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# EVOLUTION AND GLOBAL DISTRIBUTION OF GENETICALLY MODIFIED SOYBEAN AREA IN THE PERIOD 2014-2018

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***Abstract***

*Currently, genetically modified (GM) crops are an important part of world agriculture, offering numerous benefits to farmers. This study investigates the dynamics of the cultivated area with GM crops, especially with genetically modified (GM) soybean, for the period 2014–2018, by country and by transgenic trait, using ISAAA and FAOSTAT databases. In the studied period, the top 5 GM crops countries were USA, Brazil, Argentina, Canada and India which totalled 166.1 million hectares or 89.5% of the global area. Regarding GM soybean, the top 5 countries were USA, Brazil, Argentina, Paraguay and Canada which cultivated 89.9 million hectares or 96.8% of the global area with this crop. The linear regression and the Pearson correlation coefficient have pointed out a general increasing trend for both cultivated areas. The USA and Brazil occupied the leading position in world with 32.93 and 32.55 million hectares of GM soybean, respectively. Herbicide tolerance (HT) has been consistently the dominant transgenic trait for GM soybean in USA, Argentina, Paraguay and Canada. In Brazil, the cultivated areas with stacked HT/IR traits have been larger than the areas cultivated with a single HT trait, in the last 3 years. As a conclusion, the global area of GM soybean will continue to increase due to its important economic role in the agriculture development and environmental benefits.*

***Key words*****:** *GM crops, GM soybean, herbicide tolerance, insect resistance, trend*

## INTRODUCTION

1996 was the first year in which a significant area of GM crops of 1.66 million ha was cultivated (in 6 countries). Since then there has been a continuous increase in plantings, and in 2018, the global area reached 191.7 million ha (in 29 countries). Almost all of the global GM crops area comes from soybean, maize, cotton and canola [11].

Genetically modified organisms can be defined as organisms in which the genetic material (DNA) has been altered by recombinant DNA technology (combining genes from different organisms) [2].

Genetic engineering has made it possible to significantly improve crops through transgenesis (genetic modification), but nevertheless, the discussions between communities for and against this technology have failed to move forward. Those who support this technology believe that increasing production and reducing costs are ultimately beneficial to consumers. On the other hand, those who are against this technology are concerned about the risks to the environment and health [1].

Soybean (*Glycine max* (L.) Merr.), called the "king of beans" is one of the most important sources of protein, being used as a raw material to obtain many edible and inedible products, such as cooking oil, milk, vegan food, feed and biodiesel [18].

The results obtained by various authors showed that the full fat soybean used as feed can ensure high performances in broilers fattening under lower costs and a high meat and fat quality [16].

Due to the worldwide economic importance of soybean, this crop has become a target for genetic improvement.

Soybean have a very limited tolerance to many of the herbicides used, hence, to produce herbicide-tolerant soybean by conventional breeding, genes for resistance that must be available in crossing material that is compatible with soybean are needed. A lack of sufficient variability in resistance levels of its germplasm has hindered breeding efforts [7].

Genetic transformation of plants has provided an attractive genetic improvement for soybean, allowing the obtaining of new and genetically diverse plant materials [8].

Genetically modified (GM) (transgenic or biotech crops) are cultivated mainly in developing countries by millions of farmers. According to [15], they provide economic benefits to farmers by increasing yields by 22% and farm profit by 68%, but also environmental benefits by reducing the use of chemicals by 37%. Also, genetic modified foods have the potential to solve problems related with malnutrition, under nutrition and environment protection [3].

In this context, the paper aimed to analyze the global trend of the area cultivated with GM soybean in the period 2014-2018, in order to determine the top 5 producing countries and what is the proportion of adoption of HT and HT/IR traits in these countries. Finally, the most approved events for GM soybeans used in food, feed processing and in cultivation were presented.

## MATERIALS AND METHODS

This study is based on International Service for the Acquisition of Agri-biotech Applications (ISAAA) and Food and Agriculture Organization of the United Nations (FAOSTAT) data collected for the period 2014-2018.

The main methods used in this study were the following: linear regression, Pearson correlation coefficient (r), coefficient of determination ($R^2$), average, standard deviation and coefficient of variation. The data were statistically processed using Microsoft Excel.

The results were presented in Tables and illustrated in Graphics.

## RESULTS AND DISCUSSIONS

### Evolution and global distribution of genetically modified (GM) crops area

The global area used for transgenic crops increased from 181.5 million hectares in 2014 to 191.7 million hectares in 2018 (+10.2 million hectares in the studied period. The total worldwide variation was slight (CV=2.79%). The general trend reflects a continuous increasing, except for 2015 when there was a fluctuation. The highest growth of GM crops area was registered in the year 2016 when the area increased by 3.0% compared to the level of 2015. In 2017 versus 2016, the area increased by 2.5%. The last year registered slight increases (+1.0%) versus 2017. The year with a slight decline was 2015, when GM crops area decreased by ~ 1.0% compared to the previous year (Figure 1).

The intensity of the linear relationship expressed by Pearson correlation coefficient (r=0.934) indicates a strong positive relationship of a linear nature between the global area used for cultivating GM crops and the year of cultivation. The coefficient of determination ($R^2$=0.871) explains that 87.1% of the variation in global area with GM crops is caused by the year of cultivation (Figure 1).

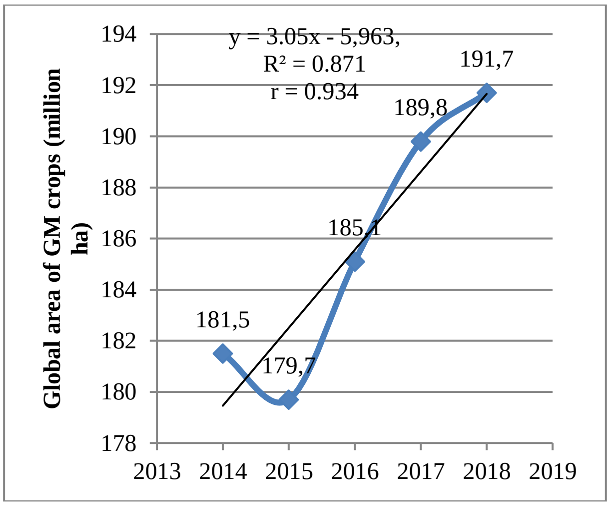


Fig. 1. Evolution of hectares (million ha) cultivated with GM crops in world, 2014-2018
Source: Own design and processing based on the data [9, 10, 11, 13, 14]

In the studied period, the top 5 biotech crops countries were USA, Brazil, Argentina, Canada and India which totalled 166.1 million hectares or 89.5% of the world's GM crops acreage (Table 1).

The data summarized in Figure 2, reflect the fact that the area cultivated with GM crops increased from 2014 to 2018 in USA, Brazil and Canada.

A higher increase over the study period was observed for Brazil where the cultivated area increased by 21.5% (9.1 million hectares) in 2018 compared to 2014. In Argentina, a decrease in cultivated areas was observed in 2016, 2017 and 2018 compared to 2015 and 2014. In India, the area of 11.6 million hectares remained relatively constant from almost every year, with fluctuations in 2016 and 2017 (Figure 2).

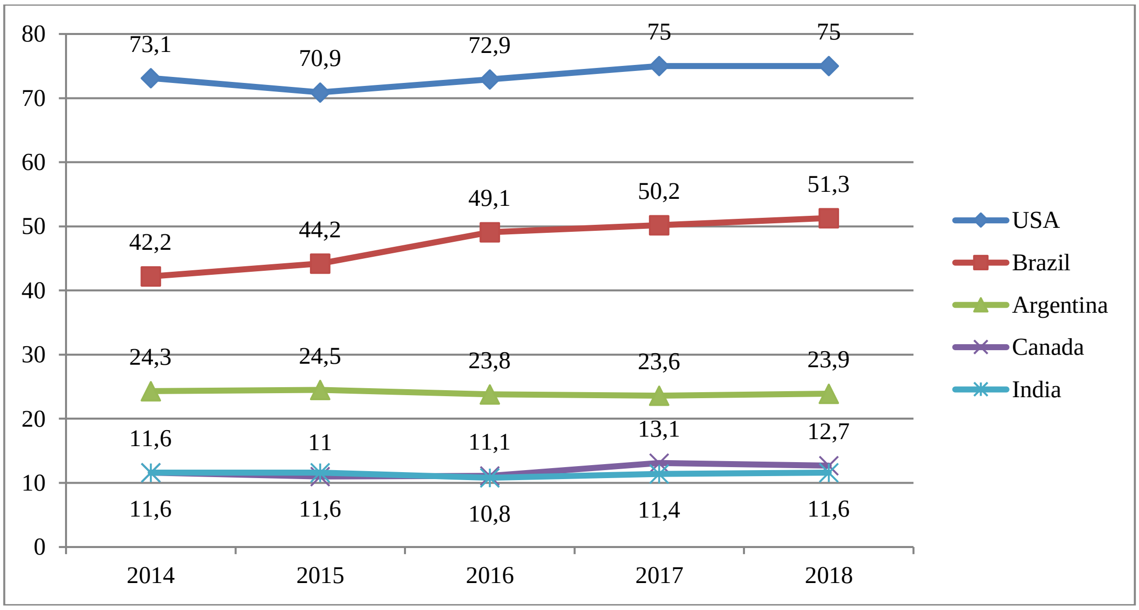

Fig. 2. Evolution of the GM crops areas in top 5 biotech crops countries (million hectares), 2014-2018
Source: Own design and processing based on the data [9, 10, 11, 13, 14]

The values of the Pearson correlation coefficients presented in Table 1 confirm the intensity of the relations between the global area and the area allocated to genetically modified crops in each of the top 5 biotech countries, during the studied period.

Table 1. Statistics values calculated for areas (million ha) with GM crops in top 5 biotech crops countries (2014-2018)

| Country | Average | St. dev. | Variation coefficient (%) | Pearson correlation coefficient |
|---|---|---|---|---|
| USA | 73.4 | 1.7 | 2.3 | 0.730 |
| Brazil | 47.4 | 4.0 | 8.4 | 0.962 |
| Argentina | 24.0 | 0.4 | 1.7 | -0.726 |
| Canada | 11.9 | 1.0 | 8.4 | 0.715 |
| India | 11.4 | 0.3 | 2.6 | -0.091 |
| Total GM crops in top 5 countries | 166.1 | 7.4 | 4.4 | |
| Global GM crops | 185.6 | 5.2 | 2.8 | |

Source: Calculated by author based on the data from [9, 10, 11, 13,14].

Globally, the largest area of genetically modified crops was registered in the USA where, on average, 73.4 million hectares (39.5% of the global area) were cultivated. Brazil occupied the second position globally, the cultivated area being 47.4 million hectares (25.5% of the global area). Argentina was the third largest producer of GM crops, registering 24 million hectares (12.9% of global area), Canada was the fourth largest producing country with 11.9 million hectares (6.4%) and India was fifth largest producing country with 11.4 million hectares (6.1%) (Table 1).

The variation coefficient for the area with GM crops in each country is shown in Table 1. The values of this coefficient were less than 10% showing that the cultivated area did not varied too much and remained relatively homogeneous over years.

**Evolution and global distribution of genetically modified (GM) soybean area**

The global area with GM soybean had, in general, a continuous increasing from 90.7 million hectares in the year 2014 to 95.9 million hectares in the year 2018 (+5.7%). A highest hectare of GM soybean was registered in the year 2017 when area increased by 2.9% compared to the level of 2016. Also, in 2015 versus 2014, the area increased by 1.5%. The last year registered a slight increase (+1.9%) versus 2017. The year with a slight decline was 2016 when area decreased by 0.8%

compared to the previous year. The value of Pearson correlation coefficient (r=0.920) indicated a strong positive relationship of a linear nature between the global area used for planting GM soybean and the year of cultivation. The coefficient of determination ($R^2$=0.847) explains that 84.7% of the variation in global area with GM soybean is caused by the year of cultivation (Figure 3).
Therefore, an increase in the global area allocated to GM crops was confirmed, and the global area with GM soybean shows a similar increasing trend in the number of hectares cultivated.

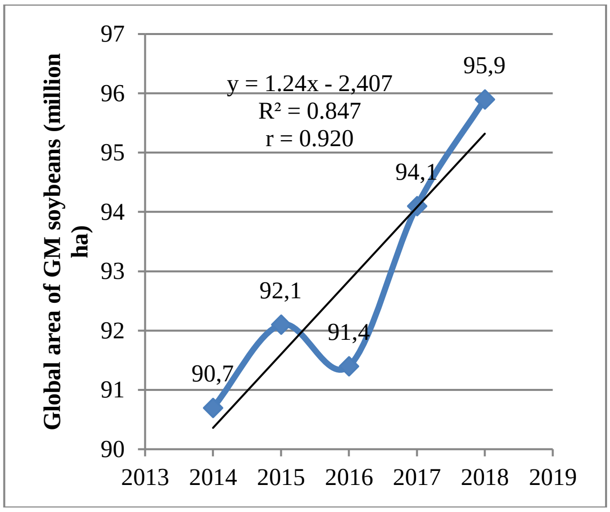


Fig. 3. Evolution of hectares (million ha) cultivated with GM soybean in world (2014-2018)
Source: Own design and processing based on the data [9, 10, 11, 13, 14].

For the studied period, the top 5 countries that cultivated the largest areas of GM soybean were the USA (32.93 million hectares), Brazil (32.12 million hectares), Argentina (19.34 million hectares) Paraguay (3.19 million hectares) and Canada (2.28 million hectares) (Table 2).
During the studied period, India did not grow GM soybean, but only GM cotton and GM mustard, so we excluded it from the top 5 countries.
The global area with GM soybean of 92.84 million hectares was comprised especially in these top 5 countries, which totalled 89.86 million hectares or 96.8% of the global area cultivated with GM soybean, and 73.6% of the global area with soybean crop (Table 2).

The area with GM soybean in the USA had an increasing trend, but in certain years there have some fluctuations. A higher increase trend was observed for Brazil where the area cultivated increased from 29.07 million hectares in 2014 to 34.86 million hectares in 2018 (+19.9%). In Argentina, area registered a decline in the last 3 years (2016, 2017 and 2018) versus 2015 and 2014. The general trend for Paraguay remained relatively stable, reflecting a continuous decline, but in 2018 it registered a slight increase. In Canada, the area of GM soybean increased continuously from 2.1 million hectares in 2014 to 2.5 million hectares in 2017, and decreased in 2018 versus 2017 (Figure 4).

Table 2. Statistics values calculated for areas (million ha) with GM soybean in top 5 countries (2014-2018)

| Country | Average | St. dev. | Variation coefficient (%) | Pearson's correlation coefficient |
|---|---|---|---|---|
| USA | 32.93 | 1.06 | 3.22 | 0.783 |
| Brazil | 32.12 | 2.39 | 7.45 | 0.989 |
| Argentina | 19.34 | 1.50 | 7.76 | -0.908 |
| Paraguay | 3.19 | 0.29 | 9.09 | -0.393 |
| Canada | 2.28 | 0.17 | 7.46 | 0.877 |
| Total GM soybean in top 5 biotech countries | 89.86 | | | |
| Global GM soybean | 92.84 | | | |
| Global soybean crop | 122.1 | | | |

Source: Own calculation based on the data [5, 9, 10, 11, 13, 14].

According to [11], the reduction in the area of GM soybeans in 2018 compared to 2017 and 2016 in Argentina and reduction in 2018 compared to 2017 in Canada was due to drought in these countries and low soybean prices, especially in Canada.
The intensity of the linear correlation between year of cultivation and area allocated to GM soybean in each of top 5 countries was confirmed by the values of Pearson correlation coefficients. The coefficients of variation were small (<10%) in each country, reflecting the fact that there are no large discrepancies over years (Table 2).
In European Union, including in Romania, only one GM crop event is authorized for cultivation, i.e. maize MON810, although its cultivation is prohibited in a number of EU

countries and territories by Commission implementing decision 2016/321 [19].

Although only one maize event is authorized for cultivation in the EU, over 50 events from various genetically modified crops are authorized for import and use as food and feed. As GM soybean is not cultivation, it is estimated that the EU will import about 30 million tonnes of GM soybean annually [17].

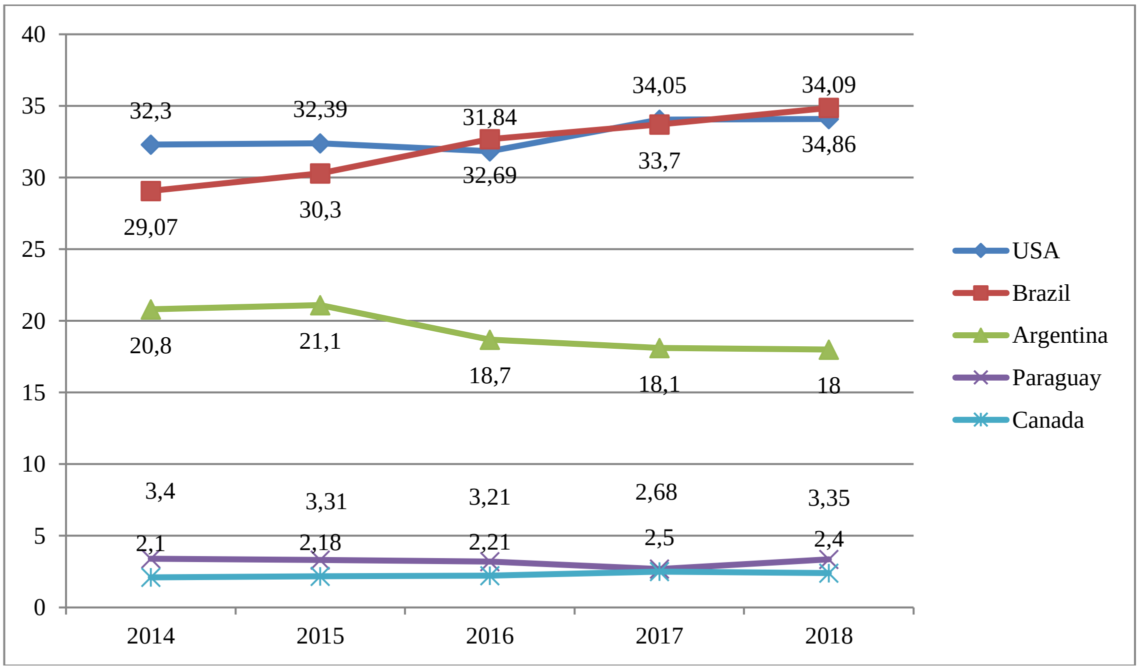


Fig. 4. Evolution of the GM soybean areas in top 5 countries (million hectares), 2014-2018
Source: Own design and processing based on the data [9, 10, 11, 13, 14]

**Evolution and global distribution of transgenic traits in the area of GM soybean**

Herbicide-tolerant (HT) crops were developed to survive the application of some effective herbicides (such as glyphosate, glufosinate, dicamba etc.) [4]. Insect-resistant (IR) crops contain a gene from the soil bacterium *Bacillus thuringiensis (Bt)* that produces a protein toxic to specific insects, protecting the plant over its entire life [6]. During the studied period, herbicide tolerance trait (sometimes associated with another) was consistently the dominant trait of GM soybean cultivated in USA, Argentina, Paraguay and Canada. In average, the GM soybean cultivated in the USA and Canada on 32.9 and 2.2 million hectares, respectively, was 97-100% herbicide-tolerant (Table 3).

Table 3. Evolution and distribution of GM soybean area by traits in top 5 countries (2014-2018)

| Country | By trait | Area (million ha) | | | | | % transgenic trait | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2014 | 2015 | 2016 | 2017 | 2018 | 2014 | 2015 | 2016 | 2017 | 2018 |
| USA | HT | 32.3 | 32.4 | 31.8 | 34.0 | 34.1 | 100 | 100 | 100 | 100 | 100 |
| | Stacked HT/IR | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - |
| Brazil | HT | 23.9 | 18.5 | 12.4 | 13.6 | 14.6 | 82.2 | 61.0 | 37.9 | 40.3 | 41.9 |
| | Stacked HT/IR | 5.2 | 11.9 | 20.3 | 20.1 | 20.2 | 17.9 | 39.3 | 62.1 | 59.6 | 57.9 |
| Argentina | HT | 20.8 | 20.4 | 16.2 | 15.0 | 13.7 | 100 | 96.7 | 86.7 | 82.9 | 76.1 |
| | Stacked HT/IR | 0 | 0.7 | 2.5 | 3.1 | 4.3 | - | 3.3 | 13.3 | 17.1 | 23.9 |
| Paraguay | HT | 3.3 | 3.2 | 2.7 | 1.7 | 1.7 | 97.0 | 96.7 | 84.3 | 63.1 | 50.0 |
| | Stacked HT/IR | 0.1 | 0.1 | 0.5 | 1.0 | 1.7 | 3.0 | 3.3 | 15.7 | 3.9 | 50.0 |
| Canada | HT | 2.1 | 2.0 | 2.1 | 2.5 | 2.4 | 100 | 91.7 | 95.0 | 100 | 100 |
| | Stacked HT/IR | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - |

HT: herbicide tolerance; IR: insect resistance
Source: Own processing based on the data [9, 10, 11, 13, 14].

Brazil, Argentina and Paraguay cultivated GM soybean with a single HT trait on 16.6, 17.2 and 2.5 million hectares, respectively and with the stacked HT/IR traits (combined of herbicide tolerance and insect resistance) on 15.5, 2.1 and 0.7 million hectares, respectively. In these countries was observed a declining in HT trait over the years, with the increasing the proportional of the stacked HT/IR traits, but in Brazil, the cultivated areas with stacked HT/IR traits have been larger than the cultivated areas with HT trait, in the last 3 years (Table 3). According to [11], stacked HT/IR traits products are preferred by many farmers due to their cost-saving technology, especially the Intacta™ soybean. The variation coefficients for transgenic traits were high and very high in Brazil, Argentina and Paraguay, reflecting that there are discrepancies during the analyzed period (Table 4).

Table 4. Statistics values calculated for traits of GM soybean cultivated (million ha) in top 5 countries (2014-2018)

| Country | HT | | | Stacked HT/IR | | |
|---|---|---|---|---|---|---|
| | Average | St. dev. | Variation coefficient (%) | Average | St. dev. | Variation coefficient (%) |
| USA | 32.9 | 1.1 | 3.2 | 0 | - | - |
| Brazil | 16.6 | 4.7 | 28.3 | 15.5 | 6.8 | 43.9 |
| Argentina | 17.2 | 3.2 | 18.6 | 2.1 | 1.8 | 85.7 |
| Paraguay | 2.5 | 0.8 | 32.0 | 0.7 | 0.7 | 100.0 |
| Canada | 2.2 | 0.2 | 9.09 | 0 | - | - |
| Total GM traits soybean in top 5 countries | 71.4 | | | 17.2 | | |

HT: herbicide tolerance; IR: insect resistance
Source: Own calculation based on the data [9, 10, 11, 13, 14].

**Status of some GM soybean approved events used in food, feed processing and in cultivation in world**

Since 1996, when GM crops events began to be marketed, the number of approvals has varied from year to year.

In 2018, approvals were issued for genetically modified crops in 70 countries. These authorizations were intended to regulate genetically modified crops used for cultivation, food and feed. Among the GM soybean events, herbicide-tolerant soybean (HT) with the name GTS 40-3-2 received 57 approvals (in EU 28 + 28 countries), herbicide-tolerant soybean with the name MON89788 received 45 approvals (in EU 28 + 25 countries) and herbicide-tolerant soybean with the name A2704-12 also received 45 approvals (in EU 28 + 24 countries) [11].

Tables 5, 6 and 7 present the top 3 soybean approval events, by country and by type of approval.

Approvals are granted for food, feed and cultivation on a per event basis according to the regulations of each country.

It is possible, then for an event of GM crop to receive 3 different approvals per each country (food, feed and cultivation), 2 approvals (food and feed) or only one approval.

Thus, the GTS 40-3-2 event has approvals for food, feed and cultivation in Argentina, Bolivia, Brazil, Canada, Japan, Paraguay, USA and Uruguay, but has approvals for cultivation only in Chile, Costa Rica and South Africa.

The MON89788 event has approvals for food, feed and cultivation in Canada, Japan and USA, but has approvals for cultivation only in Costa Rica, Mexico and Uruguay.

The A2704-12 event has approvals for food, feed and cultivation in Argentina, Brazil, Canada, Japan and USA, but has approvals for cultivation only in Uruguay.

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Table 5**.** Herbicide-tolerant soybean GTS 40-3-2 event

| Trade name/ Developer | Method of trait introduction | Commercial trait | Authorizations | | | |
|---|---|---|---|---|---|---|
| | | | Country | Food | Feed | Cultivations |
| Roundup Ready™ soybean/<br><br>Monsanto Company (including fully and partly owned companies) | Microparticle bombardment of plant cells or tissue | Herbicide tolerance | Argentina | x | x | x |
| | | | Australia | x | | |
| | | | Bolivia | x | x | x |
| | | | Brazil | x | x | x |
| | | | Canada | x | x | x |
| | | | Chile | | | x |
| | | | China | x | x | |
| | | | Colombia | x | x | |
| | | | Costa Rica | | | x |
| | | | European Union | x | x | |
| | | | Indonesia | x | | |
| | | | Iran | x | | |
| | | | Japan | x | x | x |
| | | | Malaysia | x | x | |
| | | | Mexico | x | | x |
| | | | New Zeeland | x | | |
| | | | Nigeria | x | x | |
| | | | Paraguay | x | x | x |
| | | | Philippines | x | x | |
| | | | Russia | x | x | |
| | | | Singapore | x | x | |
| | | | South Africa | | | x |
| | | | South Korea | x | x | |
| | | | Switzerland | x | x | |
| | | | Taiwan | x | | |
| | | | Turkey | | x | |
| | | | United States | x | x | x |
| | | | Uruguay | x | x | x |
| | | | Vietnam | x | x | |

Source: Own processing based on the data [12].

Table 6. Herbicide-tolerant soybean MON89788 event

| Trade name/ Developer | Method of trait introduction | Commercial trait | Authorizations | | | |
|---|---|---|---|---|---|---|
| | | | Country | Food | Feed | Cultivations |
| Genuity® Roundup Ready 2 Yield™<br><br>Monsanto Company (including fully and partly owned companies) | *Agrobacterium tumefaciens* - mediated plant transformation | Glyphosate herbicide tolerance | Argentina | x | x | |
| | | | Australia | x | | |
| | | | Canada | x | x | x |
| | | | China | x | x | |
| | | | Colombia | x | x | |
| | | | Costa Rica | | | x |
| | | | European Union | x | x | |
| | | | India | x | x | |
| | | | Indonesia | x | | |
| | | | Iran | x | | |
| | | | Japan | x | x | x |
| | | | Malaysia | x | x | |
| | | | Mexico | x | | x |
| | | | New Zeeland | x | | |
| | | | Nigeria | x | x | |
| | | | Philippines | x | x | |
| | | | Russia | x | x | |
| | | | Singapore | x | x | |
| | | | South Africa | x | x | |
| | | | South Korea | x | x | |
| | | | Switzerland | x | x | |
| | | | Taiwan | x | | |
| | | | Thailand | x | | |
| | | | Turkey | | x | |
| | | | United States | x | x | x |
| | | | Uruguay | | | x |
| | | | Vietnam | x | x | |

Source: Own processing based on the data [12]

Table 7. Herbicide-tolerant soybean A2704-12 event

| Trade name/ Developer | Method of trait introduction | Commercial trait | Authorizations | | | |
|---|---|---|---|---|---|---|
| | | | Country | Food | Feed | Cultivations |
| Liberty Link® soybean/ BASF | Microparticle bombardment of plant cells or tissue | Herbicide tolerance | Argentina | x | x | x |
| | | | Australia | x | | |
| | | | Brazil | x | x | x |
| | | | Canada | x | x | x |
| | | | China | x | x | |
| | | | Colombia | | x | |
| | | | European Union | x | x | |
| | | | India | x | x | |
| | | | Iran | x | | |
| | | | Japan | x | x | x |
| | | | Malaysia | x | x | |
| | | | Mexico | x | | |
| | | | New Zeeland | x | | |
| | | | Nigeria | | x | |
| | | | Philippines | x | x | |
| | | | Russia | x | x | |
| | | | Singapore | x | x | |
| | | | South Africa | x | x | |
| | | | South Korea | x | x | |
| | | | Taiwan | x | | |
| | | | Turkey | | x | |
| | | | United States | x | x | x |
| | | | Uruguay | | | x |
| | | | Vietnam | x | x | |

Source: Own processing based on the data [12].

## CONCLUSIONS

In the studied period, the cultivated areas with GM crops, including GM soybean, generally showed an increasing trend.

The top 5 GM crops countries were USA, Brazil, Argentina, Canada and India, but the top 5 GM soybean countries were USA, Brazil, Argentina, Paraguay and Canada.

The USA and Brazil occupied the leading position in world with 32.93 and 32.55 million hectares cultivated with GM soybean, respectively.

Herbicide tolerance (HT) has been consistently the dominant transgenic trait for GM soybean in USA, Argentina, Paraguay and Canada. In Brazil, the cultivated areas with stacked HT/IR traits have been larger than the areas cultivated with a single HT trait in the last 3 years.

In 2018, the herbicide-tolerant soybean events with the name GTS 40-3-2, MON89788 and A2704-12 have the most numerous approvals in world.

## REFERENCES

[1]Barrows, G., Sexton, S., Zilberman, D., 2014, Agricultural biotechnology: the promise and prospects of genetically modified crops. Journal of Economic Perspectives, 28(1), 99-120.

[2]Bawa, A.S., Anilakumar, K.R., 2013, Genetically modified foods: safety, risks and public concerns - a review. Journal of Food Science and Technolology, 50 (6), 1035-1046.

[3]Bonea, D., Urechean, V., 2017, Genetically modified foods: some benefits and risks. Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series, Vol. XLVII (1), 50-56.

[4]Bonny, S., 2008, Genetically modified glyphosate-tolerant soybean in the USA: adoption factors, impacts and prospects. A review. Agronomy for Sustainable Development, 28, 21–32.

[5]FAOSTAT, 2021, Crops and livestock products http://www.fao.org/faostat/en/#data/QCL, Accessed on September 26, 2021.

[6]Fernandez-Cornejo, J., Wechsler, S., Livingston, M., Mitchell, L., 2014, Genetically engineered crops in the United States. USDA Economic Research Report No. (ERR-162), 60 pp: https://www.ers.usda.gov/publications/pub-details/?pubid=45182, Accessed on September 10, 2021.

[7]Gianessi, L., Carpenter, J., 2000, Agricultural biotechnology: benefits of transgenic soybeans: https://www.iatp.org/sites/default/files/Agricultural_Biotechnology_Benefits_of_Transge.pdf, Accessed on October 4, 2021.

[8]Homrich, M.S., Wiebke-Strohm, B., Weber, R. L., Bodanese-Zanettini, M.H., 2012, Soybean genetic transformation: A valuable tool for the functional study of genes and the production of agronomically improved plants. Genetics and molecular biology, 35(4 (suppl)), 998–1010.

[9]ISAAA., 2016, Global Status of Commercialized Biotech/GM Crops: 2016. ISAA Brief No 52. ISAAA: Ithaca, NY.
[10]ISAAA., 2017, Global Status of Commercialized Biotech/GM Crops in 2017: Biotech Crop Adoption Surges as Economic Benefits Accumulate in 22 Years. ISAAA brief No. 53. ISAAA, Ithaca, NY.
[11]ISAAA., 2018a, Global Status of Commercialized Biotech/GM Crops in 2018: Biotech Crops Continue to Help Meet the Challenges of Increased Population and Climate Change. ISAAA Brief No. 54. ISAAA: Ithaca, NY.
[12]ISAAA., 2018b, GM Approval Database: https://www.isaaa.org/gmapprovaldatabase/, Accessed on October 4, 2021.
[13]James, C., 2014, Global Status of Commercialized Biotech/GM Crops: 2014. ISAAA Brief No. 49. ISAAA: Ithaca, NY.
[14]James, C., 2015, 20th Anniversary (1996 to 2015) of the Global Commercialization of Biotech Crops and Biotech Crop Highlights in 2015. ISAAA Brief No. 51. ISAAA: Ithaca, NY.
[15]Klumper, W., Qaim, M., 2019, A meta-analysis of the impacts of genetically modified crops. Plos One, 9 e111629.
[16]Popescu, A., Criste, R., 2003, Using full fat soybean in broiler diets and its effect on the production and economic efficiency of fattening. Journal of Central European Agriculture, 4(2), 167-174.
[17]Rostoks, N., Grantiņa-Ieviņa, L., Ieviņa, B., Evelone, V., Valciņa, O., Aleksejeva, I., 2019, Genetically modified seeds and plant propagating material in Europe: potential routes of entrance and current status. Heliyon, 5(2), e01242.
[18]Thrane, M., Paulsen, P.V., Orcutt, M.W., Krieger, T.M., 2017, Soy protein: Impacts, production, and applications (Chapter 2). In Nadathur, S.R., Wanasundara, J.P.D., Scanlin, L. (Eds.), Academic Press. Sustainable Protein Sources, 23–45. http://www.sciencedirect.com/science/article/pii/B9780128027783000020 , Accessed on September 10, 2021.
[19]Urechean, V., Bonea, D., 2018, The role of buffer zones in ensuring the coexistence of GM and non-GM maize. Scientific Papers. Series A. Agronomy, Vol. LXI(1), 420-425.