Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 22, Issue 1, 2022
PRINT ISSN 2284-7995, E-ISSN 2285-3952

ANALYSIS OF GLOBAL TRENDS IN GM MAIZE APPROVALS IN THE PERIOD 2014-2018

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Abstract

GM maize events are developed for the benefit of the global population but their approval in each country varies according to consumer acceptance, needs and commercial interests. This study analyzed the number of global approvals (by country and type of approval) for GM maize in the period 2014-2018, based on statistical data collected from the ISAAA-GM Approval Database. Descriptive statistics, regression equations and coefficient of determination were used to identify the trends for these indicators. The results showed that a total of 691 applications were approved in 28 countries. In 2016 was registered the highest number of food, feed and cultivation approvals. South Korea, Argentina, Brazil and Taiwan were the top four countries with the most food approvals, Brazil, South Korea, Argentina and Japan were the top four countries with the most feed approvals, and Argentina, Brazil, Japan and Canada were the top four countries that issued the most cultivation approvals. In developing country the rate of acceptance for GM maize was higher compared to developed countries. Europe issued a total of 26 approvals only for food and feed, with most approvals being issued in 2016.

Key words**:** *cultivation approvals, feed approvals, food approvals, events*

INTRODUCTION

The first genetically modified (GM) crops were established in China (1992) for tobacco and cucumber, but officially China started cultivating GM crops in 1996. The first approval for commercial sale of a food product from a GM crop was in the USA, in 1994 for FlavrSavr™ tomato (delayed ripening) developed by Calgene Company. The first approval for the commercialization of GM maize was in the United States in 1995, namely for *Bt* maize with insect resistance developed by Ciba-Geigy Company [14].

In 1996, only six countries (USA, China, Canada Argentina, Australia and Mexico) cultivated GM crops on 1.7 million hectares, and in 2018, it reached to 29 cultivating countries and an area of 191.7 million hectares. In 2018, the top five GM crops cultivating countries were the USA, Brazil, Argentina, Canada and Paraguay, and the main commercially GM crops were soybean, maize, cotton and canola. GM maize occupied the second position (after soybean) with of cultivated area of 33.14 million hectares [5, 13].

Genetically modified crops offer many benefits to farmers, representing an important part of global agriculture [5]. Increasing the number of GM events, crops and traits leads to increased benefits for the global population but their approval for cultivation, food or feed in each country according on demand, needs and trade interest [1].

Farmers have adopted GM crops rapidly since its first commercialization in 1996. The expansion of these areas is due to the approval and marketing of new events that have improved traits to increase food production and mitigate problems related to unfavorable environmental factors (climate change, new diseases and pests).

According to [7], in 2018 the global economic benefits obtained by farmers have been of US$225 billion, and 53.8% of these income gains were for developing country farmers.

A transformation event (shortened to „event”) is the insertion of a piece of foreign DNA into the genome of an organism. To harmonize their regulatory approach for GM events, countries' efforts are coordinated by

multilateral fora such as the Codex Alimentarius Commission, Cartagena Protocol on Biosafety (a supplementary agreement to the Convention of Biological Diversity) and Codex Alimentarius [16].
In 2018, maize (*Zea mays* L.) ranked as the first cereal crop globally in terms of grain yield. Of the global area of 197.2 million hectares, 30% (58.9 million hectares) were cultivated with GM maize [10, 13].
Maize is used as a raw material for industry or as direct human food, as well as feed. Also, maize is an important source of profit farms with export potential [18, 19, 20, 21].
The continuous increase of the human population and implicitly of the consumption of food of animal origin leads to the increase of the maize demand. The climatic changes and various other biotic and abiotic stresses limit the increase of maize yield and its quality. In order to overcome these challenges, it was necessary to use genetic engineering for the genetic improvement of this crop [23]. GM maize events incorporate not only abiotic stress tolerance, but and high yield and improved nutritional quality.
Currently, there is the possibility of developing new traits using transformation combined with genomics and genome editing, technologies that will have a major influence on the dynamics of global agriculture ushering in a new era of molecular breeding and varietal development [15].
In this context, the present paper analyzed the trends of GM maize events and approvals in the period 2014-2018.

MATERIALS AND METHODS

This study is based on statistical data collected from the International Service for the Acquisition of Agri-biotech Applications: GM approval Database in the period 2014-2018, in terms of the GM maize events and approvals in the world. In this paper food, feed and cultivation approvals are treated individually (approvals expired or under renewal are not included).
The indicators analyzed were: number of events, number of approvals for food; number of approvals for feed, number of approvals for cultivation, number of countries that issued approvals for food, number of countries that issued approvals for feed, and number of countries that issued approvals for cultivation.
The number and share of dominant transgenic traits in GM maize events were also analyzed.
On the other hand, the number of GM maize events and approvals for Europe (EU-28 as 1 country) was detailed. The methods used were: descriptive statistics (mean, standard deviation, coefficient of variation, minimum and maximum values); trend line, regression equations (Y=bX+a) and coefficient of determination (R^2). The data were statistically processed using Microsoft Excel, and presented in Tables and illustrated in Figures.

RESULTS AND DISCUSSIONS

Global trends in GM maize approvals

In the 5-year period (2014-2018), 28 countries (EU-28 counted as 1) imported and cultivated a total of 92 GM maize events and approved a total of 691 applications (Table 1 and 3).
In addition to these commercialized events, there are other events that have been developed, tested and then abandoned for commercial purposes [1]. Brazil, Argentina, Japan and South Korea were the top four countries by total number of approvals food, feed and cultivation). It was noticed that South Korea did not cultivate GM maize in the studied period. For use as food there were approved 320 applications in 26 countries with the top four countries being South Korea, Argentina, Brazil and Taiwan (Table 1). A total of 249 applications were approved in 23 countries for use as feed, the top four countries being Brazil, South Korea, Argentina and Japan. Also, a total of 122 approvals were approved in 12 countries for cultivation, the top four countries being Argentina, Brazil, Japan and Canada (Table 1). Of the total approving countries, 17 (65.3%) were developing countries that issued food approvals, 17 (73.9%) were developing countries that issued feed approvals, and 9 (75%) were developing countries that issued cultivation approvals, which indicates a higher acceptance rate in these countries compared to developed countries (Table 1).

Table 1. Number of GM maize events and approvals: by country and by type of approval (2014-2018)

Country	No. approvals as:							
	Total	Rank	Food	Rank	Feed	Rank	Cultivation	Rank
Argentina*	82	2	29	2	24	3	29	1
Australia	6	21	6	17	0		0	
Brazil*	84	1	29	3	29	1	26	2
Canada	33	5	11	12	11	9	11	4
China*	10	19	5	19	5	17	0	
Colombia*	29	8	21	5	6	16	2	11
Costa Rica*	1	28	0		0		1	12
European Union	26	10	13	10	13	6	0	
Honduras*	2	27	1	25	1	22	0	
Indonesia*	4	26	3	23	1	23	0	
Iran*	5	25	5	20	0		0	
Japan	62	3	20	7	20	4	22	3
Malaysia*	24	13	12	11	12	7	0	
Mexico*	33	6	21	6	12	8	0	
New Zealand	6	22	6	18	0		0	
Nigeria*	19	15	10	14	9	12	0	
Pakistan*	12	18	4	22	4	20	4	7
Paraguay*	26	11	8	15	8	14	10	5
Philippines*	26	12	11	13	11	10	4	8
Russia*	6	23	3	24	3	21	0	
Singapore	24	14	15	8	9	13	0	
South Africa*	19	16	8	16	8	15	3	10
South Korea	59	4	31	1	28	2	0	
Taiwan	28	9	28	4	0		0	
Turkey*	10	20	0		10	11	0	
United States	16	17	5	21	5	18	6	6
Vietnam*	32	7	14	9	14	5	4	9
Zambia*	6	24	1	26	5	19	0	
TOTAL	691		320		249		122	

* Developing countries
Source: Own calculation based on the data from [11].

In the studied period, the evolution of the number of all types of approvals (food, feed or cultivation) registered decreasing trends with peaks and lows (Figure 1).

The number of food approvals reached its peak at 84 approvals in 2016 and declined to 57 in 2015, to 53 in 2017 and to 58 in 2018. The number of feed approvals reached its peak in 2016 at 61 approvals and declined to 45 in 2017 and to 40 in 2018. Also, the number of cultivation approvals reached its peak in 2016 at 28 approvals and declined to 20 in 2017 and 2018. The coefficients of determination showed that 9.2%, 24.6% and 67.6%, respectively, of the variation of the number of food, feed or cultivation approvals is caused by year’s variation (Figure 1).

The declining trends for the number of events and approvals were determined probably due to the trend in more developing countries to adopt other GM crops, such as rice and potato and also due to the low international price of maize in 2017 [12].

The global trends of approving countries presented in Figure 2 showed decreases during the studied period. The number of countries that issued food approvals reached its peak in 2016 at 18 countries then declined to 15 in 2015 and 2017 and to 14 in 2018. The number of countries that issued feed approvals stagnated at 13 in 2015, 2016 and 2017, and declined to 11 in 2018. Also, the number of countries that issued cultivation approvals registered a decline significantly from 10 countries in 2014 to 5 countries in 2017 and 2018.

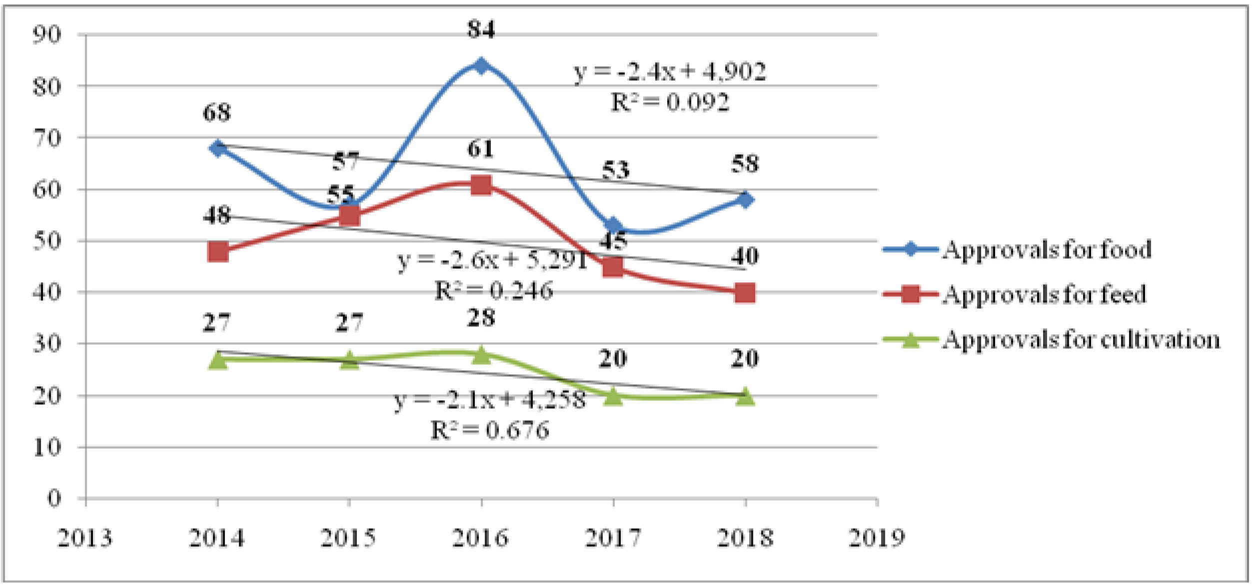

Fig. 1. Global trends in number of GM maize approvals for food, feed or cultivation (2014-2018)
Source: Own design and calculation based on the data from [11].

The coefficients of determination showed that 17.3%, 50% and 70.3%, respectively, of the variation in the number of countries that issued food, feed or cultivation approvals is determined by variation of the years.

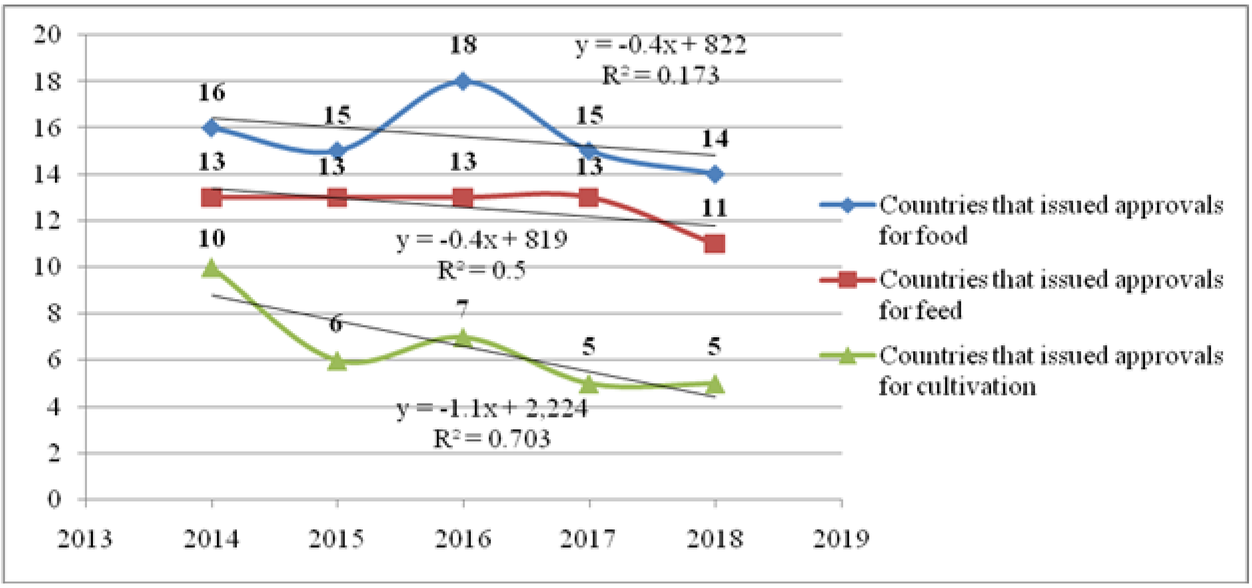

Fig. 2. Global trends in number of countries that issued GM maize approvals (for food, feed or cultivation) in the period 2014-2018
Source: Own design and calculation based on the data from [11].

In the 5-year period, the average of the total number of approvals was of 138.2 with a minimum level of 118 in 2017 and 2018, and a maximum level of 173 in 2016 (Table 2).
In term of type of approval (for food, feed or cultivation) the minimum level was of 53 (2017), 40 (2018) and 20 (2017, 2018), respectively, and the maximum level was of 84 (2016), 61 (2016) and 28 (2016), respectively.
In the case of the number of approving countries that have issued approvals for food, feed or cultivation, the minimum level was of 14 (2018), 11 (2018) and 5 (2017, 2018), respectively, and the maximum level was of 18 (2016), 13 (2014, 2015, 2016, 2017) and 10 (2014), respectively.

The values of the coefficients of variation varied from a studied indicator to another. In the case of the number of total approvals, food approvals, feed approvals and cultivation approvals, the values of the variation coefficients ranged between the limits of 10% and 20% reflecting that the these data are relatively homogenous. In the case of countries that issued approvals for food and for feed, the values of the variation coefficients were lower than the 10% limit, showing that these two indicators did not varied too much and remained relatively homogeneous over years, but in the case of countries that issued approvals for cultivation, the coefficient of variation was higher than the 30 % limit, reflecting a very large variation in the data (Table 2).

Table 2. Statistics calculated for the studied indicators in global context (2014-2018)

Indicator	Average	St. dev.	Variation coefficient (CV %)	Minimum	Maximum
Total approvals	138.2	22.6	16.3	118	173
Approvals for food	64.0	12.5	19.5	53	84
Approvals for feed	49.8	8.3	16.6	40	61
Approvals for cultivation	24.4	4.0	16.6	20	28
Countries that issued approvals for food	15.6	1.5	9.6	14	18
Countries that issued approvals for feed	12.6	0.9	7.1	11	13
Countries that issued approvals for cultivation	6.6	2.1	31.8	5	10

Source: Own calculations based on the data from [11].

GM maize events approved in the studied period were improved for 6 commercial traits (single or stacked): herbicide tolerance, insect resistance, modified product quality; altered growth/yield, abiotic stress tolerance and pollination control (Table 3).

Table 3. GM maize events approved in world: by commercial traits (2014-2018)

Rank	Commercial traits	Events	
		No.	%
1	HT +IR	59	64.1
2	HT	12	13.0
3	IR	10	10.8
4	HT + IR + MPQ	3	3.3
5	HT +IR + AST	2	2.2
6	AG/Y	1	1.1
7	AST	1	1.1
8	MPQ	1	1.1
9	HT + AST	1	1.1
10	IR + AST	1	1.1
11	PC	1	1.1
	TOTAL	92	100

HT-Herbicide tolerance; IR-Insect resistance, MPQ - Modified product quality, AG/Y-Altered growth /yield; AST -Abiotic stress tolerance; PC-Pollination control
Source: Own calculations based on the data from [11].

The top three GM maize events with the highest number of approvals in world were events with HT+IR stacked traits included in 59 events or 64.1% of the total number of events, followed by events with HT trait included in 12 events (13%), and events with IR trait included in 10 events (10.8%) (Table 3).

GM maize approvals in EU

In the studied period, the European Union approved 13 GM maize events. 9 events (69.2%) of them have a combination of herbicide tolerance and insect resistance, 2 (15.4%) events have only herbicide tolerance, 1 (7.7%) has insect resistance, and 1 (7.7%) has abiotic stress tolerance (Table 4).

In 2014, the EU did not issue any approvals, and since 2015 it has issued approvals only for food and feed. In 2016, most approvals were issued.

A total of 26 approvals were issued: 13 food approvals and 13 feed approvals (without cultivation approvals (Table 5)

According to [2] the authorization process of applications for the events crops in the EU is considered as one of the strictest in the world, each new event has to undergo a risk analysis before a committee of the member states can vote on its approval.

Table 4. GM maize events approved in EU: by commercial traits (2014-2018)

Rank	Commercial traits	Events	
		No.	%
1	HT +IR	9	69.2
2	HT	2	15.4
3	IR	1	7.7
4	AST	1	7.7
	TOTAL	13	100

HT-Herbicide tolerance; IR-Insect resistance, AST - Abiotic stress tolerance
Source: Own calculations based on the data from [11].

Table 5. Indicators studied for EU (2014-2018)

Indicators	2014	2015	2016	2017	2018
Total approvals	0	4	14	4	4
Approvals for food	0	2	7	2	2
Approvals for feed	0	2	7	2	2

Source: Own calculation based on the data from [11].

MON810 event with the inserted *cry1A(b)* gene which confers protection against certain lepidopteran insect was the only maize event approved for cultivation in EU, but this event was first authorized in 1998 (for 10 years) for use as food and feed and also, for cultivation. In 2007, Bayer applied for the renewal of the MON10 authorization, receiving a favorable opinion in 2009 only from EFSA. To date, the cultivation authorization for the MON 810 is considered „no expiration date as long as the renewal application is pending". For use as food and feed, the European Commission adopted the renewal of the authorization in 2017 [9]. In 2014 and 2015, 5 member states (Spain, Portugal, Czech Republic, Romania and Slovakia) cultivated MON810 maize, and in 2016 only 4 (Spain, Portugal, Czech Republic and Slovakia). Although the benefits of cultivating MON810 have been reported in numerous studies [3, 4, 6, 8, 22], Romania has not cultivated GM maize since 2016, probably for variety reasons, such as strict requirements for reporting on cultivation of GM crops and non-preference of farms for this GM crop.

According to EU Decision 2016/321, since 2016 a number of 21 member states announced that they restrict the cultivation of GM maize [17], and only two countries (Spain and Portugal) continued to cultivate this crop in the period 2016-2018 [13].

CONCLUSIONS

In the studied period (2014-2018), a total of 28 countries (with EU-28 as one) have approved a total of 691 applications (for food, feed and cultivation).

The commercialization and cultivation of GM maize approvals showed that since 2014, when 143 total approvals were issued, the number decreased in 2017 and 2018 to 118 total approvals.

On the other hand, in 2016 was registered the highest number of food, feed and cultivation approvals, and the highest number of countries that issued approvals for food.

South Korea, Argentina, Brazil and Taiwan were the top four countries with the most food approvals.

Brazil, South Korea, Argentina and Japan were the top four countries with the most feed approvals, and also, the top four countries that issued the most cultivation approvals were Argentina, Brazil, Japan and Canada.

Globally, the top three maize event with the highest number of approvals were events that combined herbicide tolerance with insect resistance traits (64.1% of total events), followed by events with herbicide tolerance (13%) and events with insect resistance (10.8%).

EU-28 (as 1 country) issued a total of 26 approvals, only for use as food and feed, with most approvals being issued in 2016.

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