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SORGHUM PRODUCTION IN THE EU-28 IN THE PERIOD 2008-2019 AND ITS FORECAST FOR 2020-2014 HORIZON

Agatha POPESCU[1,2,3]

[1]University of Agronomic Sciences and Veterinary Medicine Bucharest, 59 Marasti Boulevard, District 1, 011464, Bucharest Romania, Phone: +40213182564, Fax: +40213182888, Email: agatha_popescu@yahoo.com
[2]Academy of Agricultural and Forestry Sciences "Gheorghe Ionescu-Sisesti", 61 Marasti Boulevard, District 1, 011464, Bucharest Romania, Email: agatha_popescu@yahoo.com
[3]Academy of the Romanian Scientists, 1 Ilfov Street, Bucharest, 030167, Romania,
Email: agatha_popescu@yahoo.com

Corresponding author: agatha_popescu@yahoo.com

Abstract

The paper analyzed the status of Sorghum cultivated area, production and yield at the EU-28 level and in each producing country in the period 2008-2019, and then the forecast for these indicators was estimated for the horizon 2020-2024. Fixed index, trend line, descriptive statistics and regression modeling were used to process the data. The cultivated surface with sorghum in the EU reached 197 thousand ha in 2019, being almost double than on 2008. The cultivated area with Sorghum increased in all sorghum producing countries: France, Italy, Hungary, Romania, Bulgaria, Austria and Greece, except Spain and Slovakia were it remained constant. The largest cropped areas are in France, Italy and Romania, accounting for 76%. Sorghum output doubled its figure and in 2019 reached 1,019 thousand tons. About 91% of production being achieved by France (431), Italy (312), Hungary (117) and Romania (68). The EU yield was 5,179 kg/ha, but higher yields were recorded by Austria, Italy and France. In 2024, it is estimated that the EU will produce 1,045 thousand tons sorghum. Production will increase in Italy, Austria, Bulgaria, Romania and Greece, will decline in France and Hungary and will remain constant in Spain and Slovakia. The EU will continue to pay attention to this crop as a response to climate change. The main purposes of sorghum being animal feed, biomass for bio-fuels, raw material in food industry, component in crop rotation, maintenance of biodiversity and environment preservation.

Key words**:** *Sorghum, cultivated area, production, present status, forecast, EU*

INTRODUCTION

Sorghum is among the top cereals cultivated in the world coming on the fifth position after corn, rice, wheat and barley [23].
Sorghum is one of the basic crops providing food in the geographical regions with the highest temperatures and arid climate of the globe like Africa, Central America, and South Asia, where grains are not able to produce as much as it is needed to nourish the population. Therefore, Sorghum is an important plant in human nutrition.
Secondly, Sorghum is an important animal feed for pigs, poultry, and even dairy cows in various recipes (mixed concentrated feed, silage, grazing etc).
Thirdly, Sorghum is a raw material, an excellent resource of biomass for producing renewable energy in terms of bio-fuels.
While the tropical and semi-tropical countries from Africa, Central America Asia are interested to produce Sorghum especially as human food, in the USA, South America and Europe, Sorghum is mainly used as animal feed and as a bio-fuel resource [10].
This crop is highly resistant to high temperatures and long periods of drought as it has a deep root able to penetrate the ground and find moisture. Its requirements for water are lower compared to other crops, and for this reason it is appreciated as a friendly plant with the environment assuring water preservation.
The need in fertilizers is also low in case of Sorghum compared to corn, as its long and branched root has the capacity to fix nitrogen from the soil, a reason to include this plant in crop rotation reducing the amount of fertilizers per ha and production costs [23].

In the regions where maize is deeply affected by the extreme phenomena like high temperatures and severe droughts due to the climate change, Sorghum looks to be the only alternative to produce food, feed and bio-fuels.

The world Sorghum production increased across the time and reached 66 million tons, the top level in 2015, then it declined a little, and stabilized around 60 million tons in 2020/2011, keeping its 5th position among the world most cultivated cereals [24, 26, 37, 38, 40].

The top 10 producing countries worldwide, based on Sorghum output level in 2019 in million metric tons, were, in the decreasing order: USA (8.7), Nigeria (6.7), Ethiopia (5.2), India (4.6), Mexico (4.3), Sudan (4), China (3.6), Argentina (2.5), Brazil (2.20 and Niger (1.9) [16, 35].

The world cultivated area with *Sorghum bicolor* increased from 40.9 million ha in the year 2000 to 44.77 million ha in 2016, being ranked the third after maize and barley [16, 18, 29, 35].

Production increased due to the higher and higher requirement for consumption, whose level reached 63.2 million tons globally in 2017. The biggest Sorghum consumers are China (14%), followed by USA, Sudan, Mexico, India, Ethiopia and Argentina.

Due to the high demand, Sorghum global trade has been intensified so that in 2017, it was traded an amount of 7.6 million tons. The main exporting countries are USA, Australia, Argentina and Ukraine, while the principal importing countries are China, Japan, Mexico, the EU-28, Kenya and South Africa [24].

The changes in Sorghum cultivated area, yield, production and trade at the global level and in various geographical regions are caused by a large range of factors among which the most important ones are: climate change, demographic growth, economic development, agricultural inputs, demand for other agricultural crops, the scarcity of agricultural resources, the need to preserve biodiversity, traditions in agricultural practices and cultures, production and consumption, and cereal price volatility [25].

The EU-28 is not an important producer of Sorghum, but its interest has become more evident for this plant mainly during the last decades when the change in the global climate started to affect almost all European countries, but especially the ones situated in the Southern, Central and Eastern part of Europe, where the temperatures have significantly increased year by year and long periods of drought and other extreme meteorological phenomena diminished agricultural production and farmers' income. Therefore, sorghum cultivation in the EU is related to weather conditions (spring frosts, spring-summer droughts, heat waves, winds, heavy rainfalls) which affect seeds germination, plant development in vegetation stage, pollination, harvesting and lead to production and income losses, to an unbalanced demand/offer ratio with a negative effect on price.

Bioethanol is considered the fuel of the future which could produced green energy, preserving the fossil resources, assuring a healthy environment diminishing the release of CO_2 in the atmosphere. For this reason, Sorghum is an alternative to corn in the temperate regions for producing biomass for ethanol or biogas production, and farmers look to be interested in this business [6, 9, 27].

The need to adapt crop structure and mapping to climate change and produce bio-fuels determined the EU to establish a Programme which promote Sorghum among farmers sustaining their business with subsidies destined to expand the cultivated area, increase yields and production, and reduce imports [11, 12, 20, 23].

As a result, Sorghum started to be cultivated area on larger surfaces in France, Italy, Romania, Spain, Bulgaria, Hungary, and even in Austria, Greece and Slovakia. Compared to maize, Sorghum proved its higher efficiency in production performance being drought resistant and lower cost [33, 36].

It is expected as the geographical area of sorghum cultivation to move to the Northern European countries because of the high temperatures which also reached this part of

the continent and where it is a lower water requirement. In this area, sorghum could be an alternative to corn silage in various variants [13, 15].

In this context, the paper aimed to study the dynamics of Sorghum cultivated area, yield and production at the EU-28 level and in the producing countries in the period 2008-2019 and estimate the production forecast for the period 2020-2014.

MATERIALS AND METHODS

Data collection

The paper was set up based on the data provided by Eurostat for the period 2008-2019.

The studied indicators were:

(i)cultivated area with Sorghum both at the EU level and by each producing country;

(ii)Sorghum production both at the EU level and by each producing country;

(iii)Sorghum yield both at the EU level and by each producing country.

These indicators were studied in their dynamics identifying the main trends both at the EU-28 level and in each producing country. Based on these results, it was established the level of sorghum production in the period 2020-2024 for each country and at the EU level.

Methodological aspects used in this study

Dynamics analysis was used in order to quantify the growth rate on the interval 2008-2019, based on the formula: $I_{FB(\%)} = (Y_n/Y_0)100$, where: Y_n is the value of the variable in the year n and Y_1, the value of the variable in the year 0.

Trend line for each indicator was established using the linear regression, $Y(t_i) = a + bx_{ti}$

Descriptive statistics in terms of mean, standard deviation, coeffcient of variation, minumum and maximum value.

The market share of each Sorghum producing country in the EU-28 cultivated area with Sorghumand production.

Forecast for the 2020-2014 horizon was established using the system of normal equations and the Least Square Method which allowed to determine the value of the parameters a and b and finally to set the linear regression model, $Y(t_i) = a + bx_{ti.}$

The results are included in tables and illustrative graphics and the main aspects have been commented and interpreted.

Finally, the key results are pointed out in conclusions.

RESULTS AND DISCUSSIONS

Cultivated area

The EU-28 has a relatively small cultivated area with Sorghum, but its dynamics reflects a continuous increasing trend in the period 2008-2019. From 97 thousand ha in 2008, the EU doubled its sorghum surface which accounted for 187 thousand ha in 2019 (Fig. 1).

In Europe, there are four types of Sorghum which are cultivated: Grain Sorghum, Sweet Sorghum, Sudan grass along with Sorghum and Broomcorn [4].

Sorghum is cultivated in a small number of countries situated mainly in the Southern, Central and Eastern Europe, where climate conditions are suitable for this crop. Because during the last decade higher temperatures and drought affected cereal crops in this geographical part of Europe, Sorghum could be an alternative to maize having a high resistance to drought grace to its deep root able to find water in the ground and giving high productions which could be successfully used as animal feed, raw material for renewable energy based on biomass, and even as food being a gluten-free plant with mutiply uses in food industry.

The countries dealing with Sorghum cropping in the EU are France, Italy, Hungary, Romania, Spain, Bulgaria, and in a smaller measure Austria, Greece and Slovakia.

The purposes why Sorghum is grown in the EU is as animal feed, as raw material for bio-fuels, and medicinal goals, as the plant is gluten-free and could be included in treatments against various diseases, in food industry for carrying out various flours, syrups, beer and other products and also it is expected as production growth to reduce imports [9, 31].

Sorghum is used in animal diets (as silage for dairy cows), mixed feed (for poultry and pigs), grace to its low tannin content in the chemical composition.

But, from a country to another, the purposes could differ.

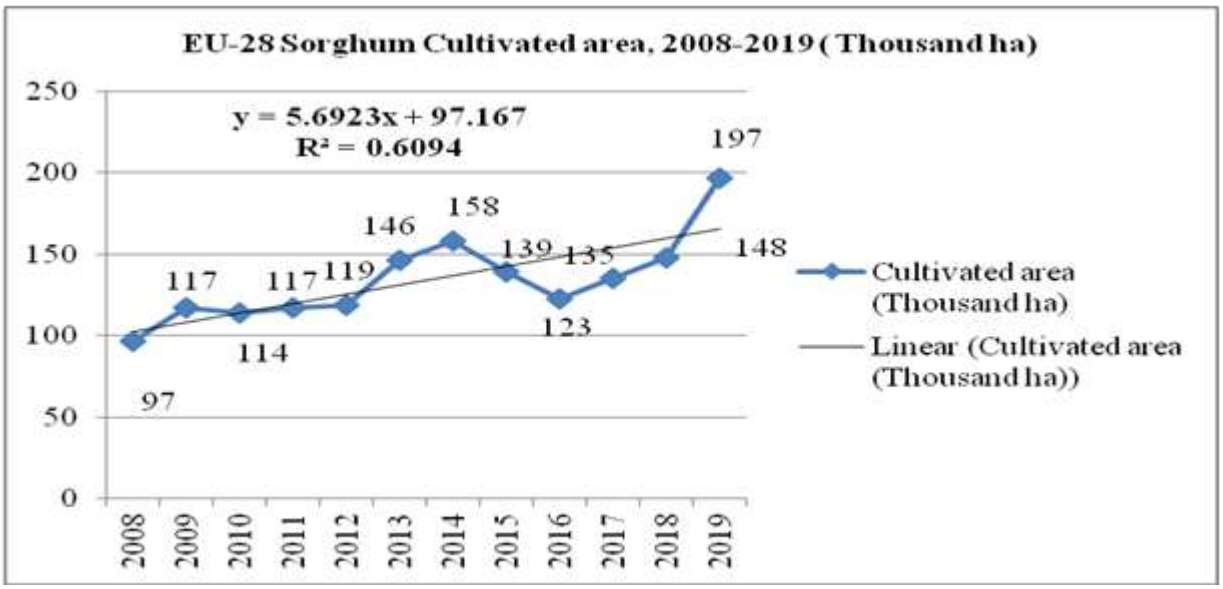

Fig. 1. The cultivated area with Sorghum in the EU-28, 2008-2019 (Thousand ha)
Source: Own calculation and design based on Eurostat Data, 2020 [14].

In France, Sorghum is mainly raised in the South West of France, but also in North East where fodder production is not enough. It is also a good plant in crop rotation to assure a better weed, pest and disease management, and has a benefic economic and environmental impact, taking into account as it could be also used for methanisation [39].

In Italy, Sorghum is produced on larger surfaces than millet, and the main purposes are: animal feed for pigs and cattle (mixed feed, silage, green mass, grazing), biomass for bio-fuels (ethanol and biogas), and raw material for food and pharmaceutical industry. Sorghum is cultivated in almost all the regions of Italy, and during the last decades in the territories where maize is usually cropped. The largest surfaces cultivated with Sorghum are in Emilia-Romagna Region (about 22%), but also Modena (11.3%), Ravenna (9.4%), Ferrara (8.3%), Forli-Cesena (4.3%), Alessandria (3.7%), Sienna (2.4%) etc. The production varies between 7-8 tons/ha, the highest level being achieved in the North-Central Italy. Because *Diabrotica virgifera* affected very much the crops in the Northern Italy, Sorghum cropped after maize succeeded to avoid damages [6, 9, 27].

In Spain, Sorghum is raised in North West of Madrid in the region of Castilla y Leon, and it is mainly used for pig feeding with mixed food. The extend of surfaces and production will diminish the imports from France and Ukraine, and also will be in the benefit of the farmers affected by droughts for other crops in the South West of Spain and in the North East [19].

In Hungary, grain sorghum is a substitute of maize in fodder mixtures for poultry (30–50%) and pigs (20%), and also it is used in food industry as a gluten-free and low tannin compound in various products. Compared to maize, Sorghum silage is a good forage for cattle and sheep in winter, to maintain yields in dry seasons and on less fertile soils. Sudan grass is used for grazing, chopped green mass, silage and hay [17]. Specific to Hungary it is the tradition as maize and sorghum to be cultivated together, according to the long intercropping cultivation system for producing silage for dairy cows. In the dry years, sorghum performed much better than

maize and the mixed silage proved a higher quality given by the higher nutritive value than cultivating Sorghum alone [22].

In Romania, Sorghum is used as grains and also green mass. Grains are used for producing mixed feed for poultry and pigs, and green mass is used as such or grazing or as silage for dairy cows. Also, grains are used in food industry for producing flour, starch, ethylic alcohol, beer, juices, alcohol and also for medicines. In the recent decade, farmers look to be more interested to cultivate Sorghum as biomass for bio-fuels (biogas, bioethanol) due to the attractive subsidies offered by the EU and to avoid losses registered in rape and maize crops due to the severe and long droughts recorded during the last years [28, 29, 30].

Sorghum is successfully cultivated in the West, North West, South and South East Romania, but also in the South Moldavia and Transilvania [3].

Sorghum yield performance varies between 4,000 and 7,000 kg per ha, but it also could reach about 10,000 kg. Economically, Sorghum crop is less costing than maize crop, due to the lower consumption of fertilizers and water, and produce a similar nutritive value like maize, sometimes even higher in case of a few hybrids. In addition, it is very resistant to *Diabrotica* attack [1].

In Austria, Sorghum has become more important due to the damages caused by *Diabrotica* in maize crop. At present Austria has 10,000 ha cultivated with sorghum, situated mainly in the pig breeding areas like Styria, Upper Austria, Lower Austria and Carinthia. Sorghum is produced to be used mainly like animal feed (mixed feed for pigs, and silage), for which the surfaces are continuously extending. Also, it is cultivated for biomass, for which the cultivated areas are stable. It is an efficient crop, with a low production cost, because it does not need any plant protection, except weed control [34].

In Greece, Sorghum bicolor L. Moench is used as an alternative for producing biomass of syrup or dry matter under a specific irrigation regime in the Central part of the country [32]. it also proved to be more profitable than maize for forage production under stressed conditions, a reason to extend the use of sorghum in crop rotations for forage for increasing farm income and protecting environment [8, 21].

In the analyzed period the cultivated area with Sorghum increased in all these countries, except Spain and Slovakia were it remained relatively stable. In the period 2008-2019, in France, the cultivated area increased from 37 thousand ha to 84 thousand ha in 2018 (+127%), in Italy from 39 thousand ha to 47 thousand ha (+20%), in Romania from 8 thousand ha to 19 thousand ha (+137%), in Hungary from 4 thousand ha to 25 thousand ha (+525%), in Bulgaria from 2 thousand ha to 7 thousand ha (+200%), and in Spain remained relatively constant at 7 thousand ha. Austria started to cultivate Sorghum on 1 thousand ha in 2010 and in 2019 the surface became 4 times higher. Greece started to cultivated this crop since 2014 on 2 thousand ha and in 2019 cultivated 3 thousand ha. Slovakia also started Sorghum cropping since 2009 and remained on the same surface of 1 thousand ha till present (Table 1).

Table 1. Statistical parameters of the cultivated area in the EU-28 Sorghum producing countries, 2008-2019

	EU-28	FR	IT	RO	HU	ES	BG	AT	EL	SK
N	12	12	12	12	12	12	12	10	6	11
Mean	134.1	53.0	43.5	13.2	6.6	7.5	4.5	2.4	2.8	1.0
St. Dev.	26.28	12.3	4.77	5.18	6.08	0.79	2.15	1.17	0.41	0.00
CV%	19.60	23.20	10.96	36.47	92.12	10.53	47.77	48.75	14.64	0
Min	97	37	38	6	3	6	1	1	2	1
Max	197	84	52	22	25	9	8	4	3	1
2019/ 2008%	203.1	227.0	120.5	237.5	625.0	100.0	300.0	400.0	150.0	100.0

Source: Own calculation based on Eurostat Data, 2020 [14].

If in 2008, the share of the cultivated area by each country in the EU cropped area with Sorghum was: 40.21% Italy, 38.15% France, 8.25% Romania, 7.2% Spain, 4.12% Hungary and 2.06% Bulgaria, in 2019 the situation was the following one: 42.64% France, 23.86% Italy, 12.695 Hungary, 9.65% Romania, 3.56% Spain, 3.55% Bulgaria, 2.03% Austria, 1.52% Greece and 0.5% Slovakia.

Sorghum production

In the EU-28, Sorghum output raised from 516 thousand tons in 2008 to 1,019 thousand tons in 2019, meaning a 1.97 times higher level than in the first year of the analysis (Fig. 2).

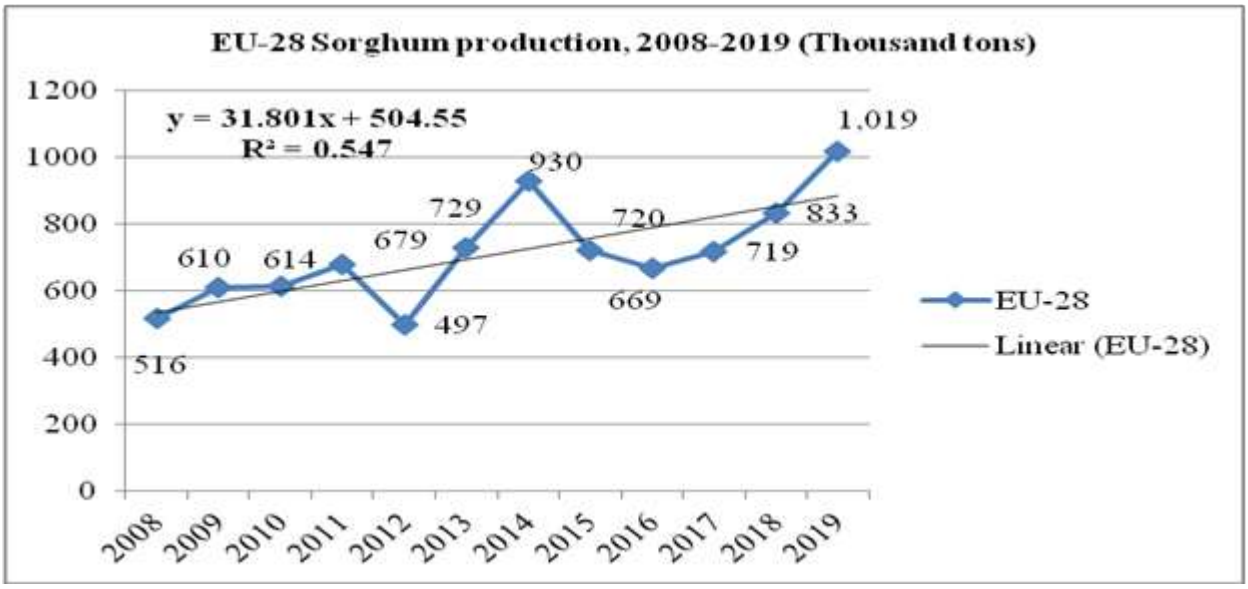

Fig. 2. Sorghum production in the EU-28, 2008-2019 (Thousand tons)
Source: Own calculation and design based on Eurostat Data, 2020 [14].

In the interval 2008-2019, Sorghum production increased in all the EU producing countries in various proportions. In France, it raised from 231 thousand tons to 431 thousand tons (+86.5%), in Italy from 225 thousand tons to 312 thousand tons (+38.6%), in Hungary from 14 thousand tons to 117 thousand tons (+737.7%), in Romania from 21 thousand tons to 68 thousand tons 9 (+223.8%), in Spain from 22 thousand tons to 27 thousand tons (+22.7%), in Bulgaria from 2 thousand tons to 23 thousand tons (+1,050%), in Austria from 7 thousand tons in 2010 to 30 thousand tons in 2019 (+328.5%), in Greece from one thousand ton in 2011 to 8 thousand tons in 2019 (+700%), and in Slovakia from one thousand ton in 2010 to 3 thousand tons in 2019 (+200%) (Table 2).

Table 2. Statistical parameters of the Sorghum production in the EU-28 producing countries, 2008-2019

	EU-28	FR	IT	RO	HU	ES	BG	AT	EL	SK
N	12	12	12	12	12	12	12	10	9	9
Mean	711.25	300.0	277.17	40.58	25.66	35.00	13.00	16.60	5.88	1.80
St. Dev.	155.03	61.49	54.26	19.82	30.22	9.33	9.51	8.46	3.55	0.78
CV%	21.79	20.49	19.57	48.84	117.77	37.32	73.15	50.96	60,37	43.33
Min	497	231	159	14	8	22	2	7	1	1
Max	1,019	431	369	76	117	51	36	30	10	3
2019/ 2008 %	197.4	186.5	138.6	323.8	835.7	122.7	1,150.0	428.5	800.0	300.0

Source: Own calculation based on Eurostat Data, 2020 [14].

In 2008, the contribution of the producing countries to the EU production was: France 44.78%, Italy 43.61%, Spain 4.26%, Romania 4.07% and Hungary 2.71%. In 2019, the situation was as follows; France 42.305, Italy 30.62%, Hungary 11.48%, Romania 6.67%, Austria 2.945, Spain 2.655, Bulgaria 2.26%, and on the last position Greece and Slovakia with 0.79% and, respectively 0.29%.

Sorghum yield at the EU level was in general over 5,000 kg/ha in almost all the studied years, except 2012 and 2013. If in 2008, the yield was 5,319 kg/ha, in 2019, it accounted for 5,172 kg/ha by 2.8% less. The lowest yield was registered in 2012, 4,176 kg, while the highest yield was recorded in 2014 and accounted for 5,886 kg/ha (Fig. 3).

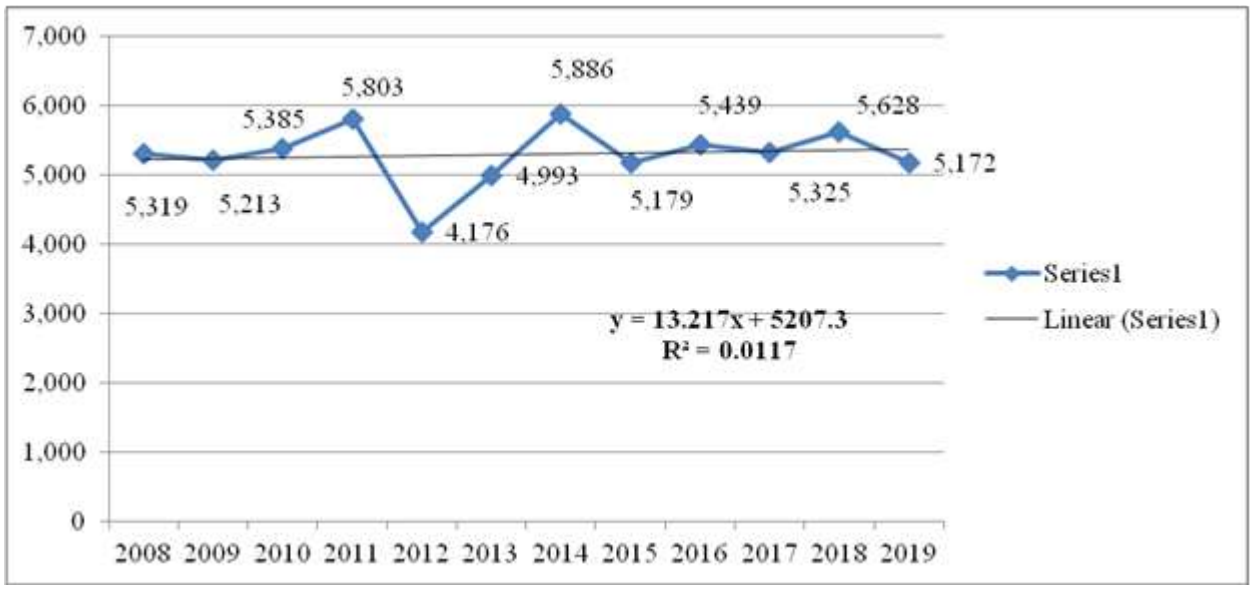

Fig. 3. EU-28 Sorghum yield, 2008-2019 (kg/ha)
Source: Own calculation and design based on Eurostat Data, 2020 [14].

Average production varied from a country to another depending on the variety and hybrids, local soil types and fertility, climate conditions, applied technologies, and farm structure.

It was noticed that the highest average yield in the analyzed interval was registered, in de decreasing order, as follows: Austria, Italy, France, Spain, Hungary, Greece, Romania, Bulgaria, and Slovakia.

Compared to 2009, in 2019, Sorghum yield was higher in Italy (+15.06%), Romania (+36.34%), Hungary (+33.71%), Spain (+22.71%), Bulgaria (+228.6%), Austria (+7.14%), and Slovakia (+50%), and lower in France (-17.82%), and Greece (-23.80%). Also, at the EU-28 level, the average yield declined by 2.77% (Table 3).

Table 3. Statistical parameters for Sorghum yield in the EU producing countries, 2008-2019

	EU-28	FR	IT	RO	HU	ES	BG	AT	EL	SK
N	12	12	12	12	12	12	12	10	6	6
Mean	5,293	5,625	6,337	2,824	3,498	4,657	2,673	6,967	2,916	2,167
St. Dev.	439.74	494.41	841.64	847.33	682.57	1,113.02	859.67	977.51	444.04	752.77
CV%	8.30	8.78	13.28	30.00	19.51	23.89	32.16	14.03	15.22	34.74
Min	4,176	5,104	4,184	1,850	2,667	3,143	1,000	5,000	2,333	1,000
Max	5,886	6.535	7,350	4,750	4,680	6,857	4,500	8,500	3,500	3,000
2019/ 2008 %	97.23	82.18	115.06	136.34	133.71	122.71	328.60	107.14	76.20	150.00

Source: Own calculation based on Eurostat Data, 2020 [14].

Sorghum production forecast for the 2020-2014 horizon

Using the linear regression models resulted for the EU-28 and each country producing Sorghum, it was established the forecast for the coming years 2020-2024, as presented in Table 4.

For the EU, it is expected as in 2020, Sorghum production to be lower than in 2019, and even in the coming years, and just in = 2024 to reach 1,045 thousand tons, being a little higher than in 2019.

In France, it is expected as Sorghum output to decline and reach 402 thousand tons in 2024, by 6.7% less than in 2019 [5].

In Italy, it is estimated that Sorghum production to continue its growth and reach 343 thousand tons in 2024, by 10% more than in 2019.

In Hungary, it is expected as the exceptional production of 117 thousand tons registered in 2019 not to be reached in the next years. The forecast for 2024 being for only 84 thousand tons.

Romania will continue to increase production year by year, being estimated that in 2024, the country will produce 86 thousand tons Sorghum.

Spain is expected to produce 35 thousand tons in 2020 and then production to remain stable till 2024 and for this reason it will continue to be the main importing country in the EU [2].

Bulgaria will substantially grow its Sorghum production which is expected to account for 35 thousand tons in 2024 by 52% more than in 2019.

Austria will also grow its production which it is expected to reach 42 thousand tons in 2024, meaning by 40% more than in 2019.

In Greece, also Sorghum output is estimated to raise and reach 16 thousand tons in 2024, a double level than in 2029.

In Slovakia, it is appreciated that Sorghum production will decrease in the next three years and in 2023 and 2024 to remain relatively stable at about 3 thousand tons (Table 4).

Table 4. Sorghum production forecast for 2020-2024 horizon (Thousand tons)

	Regression model	2020	2021	2022	2023	2024
EU-28	Y = 31.80 X + 504.54	918	950	982	1,013	1,045
France	Y = 9.727 X + 236.77	363	373	383	392	402
Italy	Y = 6.272 X + 236.39	318	324	330	337	343
Hungary	Y = 5.538 X - 10.333	62	67	73	78	84
Romania	Y = 4.29 X + 12.696	68	73	77	81	86
Spain	Y = 0.0419 X + 34.727	35	35	35	35	35
Bulgaria	Y = 2.062 X - 0.409	26	28	31	33	35
Austria	Y = 2.654 X + 1.917	31	34	36	39	42
Greece	Y = 1.05 X + 0.538	12	13	14	15	16
Slovakia	Y = 0.1575 X + 0.933	2.5	2.7	2.8	3	3.1

Source: Own calculation.

CONCLUSIONS

The EU pays more attention to sorghum as a solution of adaptation to climate change mainly in the countries situated in the South, Central and Eastern Europe.

Sorghum will continue to be cultivated for animal feeding (poultry, pigs, cattle) under various forms and rations, also as biomass for bio-ethanol and biogas, as raw material in food industry, in agriculture technologies as a component in crop rotation, as a item to maintain biodiversity and for environment preservation.

Sorghum is the best alternative for maize in animal feeding, taking its high production performance, similar nutritive value, achieved at a lower cost. Therefore, it is a solution for farmers not to lose production and income in the years affected by extreme meteo phenomena, especially by the lack of precipitations, high temperature and long period of droughts.

In the analyzed interval, 2008-2019, the EU-28 doubled its cultivated area with sorghum which accounted for 197 thousand ha in 2019.

The cultivated area with Sorghum increased in all sorghum producing countries: France,

Italy, Hungary, Romania, Bulgaria, Austria and Greece, except Spain and Slovakia were it remained constant.

The largest cropped areas are in France, Italy and Romania, accounting for 76%.

Sorghum output doubled its figure in the studied interval and in 2019 reached 1,019 thousand tons.

About 91% of production being achieved by France (431 thousand tons), Italy (312 thousand tons), Hungary (117 thousand tons) and Romania (68 thousand tons).

The EU yield was 5,179 kg/ha in 2019, but Austria, Italy and France are able to exceed this production level.

In 2024, it was estimated that the EU will produce 1,045 thousand tons sorghum, as it is expected an important production growth in Italy, Austria, Bulgaria, Romania and Greece, will decline in France and Hungary, but in Spain and Slovakia it is estimated that production will remain at the level of 2019.

In the EU, sorghum remains as an alternative to maize in forage production, in biomass resources for bio-fuels and also as raw material for food processing industry in the regions affected by droughts.

For farmers it is a crop which could assure high production at lower costs, a better crop rotation, high incomes and profit, a reason to extend the cultivated areas and increase production using high value hybrids and modern technologies adapted to climate change.

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