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COMMENTARY



Chile as a key enabler country for global plant breeding, agricultural innovation, and biotechnology

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ABSTRACT

Chile has become one of the main global players in seed production for counter-season markets and research purposes. Chile has a key role contributing to the reduction in seed production shortages in the Northern Hemisphere by speeding up the development of new hybrids, cultivars, and genetically modified (GM) organisms. The seeds that Chile produces for export include a considerable amount of GM seeds. Between 2009 and 2018, 1,081 different seed-planting events were undertaken for seed multiplication and/or research purposes. Every single event that had commodity cultivation status in 2018 in at least one country underwent field activities in Chile at least once over the last 10 y. Chile just adopted a regulatory approach for new plant breeding techniques. This type of regulatory approach should contribute to maintaining the status of Chile as a hot spot for future innovation in plant breeding-based biotechnology.

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Introduction

Agricultural biotechnology encompasses a myriad of technologies that bring about innovation and also address food and feed production challenges. Agricultural biotechnology includes several scientific disciplines such as plant breeding, genetics, microbiology, genomics, statistics, plant physiology, crop management, and chemistry, among others.

Over the last 20 y, genetically modified (GM) crops have provided farmers, consumers, and countries that have adopted the technology a series of social, economic, and environmental benefits.^{1,2} A global analysis between 1996 and 2016, in which the gains from production improvements and cost savings were considered, had established economic benefits above \$186 billion in nominal terms.¹

The current productivity of main crops (maize, wheat, rice, soybeans, canola, and cotton) cannot meet the increasing demand for food, feed, and fiber. Moreover, there are multiple regions facing a decrease in arable areas, accelerated desertification, and overall deterioration of soil quality.^{3–6} In this context, continuous innovation in plant breeding and biotechnology has become one of

the most effective known approaches to meet the increasing agricultural global challenges.^{7–12}

The annual global market of GM seeds has been valued at US\$20.07 billion, and it is projected to reach US\$30.24 billion by the end of 2026, exhibiting a compound annual growth rate of 5.3%.¹³ The main GM crop adopter is the United States with 75 million hectares or about 39% out of nearly 191.7 million hectares of global adoption in 2018. One of the main factors behind this success story is the consistent US governmental support of biotechnology and the existence of a science-driven regulatory framework. The US leads the research, development, and commercialization of GM crops. There are five important GM crops used by farmers in the US: (1) soybeans (34 million hectares); (2) maize (33); (3) cotton (5); (4) alfalfa (1.2); and (5) canola (0.9). Strikingly, the adoption rate has reached over 93% for the first three of these crops. Other countries leading global GM crop adoption are Brazil (26.2% out of 191.7 million hectares), Argentina (12.5%), Canada (6.6%), and India (6.1%) as reported by the International Service for Acquisition of Agri-biotech Applications (ISAAA).

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Within this context, according to data from the International Seed Federation (ISF), Chile is the main exporter of GM seeds from the Southern Hemisphere, with respect to supplying counter-season markets in the Northern Hemisphere.¹⁴ In addition, because of a series of competitive advantages, including a predictable regulatory framework for GM seed regulatory approval,¹⁵ Chile has experienced a significant investment in counter-season nurseries and research programs for GM seeds.

Chile has produced high-quality GM seeds under stringent field controls for reexport purposes for more than two decades, and a further factor contributing to this production has been the effective coexistence achieved between GM and non-GM seed activities. The seed industry has established a stringent self-regulation, which at the same time is closely controlled by Agricultural and Livestock Service (SAG), a regulatory agency part of the Ministry of Agriculture that is entrusted with the surveillance of GM seed activities in Chile.

Over the last 5 y, the emergence of new breeding techniques (NBTs) is revolutionizing agricultural biotechnology. NBTs encompass diverse biotechnological approaches to speed up the development of new traits in plant breeding.^{16,17} Among these approaches, genomic editing allows specific single mutations in an entire genome, knock-out of target genes, repair of specific DNA, and accurate allelic replacement among other applications to be done. Overall, they represent a more versatile, easier, and cost-effective way to generate genetic diversity.^{18,19} Thus far, only a few countries have approved the use of NBT-derived plant products in their territories,²⁰ and Chile is one of them.

Strengths of Chilean seed production and breeding programs

Off-season seed production enables research acceleration and development activities and seed multiplication processes in addition to offsetting seed production in the Northern Hemisphere when the shortage occurs due to abiotic and/or biotic factors. Chile possesses a series of advantages that have distinguished its supply chain capabilities and contributed to maintain its leadership in relation to other off-season producing countries.¹⁵ Its

main strengths consist of several parameters: (1) international credibility and outstanding track record of state agencies (SAG, customs); (2) stable and varied climatic conditions that benefit the cultivation of a wide range of crops; (3) geographic isolation by ocean, mountains, and the driest desert on Earth (Atacama desert), which decreases pest incidence; (4) implementation of cutting-edge technology; (5) quality and professionalism of the industry; (6) political and legal stability, ensuring security for the activities, programs, and contracts; (7) adequate export facilities; (8) free trade agreements with all major markets; and (9) robust and stringent, science-based regulation that fits both public and private breeders' needs and seed industry operations.

Chile offers a stable planting and growing environment for primarily supporting breeding programs in the US and to a lesser degree in Europe and South America. The Central Valley region located between the Chilean Coastal Range and the Andes Mountains extending from Santiago to the Araucanía Region is ideal for growing maize, soybean, and canola in addition to several kinds of vegetables (Figure 1). Although a long growing season could be considered a disadvantage for Chile because a single growing cycle per year can be a challenge with respect to returning seeds to North America on time for plantings, the seed industry has established a research hub in Chile's northernmost region, Azapa Valley in Arica city (Figure 1). It offers three growing cycles annually, which accelerate research and development initiatives, especially for maize. It is worth noting that using embryo rescue and *in vitro* cultures, even more generations can be obtained per calendar year. Arica is located in the desert with an annual average temperature of 18.8°C. The annual rainfall is less than 3 mm according to the Library of National Congress of Chile (<https://www.bcn.cl/siit/nuestropais/region15/clima.htm>). Thus, its geographic isolation along with its non-tropical weather and manageable plant health challenges has made this region an attractive location to accelerate crop breeding and research programs for the seed industry.

In addition, Chile has a strong and well-established National Seed Trade Association, ANPROS, which represents over 98% of the

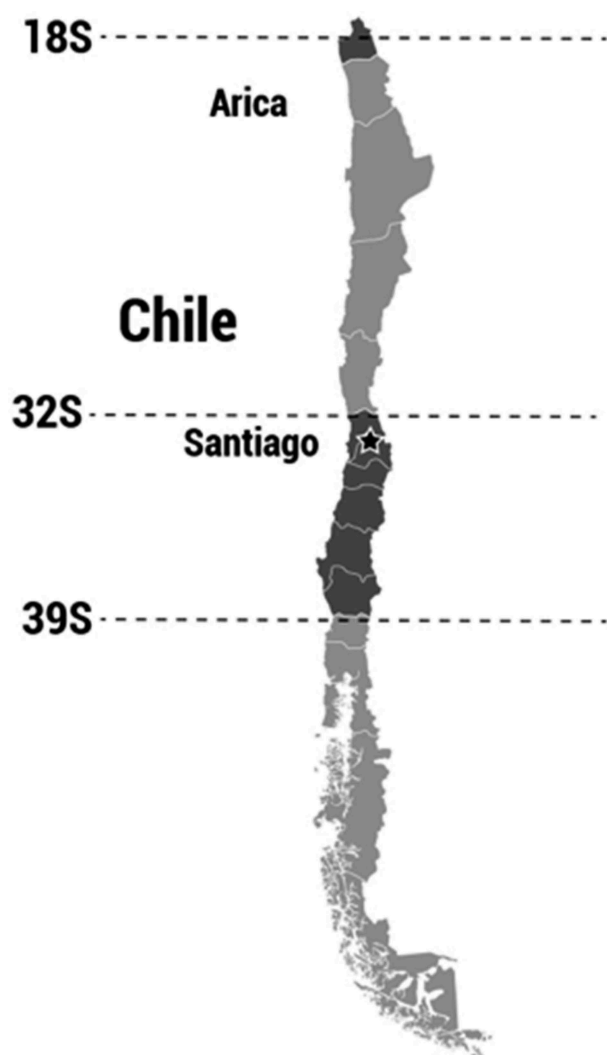


Figure 1. Chile's map depicting the main regions where genetically modified (GM) seed production and research and development (R&D) activities are conducted.

industry and includes both Chilean and local subsidiaries of major international companies. It encompasses 73 associated companies. This guild works closely with regulatory bodies in order to achieve excellence in seed production and promote sustainability for the industry (<https://www.anproschile.cl/english-version/>).

All of these special features have allowed multinational companies in addition to small- and medium-sized enterprises, start-ups, universities, and academic organizations that develop and/or commercialize non-GM and GM crops to focus on Chile for investing, conducting research, and multiplying high-value seeds.

The area allocated for seed production is approximately 45,000 hectares, which is distributed mainly

in the Central Valley region (Figure 1). In 2018, Chile's seed exports totaled US\$392 million free on board (FOB). The main seed produced and exported from Chile is maize. In 2018, there were 10,835 hectares for maize seed fields, and they represented almost 10% of all land allocated for maize production in Chile. Maize seed exports reached US\$86 million FOB. Other important seeds in terms of export value (US\$ millions FOB) were sunflower (33), broccoli (27), watermelon (26), and canola (23). Research and development (R&D) services were valued at almost US\$20 million.²¹ In relation to the extension of seed fields relative to commercial production, for sunflower, broccoli, watermelon, and canola seed fields, there were 6,434, 549, 644, and 4,458 hectares representing 50%, 22%, 18%, and 8% of the total land allocated for those crops in the country, respectively.

Chile currently ranks ninth among countries exporting seeds worldwide and over the last 7 y has ranked globally in the top ten nations of seed exporters, and for several years, Chile was in the top five (<https://www.worldseed.org/resources/seed-statistics/>).

The main competitors of Chile during the counter-season seed production period are Argentina, Australia, South Africa, New Zealand, and Peru (Figure 2). All of them are net exporters yet showing smaller export balances to date. It is worth noting Chile experienced a decline in seed exports between 2013 and 2015 as shown in Figure 2, mainly because a record harvest for corn seeds in the US was achieved during those seasons, which left extra stocks for US seed producers.²² Thus, the demand for GM seeds from Chile decreased considerably.

Most international seed companies hasten their R&D processes and breeding programs by using winter nurseries in South America. This allows a substantial reduction in the required time to launch new cultivars that are on the market and available to farmers. Argentina, Brazil, Chile, and Uruguay are the main countries providing this kind of service for seed companies located in the Northern Hemisphere. Well-established sites also exist in Guatemala, Mexico, Hawaii, and Puerto Rico, areas that provide significant nursery activity, and several of these areas offer multiple growing seasons per calendar year. However, weather conditions, pests, and diseases are ever-present hurdles. In this context, Chile offers many advantages over other areas as

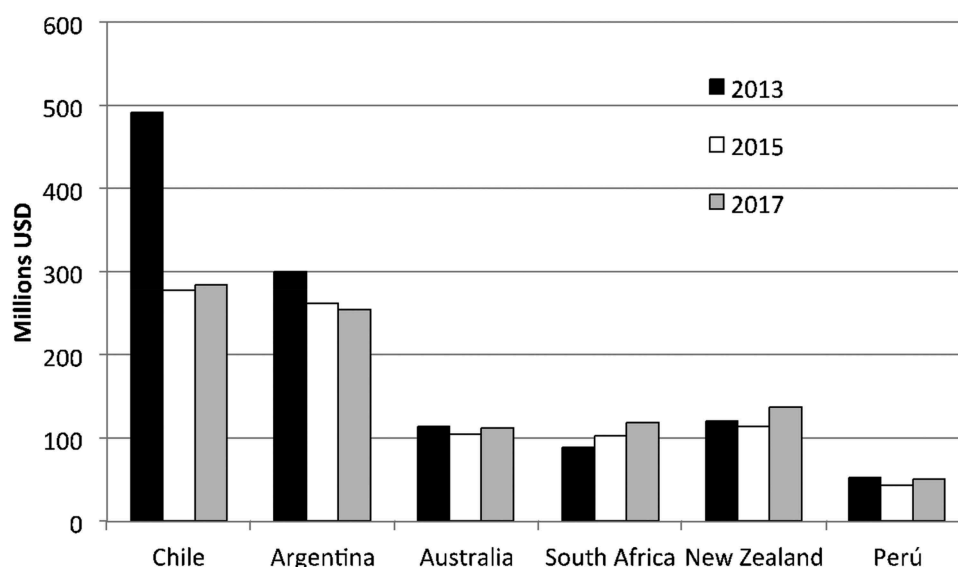


Figure 2. Exports of grain, oilseed, and forage crop seeds from off-season countries from 2013, 2015, and 2017 (elaborated from ISF data).

a provider of different regions with temperature patterns that allow year-round plant growth resulting from a reduction in the events that severely impair seed production: (1) reduced pest pressure; (2) no excessive precipitation; and (3) lack of tropical storms and hurricanes. For instance, in 2017 Puerto Rico's agriculture and livestock industries experienced more than \$2 billion in damage because of the destruction brought by Hurricanes Irma and Maria (<https://www.efe.com/efe/english/world/puerto-rico-hurricane-triggered-crop-livestock-damage-exceeds-2-bn/50000262-3453519>). Much of the damage and potential delay in R&D programs brought about by such natural disasters was offset by additional plantings and activities carried out in Chile.

GM seeds

A significant factor in the positive development of Chilean seed exports has been the use of GM seeds. Events (such as individual use of recombinant DNA to produce a GM crop) not yet approved in other countries either for field trials or for commercial use may be released in Chile for confined R&D purposes after a thorough biosafety assessment is conducted in a maximum time of 45 business days. Under the scope and mandate of Resolution 1523, issued in 2001, SAG is the

regulatory agency that oversees activities with GM seeds. The regulatory framework includes import procedures, tracking the arrival and transportation of every GM seed lot that enters to Chile, and environmental risk assessments (ERAs) and biosafety requirements, to confine materials and avoid outcrossing with sexually compatible organisms in addition to conducting post-harvest monitoring. Its predictability and robustness have led to an increasing number of new event approvals and import permits for seed production and R&D purposes.¹⁵ Despite this regulation, Chile is in an uncertain situation as there are no clear procedures to produce GM crops within the country for domestic use. This inconsistency partially depends on the fact that the environmental release of GM crops for unconfined activities is under the scope of other incomplete regulations. Since 2010, Chile's Environmental Law requires submitting GM organisms to the Environmental Impact Assessment System to obtain approvals for environmental release. Until now, no specific regulation describing how to conduct this process has been enacted. Further, no agricultural producers, such as farmers, companies, and guilds, have strongly pushed the decision-makers to solve this situation, perhaps because there have been no commercially available GM crops with traits that are significantly useful to Chilean agriculture until now.

Over the last five seasons, the area with GM crops for maize, soybean, and canola as a whole contains more than 64% each year in contrast to the 36% for their conventional counterparts (Figure 3). Specifically, 100% of soybean seed production in Chile, 81% of canola, and 61% of maize, respectively, have been GM seed. Chile is currently the largest exporter of GM seeds from the Southern Hemisphere in order to supply counter-season markets in the Northern Hemisphere.¹⁴ Furthermore, because of the regulatory framework for GM seeds along with the geographic, climatic, and political advantages described above, the private sector has invested heavily in winter nurseries and research programs for GM seeds over the last years. For instance, the installation of multinational and Chilean companies in the Azapa Valley, Arica, with the aim of building the most modern facilities of its kind in South America totaled around US\$46 million in investments in 2009 (<https://www.thisischile.cl/biotechnology-in-chile/?lang=en>).

During the 2017/2018 seed production season, the total area sown with GM seeds reached 13,915 hectares,²³ representing an increase of 36.7% over the previous season. The higher seed demand from the Northern Hemisphere (the US and Canada) was based on a decline in seed stocks and production shortages. Across the 2006/2007 to 2013/2014 seasons, the average number of hectares (ha)

allocated to GM seed-related activities was 26,227, reaching a peak of 35,864 ha during the 2012/2013 season.²³ During the 2017/2018 season, there were 1,363 GM seed fields that produced both certified and non-certified seeds according to international standards. In addition, there were 605 GM seed field trials for R&D programs.²³ The 7,808 ha allocated for GM maize seeds in 2018 represented 72% of all maize seed fields in the country. Meanwhile, the 3,697 and 2,408 ha devoted to GM canola and GM soybean, respectively, represented 83% and 99.8% of the total seed fields of those crops, respectively.

With regard to the destinations of exports, according to SAG registers, out of the 23,600 tons of GM maize seed produced in Chile last season, over 75% was sent to the US, and almost 20% reached South Africa as a final destination. For field trials and/or conditioning purposes, France, Germany, Spain, and the Netherlands as a whole unit received 1% of this production. In Asia, the Philippines imported 2%, and in the Americas, Argentina, Brazil, and Canada obtained the rest of the GM corn exports. In the case of GM soybean seed, out of 5,959 tons, the US is the main market with 92% of shipments, and Canada received the remaining 8%. For GM canola seed, out of 6,511 tons, 99.9% was sent to Canada, and the rest was shipped to Australia and the US.²³

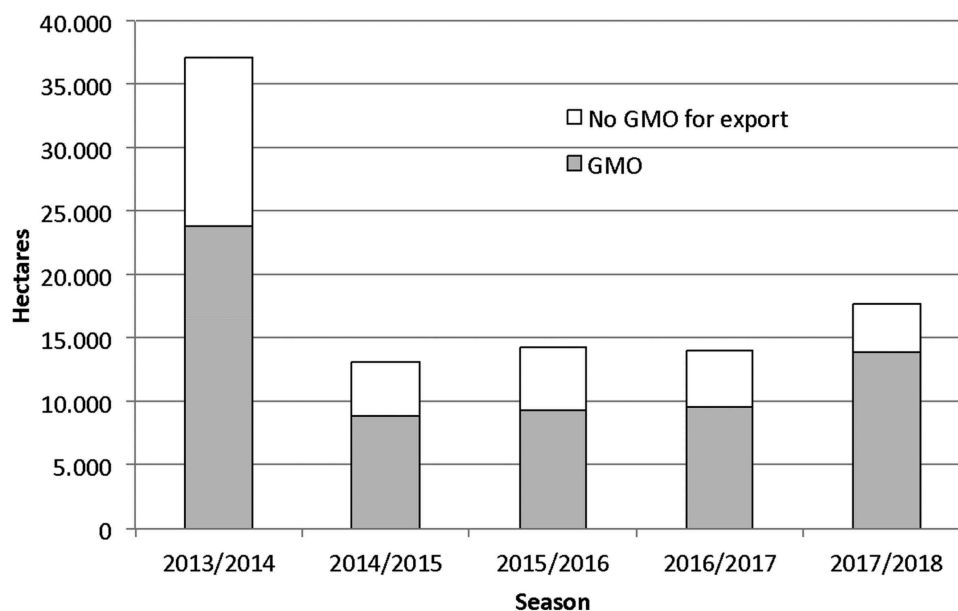


Figure 3. Seed production area for exports: GM and non-GM. It includes maize, soybean, and canola seeds (elaborated from SAG and ANPROS data).

Chile's seed industry has also thrived because of the coexistence achieved between GM and non-GM seed activities. Seed companies have established stringent practices related to stewardship and quality management systems. Among them, two findings are worth highlighting: (1) a global positioning system-based isolation system for effectively tracing all seed fields and pinpointing the exact locations at which non-desirable outcrosses may occur and (2) the Excellence Through Stewardship program (<http://excellencethroughstewardship.org>), which has successfully enabled the adoption of principles and practices for the responsible management of GM seeds. Until now, there is no single report claiming the adverse effects of GM seeds on the environment and local agriculture in Chile. Furthermore, there have not been seed trade disruptions while producing and exporting seeds for Genetically Modified Organism (GMO) and GMO-free markets.

Because of its ideal growing conditions, Chile has been a reliable country for winter seed production for three out of the four major biotech crops (maize, soybean, and canola) in terms of the globally planted area. SAG's biotechnology office keeps a register of all single and stack seed-planting events since 2009 that have been undertaken in Chile for seed production or R&D purposes. Between 2009 and 2018, 1,081 different seed-planting events were authorized for field trials or seed multiplication. A number of 937, 91, and 53 new different single or stack events of maize, soybean, and canola, respectively, have been sown in Chile over the last 10 y at least once. To put this into context, in the US, the Food and Drug Administration (FDA) has reviewed 185 events to date (<http://www.accessdata.fda.gov/scripts/fdcc/?set=Biocon>), many of which are already on the market. However, only 45, 21, and 19 of the FDA-reviewed events correspond to maize, soybean, and canola, respectively.

Activities with GM seeds in Chile are only allowed within confined areas, which are those facilities and fields having physical or reproductive isolation barriers to avoid outcrossing with sexually compatible species. The mandatory ERA for new events takes 3 months on average. It is worth noting that through local research initiatives, it has been possible to obtain insights to formulate

regulations considering agricultural co-existence, outcrossing potential, and seed genetic purity.²⁴

On the other hand, the BioTradeStatus website (<http://www.biotradestatus.com>) contains information about the commercial status of the agricultural biotechnology seeds. The database also includes information about products that may contain stacked events. This information is generally available only for countries or markets with regulatory systems in place that grant authorizations. By using this tool, it was established that 48, 9, and 4 events of maize, soybean, and canola, respectively, had a commodity cultivation status in 2018 in at least one country (Table 1). It is interesting to note that in maize only 7 out of 48 cultivated events are single. The vast majority of events bear stacked traits of herbicide tolerance, insect resistance, or drought stress tolerance. There are no differences regarding the number of

Table 1. Full list of traits in selected genetically modified (GM) crops with commodity cultivation status in 2018.

GM crop	Number of events	Traits					
Maize	3	LEP					
	2	GLY					
	1	GLU					
	1	COL					
	4	GLY	LEP				
	3	GLU	LEP				
	2	GLY	GLU				
	1	GLU	COL				
	1	GLY	DRO				
	11	GLY	GLU	LEP			
	2	GLY	LEP	COL			
	2	GLU	LEP	COL			
	1	GLY	GLU	COL			
	1	GLY	LEP	DRO			
	10	GLY	GLU	LEP	COL		
	1	GLY	GLU	24D	LEP		
	1	GLY	LEP	COL	DRO		
	1	GLY	GLU	24D	LEP	COL	
Soybean	2	GLY					
	2	GLU					
	1	GLY	DIC				
	1	GLY	ISO				
	1	GLY	LEP				
Canola	1	GLY	GLU	24D			
	1	GLY	GLU	ISO			
	2	GLY					
	1	GLU	FER				
	1	GLU	STR	FER			

All these products have been sown in Chile at least once for research and development (R&D) or seed multiplication purposes since 2009. LEP: lepidopteran insect resistance; COL: coleopteran insect resistance; GLY: glyphosate herbicide tolerance; GLU: glufosinate herbicide tolerance; DRO: drought stress tolerance; 24D: 2,4-D herbicide tolerance; DIC: dicamba herbicide tolerance; ISO: isoxaflutole herbicide tolerance; STE: male sterility; FER: fertility restoration.

single and stacked events commercially available for soybean and canola, respectively. Nevertheless, the global area planted to biotech crops with stacked traits occupied just 42% of the global biotech crop area in 2018.²⁵

When this list of events was contrasted with the SAG register, it could be observed that all of the events commercialized at worldwide level in 2018 had been sown in Chile for R&D or seed multiplication purposes at least once over the last 10 y. So, each commercially available event in the world has benefitted from the exceptional environmental and freedom-to-operate conditions existing in Chile to produce seed and conduct research activities.

The key role of Chile for agricultural biotechnology can be also observed in the development of some GM crops and traits. For instance, drought stress reduces crop productivity and yields. In maize, it has been observed to be as much a 40% loss with an approximately 40% reduction in water. Enhancing drought tolerance in corn is a major goal of breeding and biotechnology.²⁶ In this scenario, Monsanto, currently part of Bayer, developed MON87460, which reduces yield loss under water-limited conditions compared to conventional corn. It expresses a cold shock protein B (CSPB) produced from the inserted *Bacillus subtilis*-derived gene. The APHIS-USDA determined its non-deregulated status in 2011 (<https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/permits-notifications-petitions/petitions/petition-status>). The GM corn was shown to be not different from conventional corn in its phenotypic, environmental, and compositional characteristics, with the exception of the drought tolerance trait. For its development, phenotypic and agronomic data were collected from field site locations within the US and Chile. Specifically, California and Chile provided environments that are well suited for corn production but typically do not receive any rainfall during the growing season. These environments were used to establish sites with well-watered and water-limited treatments to ensure that all water applied to each site occurred through controlled irrigation. The expression levels of CSPB and NPTII (protein conferring resistance to neomycin and kanamycin) in addition to the composition of MON87460 were determined from forage and grain tissues produced during two

growing seasons in both countries. The multi-year study allowed a determination of compositional equivalence to conventional corn under a broad range of environmental conditions to be performed.²⁷

Second-generation GM crops are intended to provide benefits for consumers or industrial applications. MON87705 was developed to generate soybean oil with an improved fatty acid profile that results in oil with enhanced nutritional characteristics and improved suitability and stability for food and industrial uses. It also contains the *cp4 epsps* gene encoding the CP4 EPSPS protein that is expressed throughout the plant and confers tolerance to glyphosate.²⁸ APHIS-USDA determined its non-deregulated status in 2011 (<https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/permits-notifications-petitions/petitions/petition-status>). Phenotypic, agronomic, and environmental interaction data were obtained primarily in the US. Compositional and nutritional assessment was obtained from soybeans grown in three replicated plots at each of five sites across Chile during the 2007/2008 growing season. They were representative of soybean-producing regions suitable for commercial production.²⁸

On the other hand, maize event TC1507 was developed to provide Lepidoptera control and was commercially available in 2003. Since then, licensee and developers have used it as a component of insect-resistant stacked products. However, the use of the single event product has been phased out because of the initial confirmation in 2006 of resistance to Cry1 F in fall armyworm *Spodoptera frugiperda* in Puerto Rico.²⁹ Similar cases have been reported in Argentina, Brazil, and Florida.³⁰ As a part of an insect resistance management program, the environmental release of TC1507 maize seeds was halted in Puerto Rico. Subsequently, according to SAG registers, every year, the single event, along with other stacked events bearing this trait, continues to be imported and sown in Chile for seed production and breeding programs, enabling the development of new hybrids and events.

Finally, to meet the demand for canola seed and to minimize production risks, most seed companies have off-season seed production locations in the southwestern US and/or the Central Valley of Chile.³¹ It is worth noting that other counter-season countries are

not capable of handling this crop. For instance, GM canola cultivation has been banned since 1997 in Argentina, and since 2007, canola seed imports require the presentation of a GM organism-free analysis from the exporting country. No field trials of GM canola have been reported in Argentina in the last decades.³² The main reason behind this situation is the many sexually compatible canola relatives in that country, and extremely large isolation distances are needed in order to minimize outcrossing with weed relatives.³³ Furthermore, the high potential of seed dormancy, which leads to volunteer appearance, requires long times of land use restriction (Table 2). Meanwhile, it has been shown that GM canola has from “low” to “very low” outcrossing potential with non-cultivated relatives in Chile, and volunteers can be addressed with different agricultural strategies.³⁴ It is noteworthy that Chilean guidelines for managing GM canola plantings for research and counter-season seed production purposes are based on local scientific research.²⁴ Thus, Chile offers a great opportunity for canola breeders using biotechnology by providing optimal locations and advantageous regulatory criteria to hasten their programs.

New breeding techniques

In 2017, Chile was the second country after Argentina at the global level that implemented a regulatory approach for plant products obtained through new biotechnological breeding techniques.

According to the Cartagena Protocol, article 3, a GMO is considered as any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology (<http://bch.cbd.int/protocol/text/>). It is worth noting in general that the term Living Modified Organism (LMO) is considered to be functionally the same as

GMO, but definitions and interpretations of the term GMO vary widely. The protocol also defines the terms “living organism” and “modern biotechnology.” As NBT always uses “modern biotechnology” at some stage, it is crucial to understand what is “a novel combination of genetic material” to clarify what a GMO is. However, the protocol does not define “a novel combination of genetic material.”

Chile’s definition of a GM organism is based on the Cartagena Protocol. Thus, Chile’s regulators officially defined “a novel combination of genetic material” as “a stable and joint insertion of one or more genes or DNA sequences encoding proteins, interfering RNA, double-stranded RNA, signal peptides, or regulatory sequences having been introduced permanently into the plant genome.” Therefore, in Chile, a GM organism as a final product must fulfill with “a novel combination of genetic material” and “modern biotechnology” definitions.

Based on this, Chile’s agricultural biotechnology office, which is dependent on SAG, which at the same time depends on the Ministry of Agriculture, has established a case-by-case (product-by-product) consultation process to determine if a plant variety as a final product obtained through NBT is a GMO or not. In order to give certainty to the interested party, the consultation process requires an application form. It asks a full description of several parameters: (1) the obtained phenotype; (2) background of the biotechnological technique and specific methods to indicate the modified DNA sequences; and (3) the breeding process and techniques used to discard insertion of foreign genetic sequences (transgenes). SAG should give an official answer through a legal resolution within 20 working days.

Until now, eight products have gone through the consultation process. All of them have been considered non-GMO because they do not bear foreign DNA (Table 3).

Likewise, in South America, similar criteria have been implemented in Argentina, Brazil, Colombia, and Paraguay via the adoption of case-by-case and product-focused regulations.³⁵

Conclusions

Chile remains as a country that is known as a leader in seed production, which is based on its geographic, climatic, political, and economic

Table 2. Minimum isolation distances and post-harvest land use restriction for confined environmental releases of GM crops in Chile and Argentina.

Crops	Minimum isolation distance (m)		Post-harvest land use restriction (months)	
	Argentina	Chile	Argentina	Chile
Maize	250	200	12	6
Soybean	3	5	12	6
Canola	3,000	500	60	46

Source: Argentina: 33 (Orroño and Vesprini 2018); Chile: Biosafety resolutions enacted by SAG for each specific approval.

Table 3. Plant products assessed by the Chilean regulatory agency, SAG, under the scope of the regulatory approach for NBT.

Species	Phenotype	Methodology
<i>Brassica napus</i>	Siliques shatter resistance	CRISPR
<i>Brassica napus</i>	Siliques shatter resistance	CRISPR + RTDS
<i>Camelina sativa</i>	Change in fatty acid composition	CRISPR
<i>Glycine max</i>	Change in fatty acid composition	TALEN
<i>Glycine max</i>	Change in fatty acid composition	TALEN
<i>Zea mays</i>	Change in starch composition	CRISPR
<i>Zea mays</i>	Drought tolerance	RdDM
<i>Zea mays</i>	Drought tolerance; increase yield	RdDM

RdDM: RNA-directed DNA methylation; TALEN: transcription activator-like effector nuclease; CRISPR: clustered regularly interspaced short palindromic repeats; RTDS: Rapid Trait Development System.

advantages, which have led the private sector to focus on this country for conducting research and multiplying high-value seeds.

In Chile, GM seed multiplication and crop breeding and research programs have achieved a technical and competitive level over the last 20 y due to private sector investments and a comprehensive regulatory framework provided by SAG. The country has had a significant role in the biotech crop development process in addition to a role as a supplier of the constant needs for off-season GM seeds. The country has been critical in the development of the 100% of GM crops of maize, soybean, and canola currently used in global markets.

Chile's regulatory approach for new plant breeding techniques, specifically genomic editing tools, represents a tremendous opportunity to foster innovation and productivity. It should contribute to transform Chile into a hot spot for further innovations based on biotechnology. Moreover, it should encourage plant breeders working with NBT-derived products to conduct their research programs in addition to their counter-season seed multiplication programs in Chile.

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Disclosure of Potential Conflicts of Interest

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