NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 36, 2019
Print ISSN 1222–4227; Online ISSN 2067–5720

EFFECT OF SIMULATING HAIL AND LATE SPRING FROST ON CERTAIN PARENTAL FORMS OF REGISTERED MAIZE HYBRIDS IN THE NORTH-WEST OF TRANSYLVANIA

Claudiu Gabriel Bălaş-Baconschi[1*], Doru Pamfil[1], Mircea Savati[1], Emilia Tinca[1], Roxana Călugăr[1, 2], Voichiţa Haş[2]

[1]University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, Romania
[2]Agricultural Research and Development Station (ARDS), Turda, Romania
[*]Corresponding author. E-mail: gabriel_balas@yahoo.com

ABSTRACT

A study was performed in the North-West of Transylvania to test the reaction of certain parental forms of maize hybrids (single hybrids and inbred lines) to the following risks: simulated late spring frost in two stages and simulated hail in four stages. Being able to quantify the effects of these phenomena on maize makes it possible to estimate the losses that are involved, losses related to yield, crop tolerance and crop production costs. In 2014, due to the effect of frost, yield losses were from 8% up to 51% in hybrids and from 12% up to 70% in inbred lines. Simulated hail caused losses from 1% up to 71% in hybrids and from 0.5% up to 70% in inbred lines. In 2015, simulated frost caused a yield decrease from 43% up to 71% for hybrids and 76% for inbred lines. Frost and hail in early stages produced smaller losses, but if these risks appeared later or with higher intensity the yield decreases were significantly higher. Breaking resistance was assessed before harvest. In a favourable year, after simulating these mentioned risks, the percent of erect plants was lower compared to a drought year when the yield was smaller. The influence of frost and hail combined with drought during pollination could seriously affect the yield of maize parental genotypes. Within this study, the parental genotypes of maize used showed a remarkable re-growth capacity in early stages, being able to adapt to stressful weather condition.

Keywords: hybrids, inbred lines, maize, simulated hail, simulated frost.

INTRODUCTION

Maize is one of the most important crops worldwide; its yield is affected by several risks with greater occurrence in the past years, as shown by Bălaş-Baconschi et al. (2015). An analysis of these risks and testing the reaction of certain genotypes in case of simulating early spring frost and hail have a great importance, for both breeders and hybrid seed multiplier.

Research on these risk factors was made for hail (Egharevba et al., 1976; Dwyer et al., 1994; Coulter et al., 2011, Klein et al., 2011; Robertson et al., 2011; Bălaş-Baconschi et al., 2015) and for frost (Cristea, 2013; Cristea et al., 2004). In temperate and northern zones, maize crop success is closely related to physiological and biochemical properties of hybrids resistant to cold. Especially in northern areas after plant emergence occurs sharp cooling weather. In such conditions, growing of the plants either completely ceases, or growing is slow. For the genotypes which are not resistant to cold, the growing of the emerged plants is slowed down beginning with 14°C. Cold resistant hybrids differ from the non-resistant by higher content of dry matter. Determination of cellular sap on vegetation phases show that in the early stages, the cellular sap concentration is lower. As the growing season progresses phases, cellular juice concentration increased. It is almost in all cases higher in cold-resistant forms, as shown by Cristea et al. (2004).

According to Cristea (2013), the value of maize populations in terms of resistance to cold is important for choosing the initial breeding works, to create maize varieties or hybrids resistant to low temperatures, especially in the first part of the plant life.

Received 21 March 2018; accepted 07 January 2019. First Online: January, 2019. DII 2067-5720 RAR 2019-4

Regardless of severity, defoliation within 30 days after silking significantly reduced total accumulated dry matter. Complete defoliation was more detrimental (6.4 to 82% yield loss) than partial defoliation (1.5 to 32.7% yield loss). These losses varied with the moment (after 50% silking) of treatment application. The effect of removing all leaves above the ear was not significantly different from that obtained by removing all leaves below the ear. Yield component affected most by leaf loss, for the overall treatment period, was kernel weight (12.7 to 53% decreases). However, number of kernels was greatly reduced (62.3%) when all leaves were removed 10 days after silking. Complete leaf removal thereafter and partial leaf removal affected number of kernels considerably less (approximate decline, 20%), as shown by Egharevba (1976).

The hectolitre mass (kg hl^{-1}), known as corn test weight (TW), represents a measurement of bulk density, or the weight of a unit volume, of maize. Many factors influence the measured hectoliter mass of maize: the physical characteristics of the kernel (size, density, shape and "slickness" of the outer kernel layer), the hybrid and the moisture. Other major factors influencing final hectolitre mass are plant stresses caused by environmental conditions (hail, premature frost and drought), diseases, insects, soil fertility. In other words, anything that impacts the movement of nutrients to the kernel during corn fill or degrades the integrity of the kernel once it is filled will lower maize hectoliter mass (Nielsen, 2009). The maize hectolitre mass values can range from 70 kg hl^{-1} up 82 kg hl^{-1}. In Romania the standard hectolitre mass of maize is established at 73 kg hl^{-1} based on 14% moisture content (Hodisan and Timar, 2010).

OBJECTIVES

The objectives of the study are:

1. Testing the reaction to late spring frost in different phenophases in some hybrids and inbred lines used as parental genotypes.
2. Testing the reaction of certain parental genotypes (hybrids and inbred lines) regarding the effect of hail in different phenological phases.

MATERIAL AND METHODS

The research was conducted for two years (2014 and 2015) at the Agricultural Research and Development Station Turda (ARDS Turda), Cluj County, Romania. We chose to study these hybrids because they are representative for this Transylvanian region and are the latest creations of the ARDS Turda. The study was necessary due to increased frequency of the meteorological phenomena, respectively late spring frost and hail, and because the hybrid seed production raises special concerns.

The pedological and climatic area where the experimental fields were placed is situated in the Transylvanian Plateau, which is located in the north-western part of Transylvania, near the city Turda. The soil is a chernozem with poor drainage. The pH_{H2O} is at 6.4, humus content is at 3.69%, total N at 0.259% and mobile K at 459 ppm. The biological material (Table 1) used was represented by parental genotypes specific for the climatic conditions of Transylvania where late spring frosts and hail are common. Plant density was 70000 plants ha^{-1}.

Table 1. The description of biological material used during this study

Code name	Parental genotype description	Used as: maternal/paternal form for commercial hybrid	Plants height
Hybrids			
HSM T 201	Maternal form of a three-way hybrid – cms C*	Maternal form of Turda 201 (semi-early hybrid)	(160-190 cm) Average (UPOV 5)
HS T Star M cms C	Maternal form of a three-way hybrid – cms C*	Maternal form of Turda Star (semi-early hybrid)	(180-200 cm) Average (UPOV 5)
HS T 200 T cms T	Paternal form of a double hybrid – cms T**	Paternal form of Turda 200 (semi-early hybrid)	(235-250 cm) High (UPOV 7)
HS T 200 M cms T	Maternal form of a double hybrid – cms T**	Maternal form of Turda 200 (semi-early hybrid)	(231-255 cm) High (UPOV 7)
Inbred lines			
LC 660	Paternal form of a three-way hybrid	Paternal form of Turda 201 (semi-early hybrid)	(132-145 cm) Average (UPOV 5)
LC 733	Paternal form of a three-way hybrid	Paternal form of Turda 165 (early hybrid)	(139-179 cm) Average High (UPOV 6-7)
LC 761 cms C	Maternal form of a single cross hybrid – cms C*	Maternal form of Turda 332 (semi-early hybrid)	(185-200 cm) High (UPOV 7)
LC A T 248	Maternal form of a single cross hybrid	Maternal form of Turda 248 (semi-early hybrid)	(183-196 cm) High (UPOV 7)
LC A T 332	Paternal form of a single cross hybrid	Paternal form Turda 332 (semi-early hybrid)	(196-215 cm) High (UPOV 8)

*Cms C – cytiplasmatic male sterility type Columbia, **Cms T cytoplasmatic male sterility type Texas

In both years, ploughing was performed in autumn. In spring, the land was processed with a cultivator. Fertilization was realized with the "Complex fertilizer NPK 27:13.5:0" (Azomureş, Romania) with 459 kg ha^{-1} in 2014 and with 400 kg ha^{-1} in 2015. Before sowing, the seeds were treated in both years with Maxim XL for diseases control and with Sedoprid 600 FS for pest control. Sowing took place on May 12th, 2014, and on April 28th, 2015. Weed management control was realized with pre-emergent herbicides, (Guardian with 2.0 l ha^{-1} in 2014 and Tender with 1.5 l ha^{-1} in 2015). In both years, the pre-emergent herbicide was incorporated with tillage equipment at 3 cm depth. However, in 2015, a post-emergent herbicide treatment was applied immediately after sowing (Glyphosate with 3.0 l ha^{-1}).

Maintenance during vegetation was performed by one mechanical hoeing and one manual hoeing in 2014. However, in 2015 two mechanical and one manual hoeing were applied. The number of plants for each experience was normalized for reaching optimal density in May of both years. Total number plants, breaking resistance (number of erect plants versus broken plants), were counted before harvest. Breaking resistance was estimated by pushing the plants in order to test the resistance to medium winds. Each plant was pushed gently from the cobs level till the plant reached the next plant in the same row. The plants that felt down were considered broken plants. By reporting the number of erect plants to total number of plants, we obtained the percent of erect plants. The harvest was performed manually on October 8th, 2014, and on September 22nd, 2015.

The studied risks were:

1. The effect of low temperatures was studied with two graduations:

- Factor A – single cross hybrids (HSM T 201, HST Star M cms C, HST 200 T) and inbred lines (LC 660, LC 733, LC 761 cms C) used as parental forms.
- Factor B – natural phenomena: 1: control; 2: simulated frost in the stage of 5-6 leaves; 3: simulated frost in the stage of 7-8 leaves. The frost was simulated by cutting the plants at the soil level.

2. The effect of hail was studied with five graduations:

- Factor A – single cross hybrids (HS T 201 M cms C, HS T Star M cms C, HS T 200 M cms T) and inbred lines (LC 761 cms C, LC A T 248, LC A T 332) used as parental forms.
- Factor B – natural phenomena: 1: control; 2: soft hail in the stage of 8-10 leaves; 3: hail of average intensity after pollination; 4: defoliation of 50% of the leaves after pollination; 5: defoliation of 80-90% of the leaves after pollination.

The soft and average hail were simulated by combing the leaves using a comb with metal needles and producing the laceration of leaves just like after hail. All the leaves were fringed with this tool, but not very strongly, resulting in average laceration of a leaf within 2-4 parts and without breaking them.

This study presents the results on the yield (kg ha^{-1}), the percent of erect plants (break resistance) (%), and hectolitre mass (the bulk density) (kg per hectoliter).

In 2014 and 2015, the parental genotypes of some hybrids (single cross hybrids and inbred lines) were studied regarding their reaction to some risk factors. The risk factors were simulating late spring frost in 5-6 leaves and 7-8 leaves stages for all the parental genotypes, and simulated hail in different stages: a soft hail in 8-10 leaves stage, an average hail after pollination, a hail of 50% "defoliation" after the pollination and a strong defoliation of 80-90% of the leaves after the pollination for all the parental genotypes studied.

The experiments were set up in randomised blocks with three replications, the number of rows per plot were two, each of them having 5 m length.

For the statistical analysis, the Analysis of Variance (ANOVA) and F-test were used.

RESULTS

In both years, the mean temperature was higher than the long-term mean temperature with higher values in 2015 than in 2014 (Table 2). We see that in 2015, temperature deviation was higher compared to 2014.

Table 2. Weather characteristics during the two experimental years
(Turda Weather Station; longitude: 23°47'; latitude 46°35'; altitude: 427 m a.s.l.)

	April	May	June	July	August	September	October
Temperature (°C)							
55 years mean (1961-2016)	9.8	14.7	17.7	19.6	19.2	14.9	9.6
2014 deviation	+1.6	+0.4	+0.8	+0.8	+0.7	+1.7	+1.2
2015 deviation	-0.2	+1.1	+1.7	+2.7	+2.7	+2.4	+0.1
Rainfall (mm)							
55 years mean (1961-2016)	44.7	67.7	84.5	76.7	55.9	40.3	32.0
2014 deviation	+27.3	-1.5	-36.1	+67.7	+27.9	+8.1	+35.4
2015 deviation	-12.5	-1.7	+31.2	-24.5	+16.3	+132.3	+13.4

In 2015 there was drought during pollination, because of lack of rainfall from July, a serious environmental limitation, which is extremely critical for corn productivity in Transylvania area.

In case of simulating spring frost, significant differences between genotypes for yield, percent of erect plants and hectolitre mass were recorded both for hybrids and inbred lines (Table 3). Both the studied phenomena and the genotypes, along with the interaction of the experimental year, significantly influenced the yield and hectolitre mass. The year and the genotype as well as the interaction between them were elements with a significant influence. The inbred lines were more influenced by the interaction of genotype and phenomena compared to the hybrids.

Table 3. Analysis of variance (F-test) for the influence of simulated late spring frost on yield, percentage of erect plants and hectolitre mass for hybrids and inbred lines (Turda, 2014-2015)

Source of variation	DOF[1]	Hybrids				Inbred lines		
		Grain yield (kg ha^{-1})	Erect plants (%)	Hectolitre mass (kg hl^{-1})		Grain yield (kg ha^{-1})	Erect plants (%)	Hectolitre mass (kg hl^{-1})
TOTAL	53							
Years (Y)	1	241^{**}	36.4^{*}	200^{**}		462^{**}	7.2	31.7^{*}
Error Y	2							
Genotype (G)	2	16.8^{**}	34.7^{**}	73.8^{**}		7.0^{**}	5.0^{*}	12.2^{*}
Y × G	2	1.2	9.7^{**}	2.9		3.0	6.7^{*}	1.8
Error G	8							
Phenomena (P)	2	87.5^{**}	2.0	25.7^{**}		219^{**}	0.6	5.9^{**}
Y × P	2	7.0^{**}	0.4	1.1		71.0^{**}	1.6	1.8
G × P	4	1.3	1.5	2.0		5.7^{**}	0.8	2.3
Y × G × P	4	2.3	1.5	0.6		1.7	0.4	0.7
Error P	24							

[1]DOF = Degree of freedom. Significant differences were at a level of $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***).

The analysis of variance for the analysed characteristics showed significant differences between the genotypes in the expression of these parameters, in case of simulating hail for both hybrids and inbred lines (Table 4). The studied phenomena and the genotype along with the interaction with the experimental years significantly influenced the yield and hectolitre mass for hybrids and inbred lines. The double interaction between year and genotype influenced inbred lines more than hybrids, while the interaction between years and phenomena had significant effects for all the three studied characteristics for both hybrids and inbred lines. In the case of the yield there was a significant difference between the triple interaction of year, genotype and phenomena for inbred lines. Regarding the inbred lines for hail phenomena, (as well as for the late spring frost), are more influenced by the interaction between year and phenomena, the interaction between genotype and phenomena and also the triple interaction between year, phenomena and genotype compared to the hybrids.

Table 4. Analysis of variance (F-test) for the influence of simulated hail on yield, percentage of erect plants and hectolitre mass for hybrids and inbred lines (Turda, 2014-2015)

Source of variation	DOF[1]	Hybrids				Inbred lines		
		Grain yield (kg ha^{-1})	Erect plants (%)	Hectolitre mass (kg hl^{-1})		Grain yield (kg ha^{-1})	Erect plants (%)	Hectolitre mass (kg hl^{-1})
TOTAL	53							
Years (Y)	1	231^{**}	689^{**}	68.1^{*}		617^{**}	192^{**}	11.2
Error Y	2							
Genotype (G)	2	13.1^{**}	1.1	78.9^{**}		123^{**}	6.0^{*}	26.6^{**}
Y × G	2	2.7	8.9^{**}	1.0		7.4	11.3^{**}	17.6^{**}
Error G	8							
Phenomena (P)	4	257^{**}	41.4^{**}	75.4^{**}		149^{**}	34.4^{**}	27.4^{**}
Y × P	4	36.2^{**}	28.0^{**}	21.2^{**}		42.4^{**}	32.8^{**}	9.4^{**}
G × P	8	2.3^{*}	4.0^{**}	7.5^{**}		5.7^{**}	2.3^{*}	2.6^{*}
Y × G × P	8	1.6	1.5	2.1		6.6^{**}	2.8^{*}	0.5
Error P	48							

[1]DOF = Degree of freedom. Significant differences were at a level of $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***).

Significant differences between the means of the control treatment and other treatments were at a level of $p<0.05$ (*), $p<0.01$ (**) and $p<0.001$ (***).

The yield, the percent of erect plants and hectolitre mass showed significant differences between the genotypes (hybrids) after late spring frost (Table 5). Late spring frost produced the biggest losses, having a significantly negative influence on the yield, and the hectolitre mass. The resistance to breaking was insignificantly affected in the case of late spring frost. From the analysed genotypes, HSM T 201 hybrid proved a high tolerance to frost while HS T 200T hybrid proved the lowest capacity of tolerance, and appeared to be more sensitive to the analysed characteristics.

Table 5. Interaction between simulated late spring frost and the hybrids for yield, erected plants and hectolitre mass (Turda, 2014-2015)

Phenomena[1]	Hybrid	Grain yield ($kg\ ha^{-1}$)		Erect plants (%)		Hectoliter mass ($kg\ hl^{-1}$)	
		Mean	% Control	Mean	% Control	Mean	% Control
1	HSM T 201	10650		69.2		63.8	
2		9418	88.4	74.8	108	62.8	98.4
3		5560	52.2**	74.3	107	58.4	91.5***
1	HS T Star M cms C	11296		79.4		58.8	
2		9015	79.8**	76.1	95.8	57.6	98.0
3		5418	48	78.8	99.2	55.5	94.4**
1	HS T 200T	10095		58.2		60.8	
2		7007	69.4***	53.9	92.6	60.9	100.2
3		2591	25.7***	66.6	114	58.7	96.6*

[1] 1: Control; simulated frost in the stage of 5-6 leaves (2) and 7-8 leaves (3).

Very significant differences were observed between the inbred lines for yield, percent of erect plants and hectolitre mass, both in the early phenophase and also in the late one (Table 6). Frost had a significantly negative influence on the yield and an insignificant influence on the breaking resistance (percent of erect plants). The line LC 761 cms C proved a high tolerance to late spring frost, while line LC 660 was the most susceptible of the analysed genotypes.

Table 6. Interaction between simulated late spring frost and analysed inbred lines for yield, erected plants and hectoliter mass (Turda, 2014-2015)

Phenomena[1]	Inbred lines	Grain yield ($kg\ ha^{-1}$)		Erect plants (%)		Hectoliter mass ($kg\ hl^{-1}$)	
		Mean	% Control	Mean	% Control	Mean	% Control
1	LC 660	4907		73.3		61.9	
2		2711	55.3***	75.5	103	53.4	86.3
3		538	11.0***	76.9	105	41.4	66.9***
1	LC 733	3809		74.7		63.3	
2		2802	73.6***	77.2	103	62.7	99.1
3		1247	32.7***	80.4	108	59.1	93.4
1	LC 761 cms C	5376		84.8		64.4	
2		4123	76.7***	84.9	100	59.9	93.0
3		2184	40.6***	82.1	96.8	61.1	94.9

[1] 1: Control; simulated frost in the stage of 5-6 leaves (2) and 7-8 leaves (3).
Significant differences between the means of the control treatment and other treatments were at a level of $p<0.001$ (***).

There were significant differences between the hybrids in yield, percent of erect plants and hectolitre mass, especially for the hail with 80-90% defoliation (phenomena 5) (Table 7). On the contrary, the soft hail in phenophase of 8-10 leaves (phenomena 2) had an insignificant influence on all analysed characteristics. Among the analysed hybrids, HS T 200 M cms T appeared to be more tolerant to hail, and the hybrid HS T Star M cms T the most sensitive to hail.

According to Dwyer et al. (1994), the decrease in dry matter and yield due to hail is correlated with the temperature indexes needed for each genotype to reach maturity. If the hail storm occured when some hybrids were at the milk stage and others were at full dent, the late-maturity hybrids were the most affected by the hail storm.

Table 7. Interaction between simulated hail and hybrids for yield, erected plants and hectoliter mass (Turda, 2014-2015)

Phenomena[1]	Hybrids	Grain yield ($kg\ ha^{-1}$)		Erect plants (%)		Hectoliter mass ($kg\ hl^{-1}$)	
		Mean	% Control	Mean	% Control	Mean	% Control
1	HS T 201 M cms C	9754		67.3		63.7	
2		9522	97.6	72.4	107.6	64.4	101.1
3		9059	92.9	66.5	98.8	64.8	101.7
4		6940	71.2***	70.7	105.1	65.3	102.5
5		3053	31.3***	48.3	71.8***	55.5	87.1***
1	HS T Star M cms C	10505		76.4		60.5	
2		10491	99.9	73.7	96.47	59.7	98.7
3		9706	92.4	71.7	93.9	60.5	100
4		7668	73.0***	66.3	86.8**	61.9	102.3
5		2859	27.2***	42.1	55.1***	56.4	93.2***
1	HS T 200 M cms T	8570		67.2		64.3	
2		9041	105.5	65.9	98.1	63.6	98.9
3		8140	95.0	69.1	102.8	63.1	98.1
4		6796	79.3***	64.7	96.3	64.1	99.7
5		3174	37.0***	55.2	82.1**	60.1	93.5***

[1] 1: Control; 2: soft hail in the stage of 8-10 leaves; 3: hail of average intensity after pollination; 4: defoliation of 50% from the leaves after pollination; 5: defoliation of 80-90% from the leaves after pollination.
Significant differences between the means of the control treatment and other treatments were at a level $p<0.01$ (**) and $p<0.001$ (***).

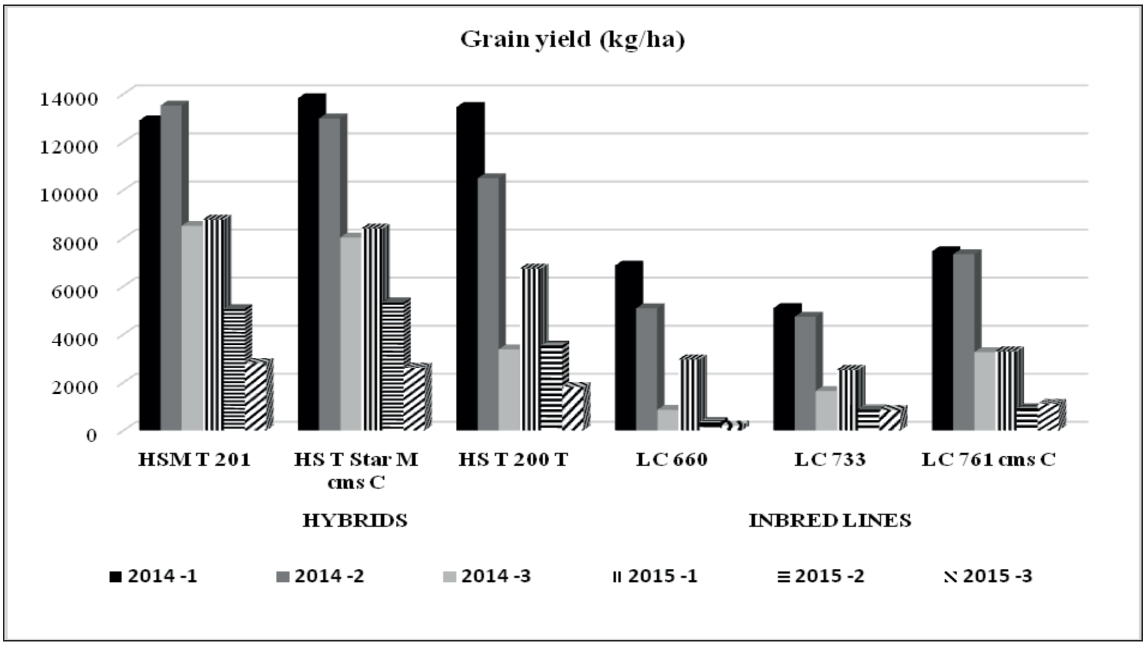
Medium to strong hail did significantly negative influence the yield, percent of erect plant and hectolitre mass of inbred lines, especially with the strongest hail with 80-90% defoliation (phenomena 5) (Table 8). On the contrary, soft hail in the 8-10 leaves phenophase (phenomena 2) had an insignificant influence for all the analysed characteristics. Among the analysed lines, the line LC A T 332 proved the best tolerance to the studied phenomena while line LC A T 248 was the most susceptible to hail.

Table 8. Interaction between simulated hail and inbred lines for yield, erected plants and hectolitre mass (Turda, 2014-2015)

Phenomena[1]	Inbred lines	Grain yield (kg ha^{-1})		Erect plants (%)		Hectoliter mass (kg hl^{-1})	
		Mean	% Control	Mean	% Control	Mean	% Control
1	LC A T 248	4456		86.4		63.9	
2		4671	104.8	82.6	95.6	63.7	99.7
3		4453	99.9	83.3	96.4	65.1	101.9
4		3434	77.1**	76.7	88.8**	65.2	102.0
5		1862	41.8***	69.7	80.7***	60.2	94.2**
1	LC A T 332	7209		83.7		63.6	
2		7095	98.4	85.3	101.9	64.7	101.7
3		6384	88.6**	82.1	98.1	64.1	100.8
4		6114	84.8***	87.2	104.2	65.9	103.6
5		2355	32.7***	66.9	79.9***	54.6	85.9***
1	LC 761 cms C	5048		84.8		59.5	
2		5151	102.0	84.2	99.3	59.5	100.0
3		5070	100.4	78.3	92.3	60.1	101.0
4		4289	84.7*	80.1	94.5	59.2	99.5
5		2108	41.8***	59.1	69.7***	54.7	91.9***

[1] 1: Control; 2: soft hail in the stage of 8-10 leaves; 3: hail of average intensity after pollination; 4: defoliation of 50% from the leaves after pollination; 5: defoliation of 80-90% from the leaves after pollination.
Significant differences between the means of the control treatment and other treatments were at a level of p<0.01 (**) and p<0.001 (***).

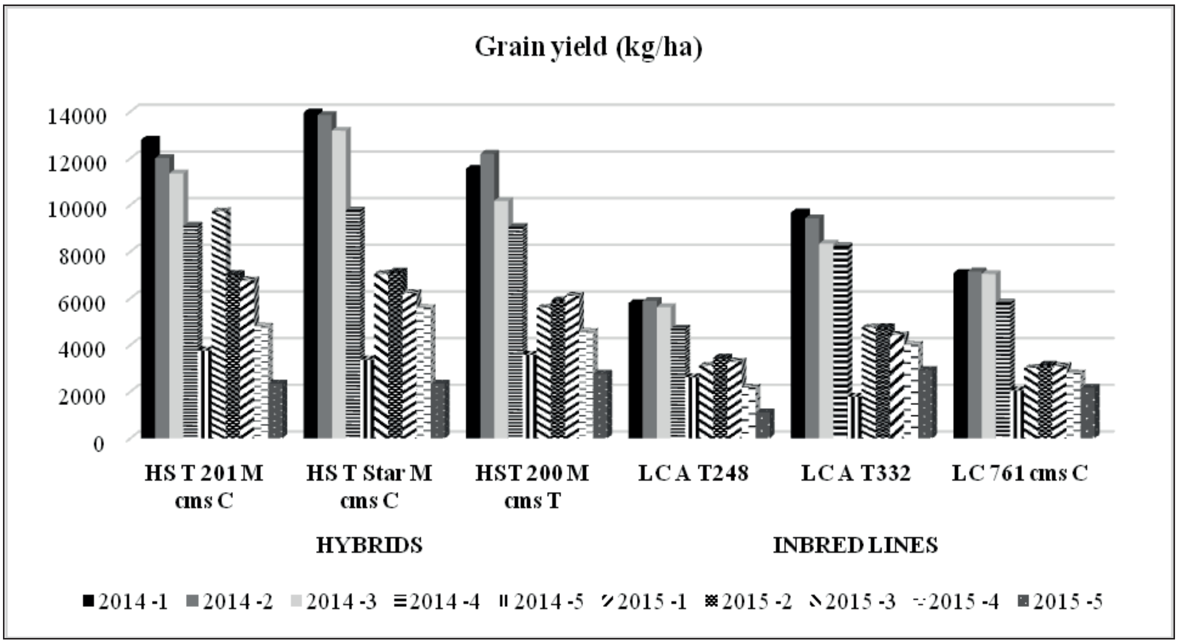
In 2014, the spring frost had no effect in the case of simulated frost in the first phenophase, when yield losses were up to 8% in hybrids and up to 12% in inbred lines, compared to the control (means over genotypes). However in 2015, the same phenomena produced a decrease of 42% for hybrids and 76% for inbred lines, compared to the control (means over genotypes). In the case of simulated frost in the stage of 8-9 leaves, late spring frost caused 71% loss in hybrids and 76% in inbred lines, compared to the control (means over genotypes) (Figure 1).



1: Control; simulated frost in the stage of 5-6 leaves (2) and 7-8 leaves (3).

Figure 1. Interaction between simulated late spring frost and hybrids or inbred lines in the years 2014 and 2015 for yield (Turda)

Simulated hail before pollination (stage 2) did not cause any yield decrease compared the control in both years, whereas defoliation of 80-90% from the leaves after pollination by simulated hail caused yield losses of 71% in hybrids and 70% in inbred lines in 2014 and 61% in hybrids and 45% for inbred lines in 2015, compared to control (means for genotypes) (Figure 2). According to Klein and Shapiro (2011) the amount of yield loss is directly related to the crop's stage of growth when the hail occurs. In corn most yield reduction due to hail damage results from a loss of photosynthetic active leaf area. The degree of yield loss depends on the crop growth stage and the amount of leaf area removed.



1: Control; 2: soft hail in the stage of 8-10 leaves; 3: hail of average intensity after pollination; 4: defoliation of 50% from the leaves after pollination; 5: defoliation of 80-90% from the leaves after pollination.

Figure 2. Interaction between simulated hail and hybrids or inbred lines in the years 2014 and 2015 for yield (Turda)

DISCUSSION

The influence of frost and hail combined with drought can affect seriously the yield of maize parental genotypes. According to Vorst (2002) extremely favourable weather during the rest of the growing season after these phenomena occur can cause actual yields to be higher than expected. Similarly, unfavourable weather can cause greater than anticipated reductions. As shown by Nielsen (2009), changes in yield and hectolitre mass are not always proportional or correlated, yield can be high when hectolitre mass is low.

Damage to maize from hail is complex and hail-induced stand reduction is often accompanied with other forms of damage to the remaining plants. Thus, the level of yield compensation provided by the undamaged remaining plants may be over-represented, when compared to that following actual hail-induced stand reduction (Coulter et al., 2011).

CONCLUSIONS

The percentage of erect plants after testing the breaking resistance before harvest was lower in a the year with more favourable growing conditions (2014) than in the year with drought during pollination (2015), as the yield was much higher in 2014 causing a higher amount of broken plants after testing.

If the simulated phenomena are combined with drought, the cumulated losses for these risk factors are much higher. If the phenomena occur in advanced phenophases, both hybrids and inbred lines respond with a lower yield and a lower hectolitre mass.

Any stress that prematurely stops or reduces corn fill and/or interferes with photosynthesis has the potential to lower yield and hectolitre mass. For inbred lines, frost has a stronger effect compared to the damage caused by hail. If the late spring frost occurs, another period of drought can reduce drastically the yield.

Late spring frost and hail in early stages produced small losses, but when these risks appear later during crop growth with higher intensity, the yield decreases significantly. Within this study, maize showed a remarkable re-growth capacity in early stages, being able to adapt to stressful weather condition.

RECOMMENDATIONS

Risk avoidance or prevention lies in taking measures to minimize the effect of these risks, including:

- Tracking the areas where the analysed risks occur and micro-zoning or location of maize crops in several plots at distances from each other, in order to avoid hail damage of the parental forms by spreading the risk.
- Giving up cultivation in some areas, especially for those genotypes that are particularly sensitive to hail or low temperatures, in conjunction with the selection of resistant plant varieties.
- Creating hybrids resistant to abiotic risk factors.
- Multiplying of the parental forms by more multipliers from different areas, to avoid the occurrence of analysed risks.

REFERENCES

Bălaş-Baconschi, C.G., Haş, I., Haş, V., Copândean, A., 2015. *Influence of some abiotic risk factors on parental forms in some registered corn hybrids.* Bulletin USAMV, series Agriculture, 72: 333-338.

Cristea, M., Căbulea, I., Sarca, T., 2004. *Porumbul, Studiu monografic*. Vol 1. Editura Academiei Române, Bucureşti: 129-135.

Cristea, M., 2013. *Rezistenţa porumbului la frig*. ANSEM, 8, 10-12.

Coulter, J.A., Nafziger, E.D., Abendroth, L.J., Thomison, P.R., Elmore, R.W., Zarnstorff, M.E., 2011. *Agronomic responses of corn to stand reduction at vegetative growth stages.* Agronomy Journal, 103: 577-583.

Dwyer, L.M., Tewart, D.W., Evenson, L., Ma, B.L., 1994. *Maize growth and yield following late summer hail.* Crop Science, 34: 1400-1403.

Egharevba, P.N., Horrocks, R.D., Zuber, M.S., 1976. *Dry matter accumulation in maize in response to defoliation.* Agronomy Journal, 68: 40-43.

Hodişan, N., Timar, A., 2010. *Materii prime vegetale – condiţionarea, păstrarea şi expertiza calităţii.* Editura Universităţii Oradea. (In Romanian)

Klein, R.N. and Shapiro, C.A., 2011. *Evaluating hail damage to corn*. University of Nebraska-Lincoln, Extension Circular, EC126.

Nielsen, R.L., 2009. *Test Weight Issues in Corn*. Corny News Network. Purdue University Dept. of Agronomy.

Robertson, A.E., Munkvold, G.P., Hurburgh, C.R., Ensley, S., 2011. *Effects of natural hail damage on ear rots, mycotoxins and grain quality characteristics of corn.* Agronomy Journal, 103: 1193-1199.

Thornton, J.H., Goodrich, R.D., Meiske, J.C., 1969. *Corn Maturity. I. Composition of Corn Grain of Various Maturities and Test Weights 1, 2.* J. Anim. Sci., 29: 977-982.

Vorst, J.V., 2002. *Assessing hail damage to corn*. Iowa State University, University Extention, NCH 1.

Womach, Jasper, 2005. *Agriculture: A Glossary of Terms, Programs, and Laws*, 2005 Edition, Washington D.C., UNT Digital Library.