Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 21, Issue 3, 2021
PRINT ISSN 2284-7995, E-ISSN 2285-3952

BEHAVIOR OF SOME GM AND CONVENTIONAL MAIZE HYBRIDS UNDER DROUGHT AND HEAT CONDITIONS

Dorina BONEA[1], Ioana Claudia DUNĂREANU[2]

[1]University of Craiova, Faculty of Agronomy, 19 Libertății Street, Dolj County, Romania, Email: dbonea88@gmail.com
[2]Agricultural Research and Development Station Simnic – Craiova, 54 Bălcești Road, Dolj County, Romania, Email: claudia.borleanu@yahoo.com

Corresponding author: dbonea88@gmail.com

Abstract

Since 2007, the GM maize event MON 810 (resistant to insects Lepidopteran) is authorized for cultivation in Romania, but since 2016 the farmers have given up cultivating it for various reasons. In this study, the main agronomic parameters of genetically modified (GM) maize hybrid (MON 810 - trade name: DKC 5784 YG) and of two conventional maize hybrids (Deliciul verii and F 376) were compared under drought and heat conditions during two years at Agricultural Research and Development Station (ARDS) Șimnic. The hybrid affected statistically significant (P≤0.05) all evaluated parameters. Similarly, climatic conditions (year) significant influenced all evaluated parameters with the exception of the days to tasseling. The GM hybrid confirmed ability to protect itself against the Ostrinia nubilalis (ECB) and the drought, and its average grain yield was higher by 1.33 - 1.69 t/ha in comparison with conventional maize hybrids. The results showed a higher level of attack on conventional maize hybrids in extremely dry year 2012 compared to 2013. Thus, adopting GM maize crops can effectively address the drought stress and its consequences for sustainable maize crop production in the dry Oltenia region.

Key words**:** *attack frequency, drought, ECB, GM maize hybrid (MON 810)*

INTRODUCTION

Maize or corn (*Zea mays* L.) is the most important annual cereal crop for food and industry. It ranks first in the world, with an annual production estimated at 1,148 billion tons cultivated on 197 million hectares. In Romania, maize is one of the strategic cereal crops for internal and foreign market [19] and the annual production is estimated at 17,432 million tons cultivated on 2,678 million hectares [8].

MON 810 maize resistant to *Ostrinia nubilalis* is authorized for cultivation in the European Union since 2007, but is currently grown only in Spain and Portugal. In Romania, MON 810 has not been cultivated since 2016, farmers giving up for various reasons [16, 32].

The grain yield of maize depends on the genetic potential of the cultivar used, the field management practices, the soil and agro-climatic factors [27].

Many factors contribute to maize low yields, among which drought and heat [4, 17, 20, 25] and Lepidopteran stem borers [1, 30, 31]. The attack of these pests is favorably influenced by dry and warm weather [21].

The European corn borer (*Ostrinia nubilalis*, *ECB*) is a Lepidopteran stem borer affecting the growing maize plants and causing damage and yield loss of 60.87% and 41.27% for white and yellow maize, respectively [1].

In the last decade, *ECB* represent one of the most dangerous maize pests in many countries, including the central and western region of Romania [9, 10], Czech Republic [14], Serbia [22] and Croatia [23].

A possible cause for area increasing of *ECB* can be climate changes such as increasing of the temperature [9, 15].

In Romania, due to *Ostrinia nubilalis attacks*, the yield losses were 1.3% in Dobrogea, 8.5% in Transilvania, 10.5% in the South of Moldova, 11.7% in Bărăgan and 17.7% in the West Plain [9].

To combat the problem of yield loss in areas affected by stem borers, use of GM maize is an available option suggested by many researchers [2, 3, 28].

The genetic potential, tolerance of drought, agronomic parameters and benefits of GM maize hybrids are little known in many regions. On the other hand, conventional maize hybrids are able to provide high grain yield and tolerance of drought, but they need efficient protection against pests, and pathogens, usually by chemical pesticides. Consequently, it is necessary to identify and develop strategies for every maize growing area of reducing the damage caused by drought and pests.

Therefore, the aim of our field study was to compare some agronomic parameters of conventional maize hybrids with the GM maize hybrid under severe drought stress.

MATERIALS AND METHODS

The field experiments were carried out in the 2012 and 2013 in the field of the Agricultural Research and Development Station (ARDS) Șimnic – Craiova (geographic coordinates: $44^0$19' N, $23^0$48' E and altitude of 182 m). This station is located in the central part of Oltenia (south- western Romania).

The climate was extremely dry in 2012 and dry in 2013. The highest average air temperatures were recorded in 2012 (21.08ºC) while the total rainfalls were the lowest in the 2013 year (246.0 mm). In 2012 the average monthly precipitations and temperatures in the months June, July and August were higher compared to the average in 2013 or to the multiannual average (Table 1). This led the maize plants to suffer, because of the lack of water during the both vegetation periods.

The factors studied were: i) Factor A – three maize hybrids (GM hybrid and two conventional hybrids) and ii) Factor B - two climatic conditions, respectively two years (2012 and 2013).

The GM maize hybrid - MON 810 (trade name: DKC 5784 YG, Monsanto Company) is a semi-late hybrid (FAO 400) resistant against Lepidopteran insects (*ECB*).

Conventional maize hybrids, Deliciul verii (ARDS Turda) are a sweet early hybrid and F 376 (NARDI Fundulea) is a semi-late yellow hybrid.

The agronomical parameters: phenological phases (days to tasseling, days to silking, days to maturity), plant height leaf area, grain yield, frequency of the attack and length of the stalk tunnels were evaluated.

Maize grain yield was calculated based on the adjustment to grain moisture content of 15.5%.

The attack frequency was calculated according to the formula:

$$F = n \times 100/N$$

where: n = number of attacked plants and N = total number of evaluated plants.

During the harvest period, the length of the stem tunnels was determined by splitting five plants/plot.

The results obtained were subjected to statistical analysis.

Table 1. Monthly mean temperature and total rainfall during studied period, ARDS Simnic

Parameter		**IV**	**V**	**VI**	**VII**	**VIII**	**Vegetation period**
Rainfall (mm)	2012	79.3	130.0	28.0	13.5	-	250.8
	2013	56.0	55.0	88.0	20.0	27.0	246.0
	Multiannual average	50.8	65.8	72.1	83.6	47.3	319.6
Temperature (^{0}C)	2012	13.7	17.9	21.8	26.6	25.4	21.08
	2013	14.5	19.4	21.3	23.4	24.5	20.62
	Multiannual average	12.1	17.7	21.6	23.8	22.2	19.48

Source: Own processing based on data from Weather Station Craiova.

The ANOVA test analysis was performer, while the significance of differences between means values was determined using the Duncan's multiple range tests ($P \leq 0.05$).

RESULTS AND DISCUSSIONS

ANOVA results

Analysis of variance was conducted to determine the effect of hybrid (H) and year (Y), and interactions among these factors - hybrid x year (H x Y) (Table 2).

The main effects of hybrid were significant ($P \leq 0.05$ level) for all studied parameters (days to tasseling, days to silking, days to maturity, leaf area, plant height, grain yield, frequency of the attack and length of the stalk tunnels). The effect of year was also, significant for all studied parameters, except days to tasseling.

The H x Y interaction was significant only for plant height, grain yield and frequency of the attack. Significant H x Y interaction indicated that hybrids under different year behaved differently for the expression of parameters of interest.

Table 2. Source of variation (SOV), degrees of freedom (DF), mean squares (MS) and significance of studied parameters

SOV	DF	MS			
		DT	DS	DM	LA
Hybrid (H)	2	446.05*	601.05*	468.22*	0.109*
Year (Y)	1	4.50^{ns}	150.22*	9.39*	0.006*
Interaction (H x Y)	2	2.16^{ns}	5.05^{ns}	0.22^{ns}	0.003^{ns}
Error	12	1.05	6.05	1.72	0.0003
SOV	**DF**	**MS**			
		PH	**GY**	**FA**	**TL**
Hybrid (H)	2	8,145.21*	4.75*	67.67*	171.58*
Year (Y)	1	12,116.06*	23.38*	19.32*	5.89*
Interaction (H x Y)	2	1,380.06*	0.69*	4.94*	1.62^{ns}
Error	12	20.04	0.06	0.71	1.23

DT = days to tasseling; DS = days to silking; DM = days to maturity LA = leaf area; PH = plant height; GY = grain yield; FA = attack frequency; TL = tunnel length;
*: significant and ns: non-significant in 5% probability level, by F test
Source: Own calculation.

Phenology and plant growth

ANOVA results showed that, in the case of tasseling (DT), only the hybrid effect was significant, but for silking (DS) and maturity (DM) both hybrid and year effects were significant ($P \leq 0.05$) (Tables 2 and 3).

The conventional maize Deliciul verii flowered earliest because it is an early hybrid.

The GM maize and F 376 hybrids recorded the highest number of days to tasseling (72.7 and 71.8 days, respectively).

Days to silking of hybrids ranged between 59.7 to 82.7 days and the mean day to silking in the studied period was 73.2 days. Maximum days to silking were observed in GM maize hybrid and in F376 in 2012 (73.0 days).

Maximum days to maturity were observed in F376 (110.2 days) and in 2013 (104.7 days).

In the central part of Oltenia, only two out of ten years are favorable to agricultural crops. Here, drought and heat are the most important abiotic factors that reduces maize yield, depending on the constrainer length, its intensity and crop stage. Thus, the identification of hybrids with tolerance of drought and high yield potential, coupled with wide adaptability, is an important task for maize or others crops breeding program [4, 6, 25].

Field experiments conducted over two consecutive crop-growing seasons revealed that severe drought stress (especially during the flowering, pollination and grain-filling stages) had a strong effect on maize growth and development.

Significant differences were observed between the GM and conventional maize for all evaluated parameters. These significant differences between hybrids for growth and development agree with previous research reported by [29]. He found that water deficit reduced leaf area as much as 33% and plant height by 15%, depending on leaf number and timing of water deficit.

According to [24], four consecutive days of severe wilting during silking and pollination can reduce maize yield by 40-50%.

The plant height and leaf area were significantly influenced by year and hybrid, but H x Y interaction effect was non-significant (Tables 2 and 4).

The mean leaf area in the studied period was 0.35 cm^2 and the mean plant height was 177.2 cm. The higher values, for both parameters, recorded for GM maize and F376 hybrids in 2013 year.

Climatically conditions during 2012 year (in the vegetative period), comparative to 2013, reduced leaf area by -14.9% in GM maize and by -13.3% in F376, and increased by +5.3% in Deliciul verii.

Plant height was reduced by -30.4% in GM maize, by -11.9% in Deliciul verii and by -29.0% in F376 (Table 6).

Table 3. The average of days to tasseling (DT), days to silking (DS) and days to maturity (DM)

Parameter	**Hybrid (H)**	**Year (Y)**		**Average per hybrid**
		2012	**2013**	
DT (days)	GM maize	73.0	72.3	72.7 a
	Deliciul verii	57.3	57.3	57.3 b
	F 376	73.0	70.7	71.8 a
	Average per year	67.8	66.8	67.3
DS (days)	GM maize	82.7	75.0	78.8 a
	Deliciul verii	63.7	59.7	61.7 b
	F 376	82.0	76.3	79.2 a
	Average per year	76.1 a	70.3 b	73.2
DM (days)	GM maize	107.0	108.7	108.0 b
	Deliciul verii	93.3	94.3	93.8 c
	F 376	109.3	111.0	110.2 a
	Average per year	103.2 b	104.7 a	104.0

Indicator	**LSD test**	**H**	**Y**	**H x Y**
DT	5%	1.29	1.05	1.82
DS	5%	3.09	2.53	4.38
DM	5%	1.65	1.34	2.33

Means followed by different letters in each column are significantly different from each other at 5% level of significance

Source: Own calculation.

Yield of grains

The results showed significant difference ($P \leq 0.05$) in the grain yield for the hybrid, the year and for the H x Y interaction (Tables 2 and 5).

The average grain yield for all hybrids and the studied period amounted to 2.67 t/ha.

The 2013 average yield (3.81 t/ha) was significantly higher than the 2012 yield (1.53 t/ha).

The GM maize hybrid had a significantly higher average yield (3.68 t/ha) than the conventional maize hybrids (1.99 and 2.35 t/ha, respectively), the highest value being obtained in 2013 (5.05 t/ha).

Reduction of grain yield in 2012, comparative to 2013 was of 35.7% in GM maize hybrid, of 54.7% in Deliciul verii and of 71.2% in F376 (Table 6). The grain yield of GM maize hybrid was least affected by severe drought stress conditions as compared to conventional maize hybrid.

According to [26], losses caused by the pest range from 250-1000 kg/ha, depending on the degree of infestation, the year and the grain yield average.

Table 4. The average leaf area (LA) and plant height (PH)

Parameter	Hybrid (H)	Year (Y)		Average per hybrid
		2012	2013	
LA (cm^2)	GM maize	0.40	0.47	0.43 a
	Deliciul verii	0.20	0.19	0.19 b
	F 376	0.39	0.45	0.42 a
	Average per year	0.33 b	0.37 a	0.35
PH (cm)	GM maize	164.8 b	236.8 a	200.8 a
	Deliciul verii	126.2 d	143.2 c	134.7 b
	F 376	162.7 b	229.3 a	196.0 a
	Average per year	151.2 b	203.1 a	177.2

Indicator	LSD test	H	Y	H x Y
LA	5%	0.023	0.019	0.031
PH	5%	5.62	4.60	7.96

Means followed by different letters in each column are significantly different from each other at 5% level of significance.
Source: Own calculation.

Table 5. The average grain yield (GY), frequency of the attack (FA) and tunnel length (TL)

Parameter	Hybrid (H)	Year (Y)		Average per hybrid
		2012	2013	
GY (t/ha)	GM maize	2.31 d	5.05 a	3.68 a
	Deliciul verii	1.24 e	2.74 c	1.99 c
	F 376	1.05 e	3.65 b	2.35 b
	Average per year	1.53 b	3.81 a	2.67
FA (%)	GM maize	0	0	0
	Deliciul verii	7.72 a	4.33 b	6.03 a
	F 376	7.00 a	4.17 b	5.58 a
	Average per year	4.91 a	2.83 b	3.87
TL (cm)	GM maize	0	0	0
	Deliciul verii	10.3	8.90	9.60 a
	F 376	9.90	7.90	8.90 a
	Average per year	6.70 a	5.60 b	6.16

Indicator	LSD test	H	Y	H x Y
GY	5%	0.30	0.24	0.41
FA	5%	1.07	0.86	1.50
TL	5%	1.37	1.10	1.90

Means followed by different letters in each column are significantly different from each other at 5% level of significance.
Source: Own calculation.

Table 6. Reduction/increase (%) in 2012 (extremely dry) comparative to 2013 (dry) for evaluated parameters

Hybrid	DT	DS	DM	LA	PH	GY	FA	TL
GM maize	+1.0	+10.2	-1.6	-14.9	-30.4	-35.7	-	-
Deliciul verii	0	-10.1	-1.1	+5.3	-11.9	-54.7	+78.2	+15.7
F376	+3.2	+7.5	-1.5	-13.3	-29.0	-71.2	+67.9	+25.3

DT = days to tasseling; DS = days to silking; DM = days to maturity LA = leaf area; PH = plant height; GY = grain yield; FA = attack frequency; TL = tunnel length
Source: Own calculation.

Resistance to European corn borer

The *ECB* tunneling and attack frequency were significantly influenced by the year and the hybrid. The H x Y interaction was significant only for attack frequency (Tables 2 and 5).

The GM hybrid plants were not infested by the *ECB* (attack 0%), confirmed its ability to protect itself against *ECB*.

The average attack frequency of *ECB* (*O nubilalis)* for the period 2012-2013 was 3.87%. The 2012 average attack frequency

(4.91%) was significantly higher than the 2013 average. The highest average attack frequency was obtained in 2012 at both conventional maize hybrids (7.72% and 7.0%, respectively).

Similarly, significant differences were also observed in tunnel length between hybrids and years, but not in the H x Y interaction.

The average tunnel length in the studied period was 6.16 cm. The highest average length was obtained in 2012 (6.70 cm).

Photo 1. *Ostrinia nubilalis* - different types of tunnels in the maize stalk
Source: Project ADER 6.1.2.

For the attack frequency of *ECB* and tunnel length at conventional maize hybrids, was observed an increase of the values from 2012 compared to 2013, by +15.7%... +25.3% and by +78.2%... +67.9%, respectively.

Also, the present study demonstrated the efficacy of MON 810 in controlling the *ECB* in Oltenia area. The biological efficacy of GM maize (MON 810) on the reduction of the attack caused by *ECB* was reported in other study [5, 14, 30, 31].

The frequency of attack on conventional maize hybrids has been influenced by years of study. Higher pest pressure was registered in year 2012. A possible explication of this was because in June and July of 2013, at ARDS Șimnic, the abundant rain and the temperatures slightly below the multiannual average (-0.3^{0}C and -0.4^{0}C, respectively) limited the flight of *O. nubilalis* butterflies, their oviposition and incubation, therefore the attack frequency was lower compared to 2012. Similarly in Croatia, climatic conditions in 2012 increased the *ECB*'s potential to damage maize [23].

[9] found that at NARDI Fundulea, the increase in attack intensity is due the climatic conditions from the end of June or beginning of July, favorable for larva development, from emergence until they enter in plant stalks.

[12] reported that the differences between years for level of attack, were significant, but between genotype (GM maize and conventional) maize were non-significant.

[11] considers that sensitivity of a plant species to the attack of pests results not only from its genetic properties, but also from growth conditions for pests.

Also, the reduction of plant height by water and heat stress can affect the level of infestation with *ECB*, because adults are attracted to the taller plants in an area during the first generation egg-laying period [28].

[7] reported an attack frequency of *ECB* between 9% and 60.5%, depending on the hybrid, in the RDCFCSS Dăbuleni area, and [13] reported an average attack frequency of 51.27% at Horia, Arad County.

The stalk tunnel length is a character typically used to quantify *ECB* damage, and it is negatively correlated with grain yield, although is unknown the genetic mechanism responsible of that relationship [18].

CONCLUSIONS

Field experiments conducted over two consecutive crop-growing seasons revealed that severe drought stress had a strong effect on maize growth and development. Significant differences were observed between the tested maize hybrid (GM and conventional maize) for all evaluated parameters. Also, the climatically conditions of years of study, significantly affected the all evaluated parameters, except days to tasseling.

The present study demonstrated the efficacy of MON810 in controlling the *ECB* in central part of Oltenia, Romania.

Climatic conditions from summer period, registered at ARDS Simnic were favorable for *ECB* larva development in conventional maize hybrids.

The grain yield of GM maize hybrid was least affected by drought stress conditions as compared to conventional maize hybrids.
Thus, adopting GM maize crops can effectively address the drought stress and its consequences, for sustainable maize crop production in the dry Oltenia region.

ACKNOWLEDGEMENTS

This research work was supported from project ADER 6.1.2. "Substantiation of coexistence restrictions for agricultural species depending on the geographical and orographic location of crop areas", (*”Fundamentarea restricţiilor de coexistenţă pentru speciile agricole în funcţie de situarea geografică şi orografică a arealelor de cultură”,* 2011-2014).

REFERENCES

[1]Al-Eryan, M.A.S., Abu-Shall Amany, M.H., Huesien Hanaa, S., Ibrahiem, H.K., 2019, Estimation of yield losses of three corn varieties due to Stem Borers *Sesamia cretica* Led. and *Ostrinia nubilalis* (Hb.) in El-Bostan Region, El-Behiera Governorate. Alexandria Journal of Agricultural Science, 64(2), 97-105.
[2]Areal, F.J., Riesgo, L., Rodríguez-Cerezo, E., 2013, Economic and agronomic impact of commercialized GM crops: a meta-analysis. The Journal of Agricultural Science, 151(1), 7-33.
[3]Bertho, L., Schmidt, K., Schmidtke, J., Brants, I., Cantón, R.F., Novillo, C., Head, G., 2020, Results from ten years of post-market environmental monitoring of genetically modified MON 810 maize in the European Union. PLoS ONE, 15(4), e0217272. https://doi.org/10.1371/journal.pone.0217272, Accessed on December 2020.
[4]Bonea, D., Urechean, V., 2020, Response of maize yield to variation in rainfall and average temperature in central part of Oltenia. Romanian Agricultural Research**,** 37, 1-8.
[5]Darvas, B., Bánáti, H., Takács, E., Lauber, E., Szécsi, A., Székács, A., 2011, Relationships of *Helicoverpa armigera*, *Ostrinia nubilalis* and *Fusarium verticillioides* on MON 810 maize. Insects, 2, 1-11.
[6]Dima, M., 2014, The influence of the climatic conditions on production of foreign varieties of peanuts grown on sandy soils. Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series, 44, 82-85.
[7]Drăghici, R., Drăghici, I., Croitoru, M., Ploae, M., 2010, Results on the tolerance of agents pest under maize hybrids experimental in sandy soils conditions. Annals of University of Craiova, Series Agricuture-Mountanology and Cadastre, Vol. XL(1), 334-340.
[8]FAOSTAT, Food and Agriculture Organization of the United Nations, 2019, http://www.fao.org/faostat/en/#data/QC, Accessed on May 2021.
[9]Georgescu, E., Cana, L., Râșnoveanu, L., 2015, Behavior of some maize hybrids to the European corn borer (*Ostrinia nubilalis* HBN) attack at NARDI Fundulea, 2013-2014. Scientific Papers Series Agronomy (Lucrări Ştiinţifice, Seria Agronomie), 58(1), 129-134.
[10]Georgescu, E., Toader, M., Cană, L., Râşnoveanu, L., 2019, Researches concerning European corn borer (*Ostrinia Nubilalis* hbn.) control, in south-east of the Romania. Scientific Papers, Series A. Agronomy, LXII(1), 301-308.
[11]Grzebisz, W., Barłóg, P., Waszak, M., Łukowiak, R., 2007, Nutritional homeostasis and plant crops resistance to biotic stresses. Fragmenta Agronomica, 3(95), 136-143.
[12]Hrčková, K., Mihalčík, P., Žák, Š., Hašana, R., Ondreičková, K., Kraic, J., 2018, Agronomic and economic performance of genetically modified and conventional maize. Agriculture (Poľnohospodárstvo), 64(2), 87-93.
[13]Jurcă, D., Popescu, G., 2009, Involvement of the pest *Ostrinia nubilalis* Hb in the amplification and movement of the pathogen within the pathosystem. Research Journal of Agricultural Science, 41(3), 87-91.
[14]Kocourek, F., Stará, J., 2012, Efficacy of Bt maize against European corn borer in Central Europe. Plant Protection Science, 48, S25–S35.
[15]Kocmánková, E., Trnka, M., Eitzinger, J., Formayer, H., Dubrovsky, M., Semerádová, D., Zalud, Z., Juroch, J., Mozny, M., 2010, Estimating the impact of climate change on the occurrence of selected pests in the Central European region. Climate Research, 44, 95-105.
[16]MARD, 2020.Genetic modified organisms (Organisme modificate genetic), https://www.madr.ro/organisme-modificate-genetic.html, Accessed on January 2021.
[17]Miao, Z., Han, Z., Zhang, T., Chen, S., Ma, C., 2017, A systems approach to a spatio-temporal understanding of the drought stress response in maize. Scientific Reports, 7, 6590.
[18]Ordas, B., Malvar, R.A., Santiago, R., Butron, A., 2010, QTL mapping for Mediterranean corn borer resistance in European flint germplasm using recombinant inbred lines. BMC Genomics, 11, 174.
[19]Popescu, A., 2018, Maize and wheat-top agricultural products produced, exported and imported by Romania, Scientific Papers. Series Management, Economic Engineering in Agriculture and Rural Development, 18(3), 339–352.
[20]Popescu C.V., Bora, C., 2009, The rational use of water as main method to combat drought. Ananls of University of Craiova, Series Agricuture-Mountanology and Cadastre, Vol. XXXIX, 455 - 459.
[21]Popov, C., Trotuş, E., Vasilescu, S., Bărbulescu, A., Râşnoveanu, L., 2006, Drought effect on pest attack

in field crops. Romanian Agricultural Research, 23, 43-51.

[22]Popović, B., Tanasković, S., Gvozdenac, S., Kárpati, Z.S., Bógnar, C., Erb, M., 2016, Population dynamics of WCR and ECB in maize field in Beĉej, Vojvodina provance. XXI Symposium of biotechnology. Proceedings, 21(21), 341-347.

[23]Sarajlić, A., Raspudić, E., Lončarić, Z., Josipović, M., Brmež, M., Ravlić, M., Zebec, V., Majić, I., 2017, Significance of irrigation treatments and weather conditions on European corn borer appearance. Maydica, 62(2), 1-8.

[24]Shirinzadeh, A., Zarghami, R., Shiri, M.R., 2009, Evaluation of drought tolerance in late and medium maize hybrids using stress tolerance indices. Iranian Journals of Crop Science, 10, 416-427.

[25]Soare, R., Dinu, M., Hoza, G., Bonea, D., Băbeanu, C., Soare, M., 2019, The influence of the hybrid and the sowing period on the production of sweet corn Scientific Papers. Series B. Horticulture. Vol. LXIII(1), 391-397.

[26]Szőke, C., Zsubori, Z., Pók, I., Rácz, E., Illés, O., Szegedi, I., 2002, Significance of the European corn borer (*Ostrinia nubilalis Hübn*.) in maize production. Acta Agronomica Hungarica, 50(4), 447-461.

[27]Tandzi, L.N., Mutengwa, C.S., 2020, Estimation of maize (*Zea mays* L.) yield per harvest area: appropriate methods. Agronomy, 10(1), 29. DOI: 10.3390/agronomy10010029, Accessed on January 2021.

[28]Tende, R., Mugo, S.N., Nderitu, J.H., Olubayo, F.M., Songa, J.M., Bergvinson, D.J., 2010, Evaluation of *Chilo partellus* and *Busseola fusca* susceptibility to d-endotoxins in Bt maize. Crop Protection, 29, 115-120.

[29]Traore, S.B., Carlson, R.E., Pilcher, C.D., Rice, M.E., 2000, Bt and Non-Bt maize growth and development as affected by temperature and drought stress. Agronomy Journal, 92, 1027-1035.

[30]Urechean, V., Bonea, D., 2017, Coexistence in cultivation of genetically modified maize (MON810) with conventional maize. Romanian Agricultural Research, 34, 51-58.

[31]Urechean, V., Bonea, D., 2018a, The comparative study of Bt corn and conventional corn regarding the *Ostrinia nubilalis* attack and the *Fusarium spp*. infestation in the central part of Oltenia. Romanian Biotechnological Letters, 23(4), 13728-13735.

[32]Urechean, V., Bonea, D., 2018b, 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.