Cas9 technology	115 Investment in pre-IPO funding, 304 raised in IPO, July 2021[118]	Corteva AgriScience (Corteva has exclusive license to Caribou technology in corn, soybeans; joint research on off-target effects of gene editing)[119]
ERS Genomics (2014, Ireland)[120]	Private	Licenses its CRISPR/Cas9 technology	N/A	Nippon Gene Co., G+FLAS Life Sciences, Axxam (all non-exclusive licensing)
Arcadia Biosciences (2002, USA)	Public	Hemp, wheat, safflower (oil products)	8,034[121] Revenue	Ardent Mills; Corteva AgriScience; Arista Cereal Seeds Pty Ltd; Bay State Milling Company (all wheat)[122]
Pairwise (2017, USA)		Crop traits (kale, mustard greens, corn, soybeans, wheat, canola, cotton, berries)	115[123] Investment ~9.19[124] Revenue	Bayer (trait development in corn, soybeans, wheat, canola and cotton); Plant Sciences, Inc. with USDA (gene-edited berries)
Tropic Biosciences (2016, UK)	Private	Crop traits (coffee, bananas, rice)	38.5[125] Investment	Genus Plc (porcine and bovine genetics); BASF (trait development)
Benson Hill Biosystems (2012, USA)	Public (IPO May 2021, after SPAC merger)[126]	Crop traits (soybean, yellow pea, corn)	282.3 Investment[127] 71.5 Revenue in *first half* of 2021[128]	Mars, Inc. (cacao traits); GDM (soybean breeding); Rose Acre Farms (soybean processing); Beck's (US seed retailer, corn traits)

Elo Life Systems (subsidiary of Precision Biosciences; Precision PlantSciences formed 2012; renamed Elo Life Systems 2018, USA and Australia)[129]	Private	Crop traits (canola, watermelon, vanilla, bananas, chickpeas)[130]	24.3 Total revenue of parent company, including Elo Life Systems	Cargill (reduced-fat canola oil); Dole (disease-resistant bananas); BASF, Bayer, Corteva,[131] Avoca (Clary Sage plants for extraction of sclareol, used in fragrances)
Sanatech Seed Co. Ltd. (2018, Japan), venture launched by University of Tsukuba	Private	High GABA tomato	N/A	Pioneer EcoScience (distributor of Pioneer brand products [Corteva AgriScience] in Japan, development of High GABA tomato)[132]
Yield10 Bioscience (founded as Metabolix, 1992, USA)	Public	Crop traits in canola, soybean, corn, sorghum, rice and wheat.[133]	0.8[134]	Bayer (soybean), Forage Genetics (sorghum), Simplot (potato), GDM (soybean) – all non-exclusive research licenses;[135] Rothamsted Research, UK, omega-3 oils[136]

In a concerted campaign to win public acceptance and side-step regulations, the biotech industry is lobbying intensely to ensure that its proprietary, gene edited plants and animals will be excluded from existing GMO regulations and labelling requirements. In the U.S. regulatory arena, industry has exceeded its goals. In response to pressure from the Trump White House, in 2020 the US Department of Agriculture announced its decision to deregulate oversight of most genetically modified plants and seeds (including gene edited-plants and seeds) and proposed a similar de-regulation of gene-edited animals.[137] (The new rules are being challenged in court.[138]) In contrast, the European Union (EU) has thus far upheld stricter regulatory oversight of gene editing. A 2018 ruling by the European Court of Justice requires genome-edited crops to be subject to the same regulations as GMOs. However, a 2021 study by Corporate Europe Observatory reveals that a powerful biotech lobby is campaigning aggressively to overturn the E.U.'s precautionary stance and ensure that new gene-editing techniques are excluded from existing GMO rules. If the industry lobby prevails, gene-edited plants, animals and microorganisms would not be subject to risk assessment, monitoring or consumer labelling in Europe.[139]

Risks, Unexpected Consequences, Knowledge Gaps With hype and hoopla paving the way for the rapid deployment of gene editing in food and farming, biotech boosters have conveniently overlooked or ignored a growing body of scientific evidence that points to potential risks related to gene-editing technologies, including CRISPR-Cas9.[140]

Recent studies indicate that, far from being precise and predictable, genome edits may often result in unwanted changes and unpredictable outcomes. A 2020 report by Testbiotech on new genetic engineering technologies explains the "potential for unforeseen genomic interactions, genomic irregularities and unintended biochemical alterations" in two main categories:

- *Off-target effects* occur when genome editing introduces a change at an additional, unintended site of the genome in addition to the intended (target) location.
- Even if the edit is achieved at the targeted site, unintended *on-target effects* relate to possible deletions and rearrangements of DNA, or gene interactions that were not anticipated.[141]

Unexpected effects could involve changes in the chemistry, biochemical pathways or protein composition of an edited organism, with potential implications for food safety and biodiversity (such as altering toxicity or allergenicity). Despite widespread R&D and a rush to market gene-edited organisms, there are enormous gaps in the scientific literature on understanding of how new traits could impact the environment, particularly if they introduce novel compounds. A 2020 report written by Janet Cotter and Dana Perls, published by Logos Environmental, Canadian Biotechnology Action Group and Friends of the Earth offers a comprehensive overview.[142]

With the advent of gene editing, it becomes technically possible to develop a far more dangerous and disruptive technology: gene drives. Gene drives are a new genetic engineering technology that seeks to rapidly spread human-directed genetic changes through entire populations of animals, insects and plants. Unlike first generation GMOs targeting commercial crops, gene drive organisms (GDOs) can be designed to manipulate both domesticated and wild populations. Gene drives aim to be invasive – to persist and to spread and, in some cases, even to extinguish an entire population or species; early proponents suggest the use of gene drives to spread "auto- extinction" genes to wipe out agricultural "pests." So far only smaller start-ups such as Agragene are openly developing gene-drives for agriculture – mostly in insects. In June 2021 scientists successfully implemented gene drives in crops for the first time.

See ETC Group's December 2019 report: *Gene Drive Organisms: An introduction to a dangerous new technology putting Africans at risk: https://www.etcgroup.org/tags/gene-drives* .

2. RNAi Pesticide Sprays

The Fat Four pesticide powerhouses (Bayer, BASF, Corteva and Syngenta), as well as many high-tech start-ups, are actively developing novel pesticide spray technologies, based on synthetic, ribonucleic acid (RNA) molecules, that are designed for widespread release in farmers' fields and in forests.[143]

"Gene-silencing pesticides," also known as RNA interference or RNAi pesticides[144] are designed to kill pests by switching off or "silencing" genes essential for the organism's survival. RNAi is the molecule of the moment, and RNAi is biotech's newest techno-fix for agriculture.

For agrochemical giants, the appeal of "RNA-based biocontrol" sprays is irresistible: they seek to manipulate the cellular machinery of an insect, weed or pest and claim that it is all based on natural, biological processes – enabling them to escape scrutiny from pesky GMO regulators and a public that overwhelmingly rejects GMOs. Despite major gaps in knowledge about the environmental, health and safety impacts of this novel pesticide technology, RNAi-based insecticidal sprays are already being field tested in the U.S.[145]

How does it work? First discovered in 1998,[146] RNA interference (RNAi) involves the use of double-stranded RNA (dsRNA) to block messenger RNA from performing its usual function (that is, instructions to make a specific protein within the cell).[147] RNAi can potentially switch off the specific nucleotide sequences that are unique to a target pest without harming beneficial insects or humans. One biotech booster likens the targeted precision of RNAi-based pesticides to "smart bombs" used in the military.[148]

Just like conventional pesticides, RNAi-based products could be sprayed on crops, injected into soil or tree roots. When applied to a crop, the RNAi pesticide could kill the targeted pest on contact, or after the bug munches on a leaf and ingests the pesticide that has been absorbed by the plant. Either way, the interfering RNA enters the insect's gut and turns off a gene that is essential for its survival. The pest ultimately dies.

Beyond Sprays: RNAi molecules can also be delivered within a genetically engineered crop plant or insect. Crops that are genetically engineered with traits triggered by RNAi are not new,[149] but in 2022 Bayer (formerly Monsanto) plans to sell the first GE crop that contains insecticidal RNAi in its genes – a genetically modified corn variety equipped with RNAi to kill the Western corn rootworm; in addition, the "SmartStax" corn will be loaded with Bayer's proprietary Bt toxins.[150]

Bringing Toxic Chemicals Back to Life? In the longer term, agrochemical firms are also exploring a far more lucrative pursuit: how to silence enzymes in weeds that make them resistant to cash-cow chemical weedkillers like glyphosate.[151] The use of RNAi for genetic "reversal" of glyphosate resistance in weeds aims to expand and fortify markets for genetically engineered herbicide tolerant traits, and entrench the use of older, chemical products. To avoid public controversy, industry is likely to focus initial efforts on RNAi products that are deemed more socially and environmentally acceptable (i.e., the use of RNAi bio-based sprays to substitute for dangerous chemicals).

Research and development (R&D) on RNAi pesticide sprays is gaining traction because the technology can be developed relatively fast, without the public stigma, cost or constraints associated with existing GMO regulations.[152] The success of closely related mRNA technology in Covid-19 vaccines will also be played upon to build public support. In addition, it's getting a lot cheaper to manufacture synthetic RNA strands. A gram of RNA initially cost upwards of US$100,000. The price plummeted to US$100 a gram in 2014, and now it's under a dollar per gram.[153]

Proponents of RNAi pesticide technologies claim:

- RNAi sprays are designed with "precise target specificity," and are based on natural, biological processes that enable the interfering RNA to dismantle the protein-making cellular machinery of a target insect, weed or other pest without harming non-target organisms.
- RNAi molecules will degrade rapidly, with little or no environmental impact.
- RNAi pesticide sprays are not a form of genetic engineering because "the nucleotide sequences in dsRNA pesticides do not code for protein, and are not inserted into the genome and are not heritable like transgenes."[154]

What Could Go Wrong? In stark contrast, critics of the technology assert that RNAi pesticides must be regulated as a form of genetic engineering. While the RNAi spray itself is *not* genetically engineered, the technology *is designed to modify organisms in the open environment*. According to a report by a team of scientists at Friends of the Earth: "Organisms may start out life as non-GMO and be modified partway through their life, constituting a vast, open-air genetic experiment."[155] RNAi pesticides can result in genetic changes in exposed organisms as well as altered traits that can be passed down to offspring.[156] Scientists have documented ways in which interfering RNAs can result in heritable alterations.[157]

RNAi pesticide sprays are a novel technology designed for widespread environmental release. As science writer Antonio Regalado put it in his 2015 article for *Technology Review*: "RNA may be natural. But introducing large amounts of targeted RNA molecules into the environment is not."[158] There are enormous knowledge gaps, and a host of potential risks.

Despite industry's claims of "precise target specificity," a study published by Monsanto (now Bayer) in 2018 found that its genetically engineered corn equipped with RNAi to kill the Western corn rootworm also killed non-target beetles in laboratory experiments.[159]

How will RNAi degrade and where will it go? Do degraded RNAi molecules pose a risk to target or non-target organisms? Double-sided RNA molecules are larger and heavier than molecules in conventional pesticides.[160] Will synthetic RNA spread via groundwater? The question is relevant because proponents envision delivery of RNAi pesticide sprays via irrigation.[161]

Plant scientists already know that insects, pests and weeds can evolve resistance to RNAi pesticides, just as they have to conventional sprays (both chemical and biological). Laboratory tests have already confirmed this scenario.[162]

Special Delivery? Potential ecological and human health risks are made even more complex because a number of companies are conducting research on novel delivery mechanisms to enhance the efficacy of RNAi sprays. Companies seek to encapsulate the RNAi in synthetic nanoparticles – so that the interfering RNA can penetrate plant cells more efficiently, or to make them degrade more slowly in the environment. The fate of engineered nanoparticles in the environment and their impact on the health and safety of target or non-target organisms raises even more unanswered questions.[163] ETC Group has been monitoring the development of nano-scale technologies since 2000. Most scientists agree that many engineered nanomaterials create novel risks that require new forms of toxicity evaluation, but risk assessment is still in its infancy. There are no internationally-accepted scientific standards governing lab research or the introduction of nanomaterials in commercial products.

An October 2020 report by Friends of the Earth (FOE) provides an excellent, in-depth introduction to RNAi pesticide technologies, their risks and concerns. FOE's major findings:

• RNAi pesticides must be regulated as a form of genetic engineering, as they can result in genetic changes in exposed organisms as well as altered traits that can be passed down to offspring.

• Country-level regulatory authorities have failed to acknowledge RNAi pesticides as a form of genetic engineering and have therefore failed to enact proper assessments or precautions for this novel application of the technology.

• Given the potential risks and major gaps in knowledge surrounding RNAi pesticides, it is imperative that civil society, farmers, and concerned scientists push for strong regulations before this technology is commercialized.

Source: Friends of the Earth (FOE), *Gene-Silencing Pesticides: Risks and Concerns*, October 2020, https://foe.org/resources/gene-silencing-pesticides-risks-and-concerns/

Who's Running Interference? Sampling of Start-ups focusing on RNAi-based Pesticide Sprays

Company (Headquarters)	R&D focus & partners
Greenlight (USA)	RNAi pioneer focusing on pharma and agriculture. Has conducted over 20 field trials of dsRNA targeting Colorado Potato Beetle in U.S.[164]
RNAissance (USA)	Using genetically engineered microorganisms to make dsRNA; conducting research on nanoparticle delivery technology; R&D focus on injection of RNAi compounds in fruit and nut trees.
AgroSpheres (USA)	Partners with Adama, subsidiary of Syngenta on RNAi-based insecticide targeting the Diamondback Moth (DBM); conducts research on nanoparticle delivery technology w/ RNAissance.
DevGen (Belgium), now owned by Syngenta	Acquired by Syngenta for US$523 m in 2012; RNAi for pest control.
Viaqua Therapeutics (Israel)	Aquaculture; RNA-based RNAi for viral control in shrimp; partners w/ Nutreco and Thai Union Group PCL.

Notes

1 Adama is now part of Syngenta Group; in 2020, Syngenta and Adama reported separately.
See *Syngenta Financial Report 2020*, p. 34:
https://www.syngenta.com/sites/syngenta/files/bond-investor-information/financial-results/Syngenta-AG-2020-Financial-Report.pdf; and Adama Q4 & FY 2020 Review, p. 9: https://investors.adama.com/files/doc_financials/2020/q4/ADAMA_External_Q4_FY_2020_LTD_Presentation.pdf.

2 See *Bayer Annual Report 2020*, p. 83:
https://www.bayer.com/sites/default/files/2021-02/Bayer-Annual-Report-2020.pdf. Bayer reports its agrochemical segments separately. Our sales figure excludes agchem used on golf courses. See "Sales by Strategic Business Entity," p. 83. Our figure includes herbicides, fungicides and insecticides.

3 See *BASF Online Report 2020*, Segment Profile:
https://report.basf.com/2020/en/managements-report/segments/agricultural-solutions/segment-profile.html. Our figure includes insecticides, fungicides, herbicides and seed treatment.

4 See *Corteva News Release*, 03 February 2021, 4Q/Full Year 2020 Results, p. 4:
https://www.corteva.com/content/dam/dpagco/corteva/global/corporate/files/press-releases/02.03.2021_4QFY_2020_Earnings_News_Release_Graphic_Version_Final.pdf .

5 See *UPL News Release*, "UPL Ltd Q4FY21 net rises 72% to Rs. 1,065cr.; full year profit jumps 62% to Rs 2,872 cr.," 12 May 2021. https://www.upl-ltd.com/financial_result_and_report_pdfs/v9RuJaxx7cAxNVh3cuwJPwLKCNbTSyflOxx8qnXN/Q4FY2021-Press-Release.pdf. Total UPL revenue in US dollars ($5,200 million) confirmed by UPL Investor Relations via personal email from Radhika Arora, 25 May 2021 for FY 2020-2021, ending 31 March 2021. For FY2021, UPL's seed revenue (Advanta) was around $310 million; total UPL Agrochem revenues = $4,890 million (rounded to $4,900 million).

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