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Behavior of Some Maize Hybrids to the Attack of the European Corn Borer (*Ostrinia nubilalis* Hbn.) and Fusarium Ear Rot (*Fusarium* sp.)

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ABSTRACT

European corn borer (*Ostrinia nubilalis* Hbn.) is the most important pest of maize, for the conditions on Romania. Through injuries produced, both on the stem and ears, it favors the penetration of the spores of *Fusarium* sp. in the plant. In this paper, some results were presented regarding the reaction of the new maize creations and some perspective hybrids from Agriculture Research and Development Station Turda (ARDS Turda), to the attack of the European corn borer (*Ostrinia nubilalis* Hbn.) larva and the fusarium ear rot (*Fusarium* sp.), in the period 2020-2022. The climatic conditions during the summer period, recorded at ARDS Turda, were more favorable to the attack in 2021 and 2022 compared to 2020 for the European corn borer, respectively, more favorable to the attack in 2022 compared to 2021 for the fusarium ear rot. Turda 380 and Turda 2020 hybrids showed a tolerance to the attack of European corn borer larva and the lowest values of fusarium ear rot attack. Turda 332, HST A483-11 and HST A483-39 hybrids were more sensitive both to the attack *of Ostrinia nubilalis* and *Fusarium* sp.

Keywords: European corn borer, fusarium ear rot, maize, Turda hybrids, attack.

INTRODUCTION

The yield of maize crops can be affected by a number of biotic and abiotic factors (Kocmánková et al., 2010; Abuzar et al., 2011; Petcu et al., 2018; Trotuș et al., 2018). The damage caused by biotic factors to cultivated plants varies between 24% and 45%. The damages produced to the maize crop are 34,8% of which: 13,0% by weeds; 9,4% by diseases and 12,4% by pests (Toncea, 2002; Toncea and Stoianov, 2002).

European corn borer (*Ostrinia nubilalis* Hbn.) is one of the most damaging pests of maize in Europe and North America (Bourguet et al., 2000; Keszthelyi and Somfalvi-Toth, 2020). Its larvae attack all aerial organs of the plant: leaves, stems and ears, being responsible for the major yeild losses (Gianessi, 2014; Trotuș et al., 2018) and, as well, a vector for fusarium ear rot (Franeta et al., 2019). In the infested areas of Europe, *O. nubilalis* is found in a high proportion, from 20% in Hungary to 60% in Spain, and the estimated yield losses are between 5% and 30%, being typical damages without many control measures. In certain surveys, the loss rate at 69% stalk infestation amounts to 11% of the potential yield (Meissle et al., 2010). In our country, it is the main pest of maize in Transylvania and second in importance after *Tanymecus dillaticolis* Gyll. in the south and south-east of the country (Popov, 2002; Cristea et al., 2004; Popov et al., 2005, 2007). According to some authors, yield losses can reach to 60% (Paulian et al., 1962). In the favorable area for corn cultivation in Transylvania, annual yield losses were recorded between 5.4% and 9.8% (Mustea, 1981).

Monitoring of the European corn borer (ECB) adult fly dynamics is crucial for distinguishing the number of generations of the pest during the season and determining the period of the most intense activity of adults (Ivezić et al., 2023). Global warming and climate change could affect the occurrence intervals and the impact of pests and pathogens (Keszthelyi and Somfalvi-Toth, 2020), the development of additional

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generations being one of the problems generated by climate change (Bebber, 2015; Chaudhry and Sidhu, 2022). In the last decade, researchers from Germany and Hungary highlighted the fact that in areas where the ECB had only one generation/year, was reported the appearance of the second generation/year - part of it, the main cause be supposed it is due to climate change, especially global warming (Szeóke et al., 1996; Schmitz et al., 2002; Vörös, 2002; Keszthelyi and Lengyel, 2003; Keszthelyi, 2004; Gathmann and Rothmeier, 2005; Keszthelyi, 2010; Kocmánková et al., 2010; Keszthelyi and Somfalvi-Toth, 2020; Pintilie et al., 2023). Since weather conditions are not easy to predict, it is necessary a sustainable management strategy in order to adapt to future climate changes (Șimon et al., 2023).

Fusarium ear rot (FER) is the most common ear disease, caused by several fungi in the genus *Fusarium*. The main *Fusarium* sp. that cause fusarium ear rot are *Fusarium graminearum* and *Fusarium verticillioides* (Mesterhazy et al., 2012; Duan et al., 2016); its are found and cause damage in all maize growing areas around the world (Tiru et al., 2021; Kovács et al., 2023). The importance of these diseases has been recognized for many years, but it still causes great problems because high levels of genetic resistance have not been discovered and incorporated into agronomically desirable high-yielding hybrids (Șopterean et al., 2018).

Several studies state that ECB dependence on weather conditions (Kornoşor and Kayapinar, 1988; Waligóra et al., 2014; Sarajlic et al., 2017). The climatic conditions of June and July are very important for the evolution of the ECB attack (Geogescu et al., 2013, 2019; Bažok et al., 2020) and, implicitly, of FER attack. Most studies show that excessive temperatures accompanied by drought cause low percentage of larva eclosion and higher mortality percent of ECB first instars larva and strong rains and winds during the same period cause the death of the larvae in the first stages of development before penetrate the stem (Paulian et al., 1976; Barbulescu et al., 2001; Roșca and Rada, 2009).

ECB is involved in the biological cycle of FER. Through injuries produced, both on the stem and ears, it favors the penetration of the spores of *Fusarium* sp. in the plant (Szőke et al., 2002; Trotuș et al., 2018). Researches also showed that spores of this fungus were found in the ECB larvae, being transported into the plant (Sobek and Munkvold, 1999; Battilani et al., 2003; Blandino et al., 2015). This pathogen causes both quantitative and qualitative damage through the mycotoxins produced such as (DON) deoxynivalenol, (ZEA) zearalenone and (FUM) fumonisins (Tiru et al., 2021; Kovács et al., 2023), which can affect human and animal health (Strange and Scott, 2005; Mukanga et al., 2010; Beev et al., 2013; Franeta et al., 2019; Negruț et al., 2019).

Some studies reported that the control of ECB larva affects FUM levels in maize kernel (Dowd, 2003; Folcher et al., 2009; Ostry et al., 2010). Application of a strategy that can reduce ECB damage could also be the most effective solution to minimize the mycotoxins produced by *Fusarium* sp. (Blandino et al., 2015). The identify ECB-resistant genotypes to ear attack under artificial infestations might be the most promising approach (Santiago et al., 2013; Franeta et al., 2019).

Using of maize hybrids with tolerance at ECB larva is one of the best method for control attack of this pest (Popov and Bărbulescu, 2007). According to the sensitivity of hybrids, the damage may vary from only a few percent in tolerant hybrids, up to 30-40% on moderately intolerant hybrids (Gošić-Dondo et al., 2022). The increase tolerance of particular genotypes it is believed to be in direct relation with several other biotic and abiotic factors, because very often this trait was not repeatable from year to year (Papst et al., 2004; Sandoya et al., 2010; Franeta et al., 2019). For FER the most efficient rot management strategy are selection of resistant hybrids as host resistance (El-Demerdash et al., 2017).

In this regard, the objective of this study was to evaluate the reaction of some Turda hybrids to the attack of ECB larva and FER in order to identify some genotypes tolerant to the attack of these damage agents.

MATERIAL AND METHODS

Experimental fields and trial design

The research was carried out at the experimental field of the Maize Breeding Collective, from Agriculture Research and Development Station for Agriculture Turda (ARDS Turda), in the period 2020-2022 and consisted of observations and determinations on the natural attack of the ECB and FER. The biological material used in our study was represented by 12 maize hybrids FAO 380: the newest creations (Turda 332, Turda 335, Turda 380, Turda 2020) and perspective hybrids (SUR 18/399, SURO 11, HST 149, HST A 483-11, HST A 478-10, HST A 478-3, HST A 483-39, HST C385cmsC-84) of ARDS Turda. The experiment design was Completely Randomized Design (CRD) in three replications, each hybrid been sown on two rows, 8.7 m length and 70 cm between rows with 88 plants per plot.

Trial assessments

The attack level of the ECB larva and FER at maize plants was analyzed in the autumn, after harvesting.

The incidence of ECB on stem in all three years was determined from each plot. The incidence of ECB on ear, the incidence and severity of FER on 50 ears randomly sampled from each plot were noted in 2021 and 2022. The severity of FER was evaluated on a 0-9 scale.

Monitoring of ECB

At maize crop, light and pheromone traps are used to capture ECB adults (Cizej and Trematerra, 2017).The evaluation of the ECB populations at ARDS Turda was carried out using Delta traps with Romanian synthetic sex pheromones from the “Raluca Ripan” Chemical Research Institute Cluj-Napoca, atraOSGAM variant (Figure 1). The common pheromonal bait for *Ostrinia nubilalis* and *Autographa gamma* contains sex pheromone emitted by the male for the purpose of capturing females and an attractant dispenser for the purpose of capturing both sexes (https://feromoni.iccrr.institute.ubbcluj.ro).

The atraOSGAM pheromone bait contains: (Z)-11-Tetradecenylacetate; (E)-11-Tetradecenylacetate. The atraOSGAM attractant dispenser contains: Phenylacetaldehyde; 4-Phenethoxyphenetyl alcohol. Pheromones were placed, in 3 replications, at a distance of 50 m from each other, between May and September. Pheromone variants were placed outside of the experimental plot and were replaced every four weeks and the adhesive plate every two weeks. The number of captured males was recorded weekly.

Figure 1. Delta pheromone trap (original)

Data analysis

When required to correct skewness, the data expressed in % were transformed into arcsin√% and then were calculated statistically, using the analysis of variance and the calculation of correlations.

RESULTS AND DISCUSSION

Data recorded at meteorological station Turda, shows that, from the thermal point of view, in all the experimental years, in June and July, montly average air temperatures above the multi-year average were recorded, with deviations between 0.5 and 3.3ºC (Table 1).

Table 1. Monthly average air temperature registered in June and July, 2020-2022, ARDS Turda

Month	Monthly average (ºC)	Multi-year average/ 65 years	Deviation	Characterization
2020				
June	19.1	17.9	**1.2**	warmly
July	20.2	19.7	**0.5**	normal
August	21.5	19.3	2.2	warm
September	17.8	15.1	2.7	warm
2021				
June	19.8	17.9	**1.9**	warmly
July	22.7	19.7	**3.0**	warm
August	19.7	19.3	0.4	normal
September	15.0	15.1	-0.1	normal
2022				
June	21.1	18.0	**3.1**	warm
July	23.1	19.8	**3.3**	warm
August	22.3	19.5	2.8	warm
September	14.3	15.2	-0.9	normal

Source of primary data: Turda meteorological station (longitude: 23°4´; latitude: 46°35´; altitude: 427 m).

Regarding the rainfall, it can be observed that the June of 2020 was excessively rainy, resulting in a higher percentage of the mortality of the ECB larva in the first stages of development before penetrate the stem. June of the years 2021 and 2022 was very dry and excessively dry, having a negative effect on egg hatching (Table 2).

Waligóra et al. (2014) following the experience with sweet corn hybrids stated that the ECB dependence on weather conditions was significant ($p<0.001$, $p<0.05$). Authors shows that ECB attack was directly proportional to air temperature and precipitation.

Table 2. Monthly rainfall registered in June and July, 2020-2022, ARDS Turda

Month	Monthly amount (mm)	Multi-year average/ 65 years	Deviation	Characterization
2020				
June	166.6	84.8	**81.8**	excessively rainy
July	86.8	77.1	9.7	little rainy
August	58.0	56.5	1.5	normal
September	57.4	42.5	14.9	very rainy
2021				
June	45.0	84.8	**-39.8**	very dry
July	123.1	77.1	46.0	rainy
August	52.9	56.5	-3.6	normal
September	39.1	42.5	-3.4	normal
2022				
June	41.8	84.6	**-42.8**	excessively dry
July	25.2	78.0	**-52.8**	excessively dry
August	94.6	56.1	38.5	excessively rainy
September	119.9	42.4	77.5	excessively rainy

Source of primary data: Turda meteorological station (longitude: 23°4´; latitude: 46°35´; altitude: 427m).

In 2021, following the monitoring of the ECB flight, with pheromone traps, the increase of the ECB population it has been observed (Figure 2). This fact is due to climate change, concretized by increases of temperatures above the multi-year average, with deviations between 1-3ºC. To specify, the fact that, if until now the pest presented 1 generation per year, can be seen from the figure the appearance of the second generation.

In 2022, the situation has changed, the second generation of ECB did not develop at all (Figure 2). A possible explanation would be excessive air temperatures accompanied by drought and low humidity.

In Hungary, the larvae pupate in late July or early August transformed into moths without a diapause. The moths belonged to second (summer) generation (Szőke et al., 2002).

In Balatonmagyaród and Várda located near to zone of Hungary where the ECB had only one generation/year, Keszthelyi and Lengyel (2003) reported appearance of the second generation at pheromone and light's traps.

Pintilie et al. (2023) state that the ECB has two generations per year in eastern Romania: a complete one between June and September and a partial one in August.

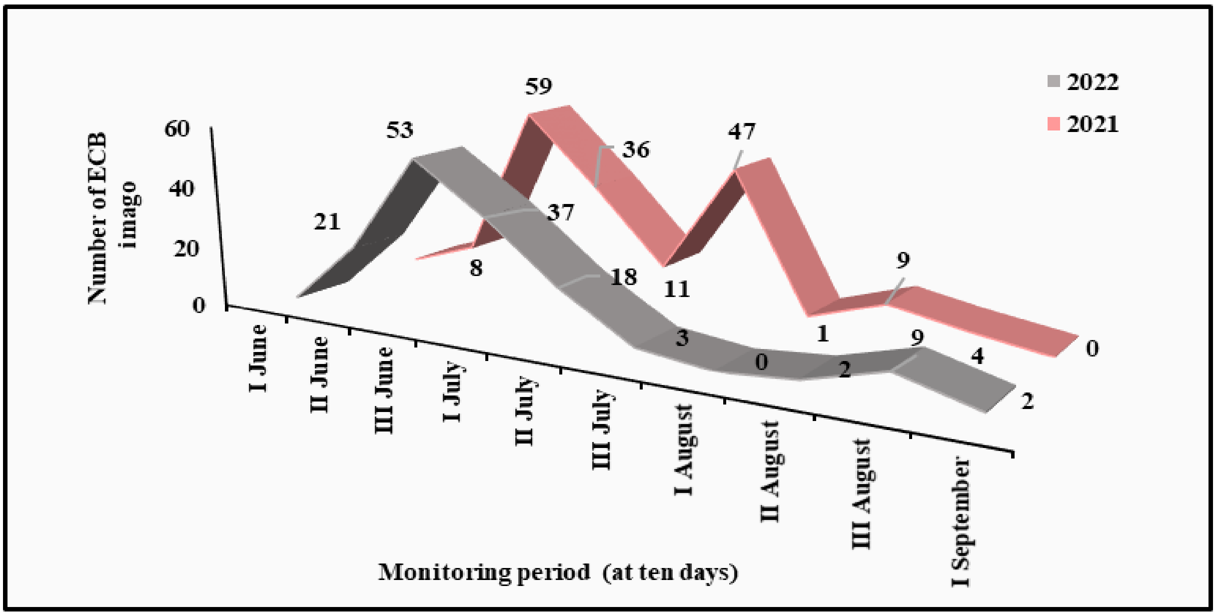

Figure 2. The dynamic of ECB flight in maize crop, 2021-2022, ARDS Turda

It is known that the environment has a major influence on the evolution of insect populations (Khaliq et al., 2014; Shrestha, 2019; Skendžić et al., 2021). In 2020, the smallest attack on the stem was recorded, the differences were very significant (p<0.1), compared to the three-year average. Hybrids behaved differently; among the new homologated creations, Turda 2020 stands out with the lowest percentage of ECB larva attack on stem, with differences assured as very significant (p<0.1), compared to the control represented by the average of the hybrids. Among the perspective hybrids, two stand out (SURO 11 and HST C385AcmcC-84), with reduced attack values on the stem, the differences compared to the control were distinctly (p<1) and very significant (p<0.1) (Table 3).

The results of other studies, on three years, show high variability of ECB larva severity attack, depending on the climatic conditions (Georgescu et al., 2013).

Pintilie et al. (2022), in a experiment where it tested six maize genotypes from different precocity groups (Turda 165, Turda 248, Turda Star, Turda 344, Turda 332 and Olt), state that the lowest value of the ECB larva incidence was 28.59% (Turda 248), and the highest was 35.83% (Turda 165).

Table 3. The influence of factors on the incidence of ECB larva on stem, Turda, 2020-2022

Factors		Incidence of ECB larva on stem		+/- control
		%	arcsin√%	
A. Year	Control - Average	53.60	47.09	$0.00^{Mt.}$
	2020	25.80	29.90	-17.19^{000}
	2021	77.10	61.39	14.30***
	2022	58.60	49.98	2.89
	LSD (p 5%) LSD (p 1%) LSD (p 0.1%)			1.52 2.52 4.72
B. Hybrid	Control - Average	53.60	47.09	$0.00^{Mt.}$
	T.332	51.30	45.77	-1.32^{00}
	T.335	48.70	44.23	-2.86^{000}
	T.380	51.00	45.57	-1.52^{00}
	T.2020	46.60	43.06	-4.03^{000}
	SUR 18/399	58.40	49.81	2.72***
	SURO 11	51.40	45.80	-1.29^{00}
	HST A 483-11	64.70	53.56	6.47***
	HST A 478-3	57.30	49.17	2.08***
	HST A 483-39	56.30	48.62	1.53**
	HST C385AcmsC-84	50.60	45.31	-1.78^{000}
	LSD (p 5%) LSD (p 1%) LSD (p 0.1%)			0.97 1.29 1.68

The interaction between the hybrid and the climatic conditions suggests that in 2020 the attack of ECB larva on the stem was the most reduced, between 20.3 and 31.4%. The highest attack being in 2021, where a incidence of 86.2% was reached. However, compared to the average, five hybrids (Turda 332, Turda 335, Turda 380, Turda 2020 and SURO 11) register a more reduced incedence of ECB larva attack. Annually, at the SUR 18/399 hybrid the attack values on the stem was high (Figure 3).

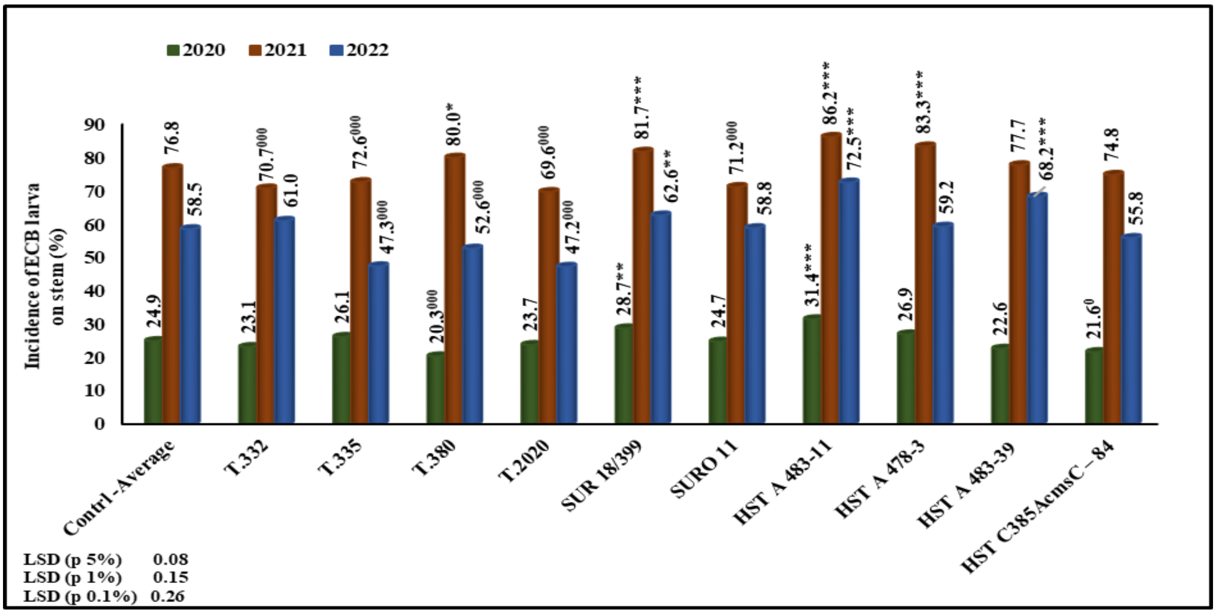

Figure 3. The influence of the interaction between the hybrid and the climatic conditions on the incidence of ECB larva on stem (Turda, 2020-2022)

Regardind to the attack of ECB larva on ear, data results reveal that, Turda 380 and Turda 2020 hybrids registered very, respectively distinctly significant differences comparative with control (Table 4). Superior differences compared to the control between 5.14% and 7.06%, are evident for three of the hybrids (Turda 332, HST A 483-11, HST A 483-39).

Negruț et al. (2019) state that, in Timiș County (ARDS Lovrin), 13 inbred lines out of 21 were attacked by ECB larva on ear, with a frequency between 7-50%.

Table 4. The influence of factors on the incidence of ECB larva on ear, Turda, 2021, 2022

Factors		Incidence of ECB larva on ear		+/- control
		%	arcsin√%	
A. Year	Control - Average	27.60	31.70	0.00$^{Mt.}$
	2021	26.90	32.25	-0.45
	2022	28.30	32.15	0.45
	LSD (p 5%) LSD (p 1%) LSD (p 0.1%)			18.73 93.82 938.22
B. Hybrid	Control - Average	27.60	31.70	0.00$^{Mt.}$
	T.332	35.90	36.84	5.14*
	T.335	24.50	29.61	-2.09
	T.380	12.80	20.97	-10.74^{000}
	T.2020	19.60	26.28	-5.42^{0}
	SUR 18/399	26.90	31.23	-0.47
	SURO 11	32.00	34.43	2.73
	HST 149	29.90	33.15	1.45
	HST A 483-11	39.20	38.76	7.06**
	HST A 478-10	28.60	32.35	0.65
	HST A 478-3	24.00	29.30	-2.41
	HST A 483-39	36.80	37.37	5.67*
	HST C385AcmsC-84	25.20	30.15	-1.56
	LSD (p 5%) LSD (p 1%) LSD (p 0.1%)			4.69 6.39 8.59

Climatic conditions more favorable to the attack of ECB larva on ear were in 2022, with values between 10% and 68% for Turda 380 and HST A483-11 hybrids. In conditions of 2021 and 2022, Turda 380 hybrid has the lowest attack values, comparative with control (Figure 4).

In a study with twenty sweet corn populations and 1 field corn population, evaluated for ear resistance of ECB and *Sesamia nonagrioides* L., under artificial infestation, Velasco et al. (1999) reported significant differences between years and the interactions genotype x year.

Grčak et al. (2022) shows there was no statistical significances between maize hybrids, in a study for resistance/susceptibility of hybrids, from different maturity groups, to the attack of ECB.

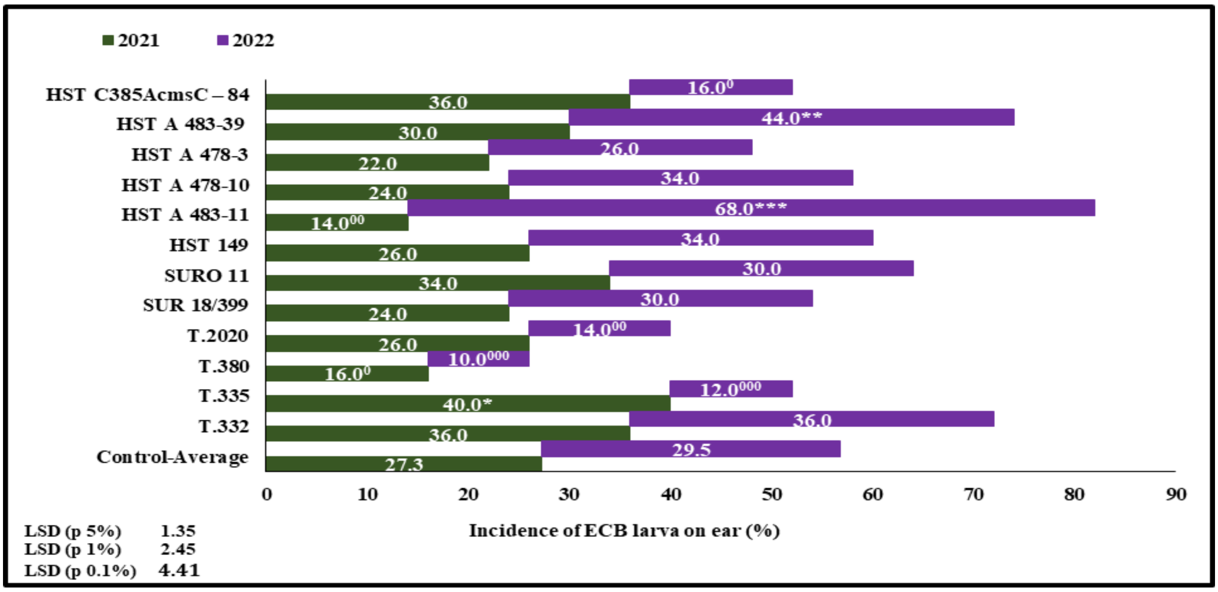

Figure 4. The influence of the interaction between the hybrid and the climatic conditions on the incidence of ECB larva on ear (Turda, 2020-2022)

Making an analogy with what was previously stated about the attack of ECB larva on ear, the degree attack of FER was manifested differently depending on the hybrids. The same three hybrids register high attack values, the differences compared to the control being between 1.80% and 3.78%. Turda 380 and Turda 2020 hybrids were the most tolerant to FER attack (Table 5).

In a paper, in which were analyzed 21 inbred lines, Negruţ et al. (2019) reported incidence of FER being between 33-100% and severity didn't surpass 25%.

Table 5. The influence of factors on the attack of FER (Turda, 2021, 2022)

Factors	I* arcsin √%	I %	+/- control	S** arcsin √%	S %	+/- control	DA*** arcsin √%	DA %	+/- control
Year									
Average	20.56	12.3	0.00$^{Mt.}$	8.07	2.0	0.00$^{Mt.}$	4.47	0.61	0.00^{Mt}
2021	26.25	19.6	-4.21	3.45	0.36	-4.62^{00}	1.61	0.08	-2.86
2022	34.87	32.7	4.21	12.70	4.8	4.62**	7.33	0.16	2.86
LSD (p 5%)			16.94			0.51			3.17
LSD (p 1%)			84.82			2.57			15.86
LSD (p 0.1%)			848.20			25.73			158.62
Hybrid									
Average	30.56	25.8	0.00$^{Mt.}$	8.07	1.95	0.00$^{Mt.}$	4.47	0.61	0.00^{Mt}
T.332	45.00	50.0	14.44***	12.49	4.7	4.42***	8.25	2.05	3.78***
T.335	26.42	19.8	-4.14	6.75	1.4	-1.33	3.13	0.30	-1.34
T.380	20.14	11.9	-10.42^{00}	7.67	1.8	-0.41	2.70	0.22	-1.77^{0}
T.2020	25.69	18.8	-4.88	7.11	1.5	-0.96	2.91	0.26	-1.56^{0}
SUR 18/399	28.58	22.9	-1.98	6.84	1.45	-1.23	3.74	0.42	-0.73
SURO 11	25.18	18.1	-5.38	6.58	1.3	-1.50	3.33	0.34	-1.14
HST 149	31.87	27.9	1.31	8.13	2.00	0.06	4.48	0.61	0.01
HST A 483-11	37.93	37.8	7.37	9.67	2.8	1.59	7.10	1.15	2.63***
HST A 478-10	31.72	27.6	1.16	8.30	2.1	0.23	4.99	0.75	0.52
HST A 478-3	24.63	17.4	-5.93	7.99	1.9	-0.09	3.51	0.38	-0.96
HST A 483-39	35.90	34.4	5.34	9.53	2.7	1.46	6.26	1.20	1.80*
HST C385AcmsC-84	33.69	30.8	3.13	5.84	1.0	-2.23^{0}	3.23	0.32	-1.24
LSD (p 5%)			6.30			1.78			1.86
LSD (p 1%)			8.58			1.36			3.26
LSD (p 0.1%)			11.53			2.43			2.50

The climatic conditions of 2021 did not favor the DA of FER attack on ear, reaching a maximum of only 0.63% (Turda 332). Instead, those of 2022, accompanied by a large presence of ECB larva, led to a much higher DA of the FER. Low attack values were recorded at four hybrids (Turda 335, Turda 380, Turda 2020 and HST C385AcmsC-84), with values below 1%. The most sensitive hybrids to the FER attack, as well as to the attack of ECB larva, were Turda 332, HST A486-11 and HST A483-39 (Figure 5).

Injuries caused by ECB larva played an important role in the development of fusarium infection, which increased in ECB-infested crops (Szeőke et al., 1996; Urechean and Bonea, 2018).

Szőke (2000) stated that ECB damage was the result of fusarium infection in maize genotypes in the very early and early maturity groups.

In a study done by Krnjaja et al. (2022) appears that climatic factors are crucial in fusarium infections.

In a three years study, Blandino et al. (2015) state that the ECB larva presence significantly affected the incidence and severity of FER in each growing season ($p<0.01$).

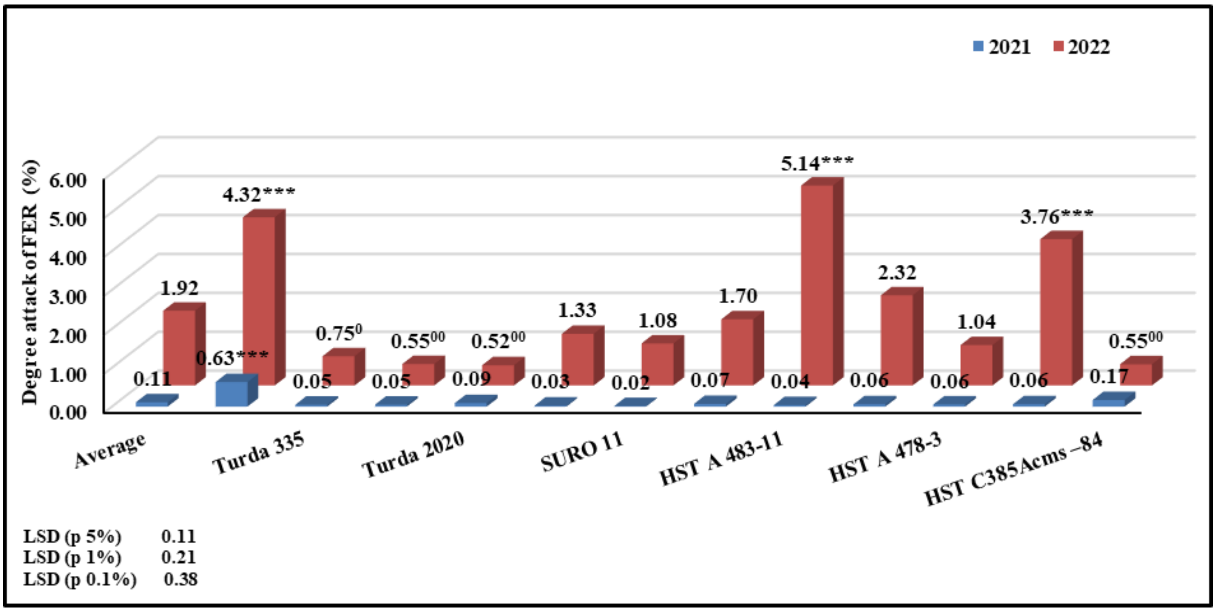

Figure 5. The influence of the interaction between the hybrid and the climatic conditions on the degree attack of FER, (Turda, 2021, 2022)

It is known that there is a close connection between the attack of ECB larva and FER (Scarpino et al., 2015), a connection that is also confirmed in our case. The relationship between the two variables is controlled largely by external factors and especially by climatic conditions. From the graphic representation, it can be seen that, in 2022, in 80% of cases, the attack of the ECB larva on ear favored the installation of FER (Figure 6).

In a two years study it was proven that there is a direct relation between the ECB attack and *Fusarium* spp., in that an intensive ECB attack favors the installation of *Fusarium* pathogens (Urechean and Bonea, 2018).

Vălean et al. (2017) also state that in about 99% of the cases, the attack of ECB larva on ear results in the increase of the attack of FER.

By contrast, the results of Negruț et al. (2019) in Timiș County showed that there isn't correlated incidence of ECB larva with incidence of FER.

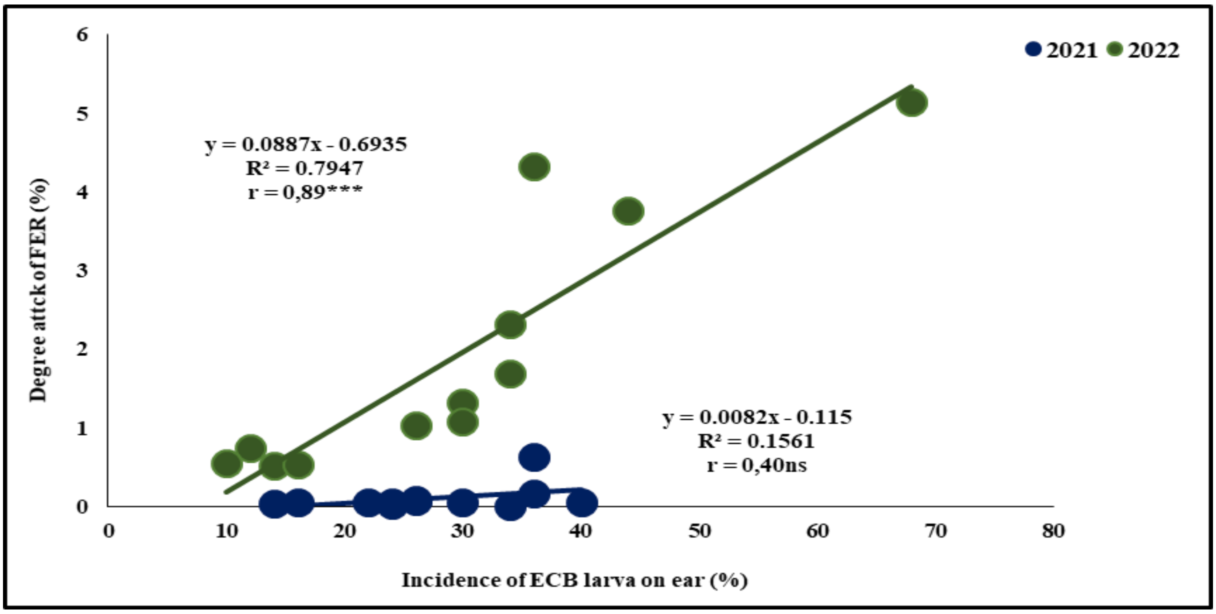

Figure 6. The relationship between the incidence of ECB larva on ear and the degree attack of FER (Turda, 2021, 2022)

CONCLUSIONS

European corn borer (*Ostrinia nubilalis* Hbn.) is the most important pest of maize, for the conditions on Transylvania area; attacks all aerial organs of the plant. The most damaging is the attack on the stem, because causes breaking it. Also, being a vector for the installation of different mycotoxigens fungi.

Climate changes, materialized by increases of air temperatures above the multi-year average, with deviations between 1-3°C, led to the complete development of the second generation of the ECB.

The studied hybrids reacted differently to the incidence of ECB larva on stem, six of the ten hybrids recorded lower attack values compared to their average. Turda 2020 hybrid standing out with a percentage of 46.60%.

The hybrids Turda 332, Turda 335, Turda 380, Turda 2020 and SURO 11 can be considered tolerant because the incidence of the ECB larva on the stem was very reduced in climatic conditions favorable to the attack (year 2021). Two of these hybrids (Turda 380 and Turda 2020) showed a tolerance to the attack of ECB larva on ear and the lowest values of degree attack of FER, too. Hybrids Turda 332, HST A483-11 and HST A483-39 were more sensitive, both to the attack of ECB larva on ear and to the attack of FER.

Between the incidence of ECB larva on ear and the degree attack of FER, there is a direct, positive, statistically very significant connection, in the year favorable to the attack.

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