RESPONSE OF TOMATO VARIETIES AND F_2 RECIPROCAL HYBRIDS TO STRESS TEMPERATURES

REACȚIA SOIURILOR ȘI HIBRIZILOR RECIPROCI F_2 DE TOMATE LA TEMPERATURI DE STRES

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Abstract.
The paper presents the results of assessing the resistance of some cultivars and 2 reciprocal F_2 hybrid combinations: Desteptarea x Flacara/Flacara x Desteptarea and Flacara x Vrojainii/Vrojainii x Flacara of tomato to stressful temperatures (41º, 43ºC). Seedlings grown at 25ºC served as a control variant. The analysis of the variability of the resistance character was carried out based on the length of the embryonic radicle, the stem, the whole seedling. In most cases, stress temperatures produced significant inhibition of growth organs. Through cluster analysis (k-means method) in the variant 41ºC, the reciprocal combinations F_2 Desteptarea x Flacara / F_2 Flacara x Desteptarea were identified, and in the case of the 43ºC temperature – Exclusiv, Prestij, Desteptarea, Flacara and F_2 Desteptarea x Flacara that formed separate clusters, with the highest values of the evaluated characters, which provides opportunities for their use in breeding programs as reliable sources of resistance. The research of the influence of stressful temperatures on the distribution of plants in phenotypic classes demonstrated that obtaining a greater number of segregates with reduced sensitivity to high temperatures is more likely in the case of the combinations F_2 Desteptarea x Flacara and F_2 Vrojainii x Flacara.
Key words: tomato, resistance, temperature, variability.

Rezumat.
În lucrare sunt prezentate rezultatele aprecierii rezistenței unor soiuri și 2 combinații hibride reciproce F_2: Deșteptarea x Flacăra/Flacăra x Deșteptarea și Flacara x Vrojainîi/Vrojainîi x Flacara de tomate la temperaturi de stres (41º, 43ºC). În calitate de martor au servit plantulele cultivate la 25ºC. Analiza variabilității caracterului de rezistență a fost efectuată în baza lungimii radiculei embrionare, tulpiniței, plantulei integrale. În majoritatea cazurilor, temperaturile de stres au produs inhibarea semnificativă a organelor de creștere. Prin analiză clusteriană (k-medii) în varianta 41ºC au fost identificate combinațiile reciproce F_2 Deșteptarea x Flacăra/F_2 Flacăra x Deșteptarea, iar în cazul temperaturii 43ºC – Exclusiv, Prestij, Deșteptarea, Flacăra și F_2 Deșteptarea x Flacăra care au format clustere separate, cu cele mai înalte valori ale caracterelor evaluate, ceea ce oferă oportunități de utilizare a acestora în programele de

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ameliorare în calitate de surse sigure de rezistență. Cercetarea influenței temperaturilor de stres asupra repartiției plantelor în clase fenotipice a demonstrat că obținerea unui număr mai mare de segreganți cu sensibilitate diminuată la temperaturi înalte este mai probabilă în cazul combinațiilor F_2 Deșteptarea x Flacăra și F_2 Vrojainîi x Flacăra.
Cuvinte-cheie: tomate, rezistență, temperatură, variabilitate.

INTRODUCTION

The challenges generated by climate change will require the implementation of new strategies to adapt the newly created varieties in a timely manner to local conditions to effectively reduce the risks of stressful temperatures [Porter *et al*., 2014; Bisbis *et al*., 2018].

The optimum temperature for growing tomatoes falls within the limits of 25-30ºC/20ºC – day/night. Although tomatoes show high adaptability to environmental conditions, stress temperatures can become a major limiting factor for plant growth, reproduction and production level [Camejo *et al*., 2005].
Increasing the temperature even by 2-4ºC above the optimal level can greatly affect reproductive organs, especially pollen viability, gamete development, pollination capacity, produce the fall of flowers and reduced fruit firmness [Firon *et al*., 2006; Ozores-Hampton *et al*., 2012]. Resistant tomato genotypes have the ability to form a much larger number of fruits than sensitive ones under stress conditions [Comlekcioglu *et al*., 2010]. So, high temperatures can cause significant productivity losses and damage to fruit quality [Ozores-Hampton *et al*., 2012; Ibukun *et al*., 2020].

The creation of resistant tomato varieties is one of the most effective strategies to control heat stress [Mihnea, 2016]. In relation to the need to create sources with sustainable resistance, special attention is paid to the interactions of tomato plants with temperature.

The aim of our research was to evaluate the influence of thermal stress on the growth and development characteristics of plants and to identify promising ones for exploitation in the breeding programs.

MATERIAL AND METHODS

As initial material for the intended research, 9 varieties were used (Pontina, Florina, Chihlimbar, Exclusiv, Prestij, Deșteptarea, Flacara, Vrojainîi, Mary Gratefully) and 2 reciprocal F_2 hybrid combinations: Desteptarea x Flacara / Flacara x Desteptarea and Flacara x Vrojainii/Vrojainii x Flacara.

Varieties and hybrid combinations were tested at 3 temperature levels: optimal – 25°C and stressful: 41°C and 43°C. The assessment of tomato samples resistance to high temperatures was carried out on the basis of the growth capacity of the embryonic radicle, stem and intact seedling for 7 days after maintaining them on day 4 at temperatures of 42° and 43°C for 6 hours [Mihnea, 2016]. Seedlings grown at 25°C served as a control.

The cluster analysis of the degree of similarity / difference of tomato genotypes based on growth and development characters at different temperatures was carried out

according to the centroid method of *k*-means, successfully used in the genetics and improvement research [Kanavi *et al*., 2020; Lupaşcu *et al*., 2019]. The obtained data were statistically processed in the STATISTICA 7 software package.

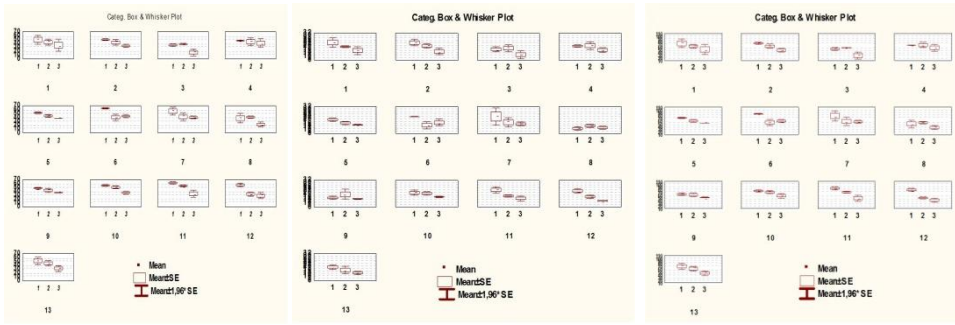
RESULTS AND DISCUSSIONS

Testing the reaction of some cultivars, reciprocal F_2 tomato hybrids at different temperature levels on the growth characteristics of tomatoes in early ontogenesis, demonstrated that the response of the plants to the 3 temperatures (25°C – optimal, 41°C and 43°C – stress) was differentiated – specific to the genotype, the hybrid, the analyzed character.

In the case of the radicle length, it was found that under optimal conditions, the root length varied within the limits of 35.6 … 61.7 mm (Fig. 1 A), and at the temperature of 41°C – 33.2 … 50.6 mm (Fig. 1 B).

The degree of growth inhibition for the studied forms varied in the range -5.1 … -41.6 (compared to optimal conditions). A strong inhibition was found in the Desteptarea variety (-36.6%) and the F_2 Flacara x Vrojainii hybrid (-41.6).

Stimulation was attested to the varieties Chihlimbar (+7.6%) and Vrojainii (+6.6%). A relatively low inhibition was found in the varieties Prestij (-5.1%), Mary Gratefully (-10.5%) and the hybrid combination F_2 Desteptarea x Flacara (-8.2%). Under the influence of temperature 43°C, a significant inhibition of radicle growth was observed in most of the F_2 cultivars/hybrids studied: -13.3 … -52.5%. Weak sensitivity was found in Exclusiv and Mary Gratefully cultivars (Fig. 1 C).



A B C

Fig. 1. The influence of temperature on the length of radicle (A), stem (B) and seedling (C) of tomato
***Horizontally*: 1 – Control (25°C), 2 – 41°C, 3 – 43°C**

1 – Pontina, 2 – Florina, 3 – Chihlimbar, 4 – Exclusiv, 5 – Prestij, 6 – Desteptarea, 7 – Flacara 8 – Vrojainîi, 9 – Mary Gratefully, 10 – F_2 Desteptarea x Flacara, 11 – F_2 Flacara x Deșteptarea,12 – F_2 Flacara x Vrojainii, 13 – F_2 Vrojainîi, x Flacara

The length of the stem in the control variant varied between 11.0 … 23.0 mm (Fig. 1 A). Under the influence of stress temperatures, the genotypes showed a

rather differentiated reaction and a high character variability: in 21 cases there was inhibition (-3.0 … -44.5%), and in 4 cases – growth stimulation stems at a temperature of 41°C in the Chihlimbar, Exclusiv, Vrojainii, Mary Gratefully varieties: + 6.7, +1.0, +22.7 +23.5%, respectively. At the temperature of 43°C, there was a 5.4% stimulation in the Vrojainii variety.

Regarding the seedling length, its reduction compared to the control varied between 0.02 … 37.2% at 41°C, and 15.0 … 47.4% – at 43°C. At the same time, the temperature of 41°C most strongly influenced the genotypes Chihlimbar (-36.4%), F_2 Flacăra x Deșteptarea (-37.2). At the temperature of 43°C, the inhibition was greater than 40.0% at varieties Chihlimbar, F_2 Flacara x Deșteptarea, F_2 Flacara x Vrojainii (Fig. 1 C).

The evaluation of tomato genotypes based on three test parameters demonstrated that the Exclusiv variety showed complex resistance to stress, the resistance falling within the limits of 80.6 … 101.0. Florina, Prestij, Flacara, Mary Gratefully, F_2 Desteptarea x Flacara, F_2 Vrojainii x Flacara proved to be resistant. They are of interest as sources of heat resistance and can be included in prospective breeding activity.

Classification of the genotypes by the centroid method of *k*-means based on the 3 characters, revealed that in the control variant cluster 1 met 4 genotypes – 6, 7, 11, 12, with the highest values of the analyzed characters: radicle length – 59.50 mm, stem length – 22.25 mm, plant length 81.75 mm; cluster 2: 7 genotypes – 1, 2, 4, 5, 9, 10, 13, with average values of the analyzed characters: radicle length – 37.4% mm, stem length – 22.7 mm and seedling length 70.3, respectively; cluster 3: 2 genotypes – 3, 8, with the lowest values.

In the 41ºC variant, hybrids 10, 11 (cluster 2), and the 43ºC variant, genotypes/hybrid – 4, 5, 6, 7, 10 (cluster 3) they recorded the highest values of the evaluated characters. It should be noted that the stem length slightly differs between the clusters in both variants (Table 1), which denotes that this character showed a weaker discriminating capacity compared to the other two characters.

Table 1

Descriptive cluster analysis

Cluster	Caracter	*Control (25°C)*		*Temperature 41°C*		*Temperature 43°C*	
		Average	**Genotype**	**Average**	**Genotype**	**Average**	**Genotype**
1	Legth of the radicle, mm	59.50	6, 7, 11, 12	43.51	1, 2, 4, 5, 7, 9, 13	19.15	3, 8
	Legth of the stem, mm	22.25		18.00		11.45	
	The seedling length, mm	81.75		61.83		32.00	
2	Legth of the radicle, mm	50.46	1, 2, 4, 5, 9, 10, 13	52.40	10, 11	33.58	1, 2, 9, 11, 12, 13
	Legth of the stem, mm	19.83		18.10		13.92	
	The seedling length, mm	70.30		70.45		47.47	
3	Legth of the radicle, mm	36.75	3, 8	38.025	3, 6, 8, 12	39.56	4, 5, 6, 7, 10
	Legth of the stem, mm	13.70		15.30		15.60	
	The seedling length, mm	50.40		53.30		56.34	

The influence of the temperature factor on the distribution of plants in phenotypic classes in the segregating populations was analyzed based on the reciprocal hybrids F_2 Desteptarea x Flacara, F_2 Flacara x Vrojainii (Fig. 2-4).

In optimal conditions, in the combination Desteptarea x Flacara the maximum distribution frequencies were located in the phenotypic class 50-60 mm (26%), then at F_2 Flacara x Desteptarea – in the class 60-70 mm class (23%).

Regarding the reciprocal combination F_2 Flacara x Vrojainii/ F_2 Vrojainii x Flacara, the maximum of the distribution of frequencies in both combinations was represented by the phenotypic class 50-60 mm, being 27 and 24%, respectively (Fig. 2).

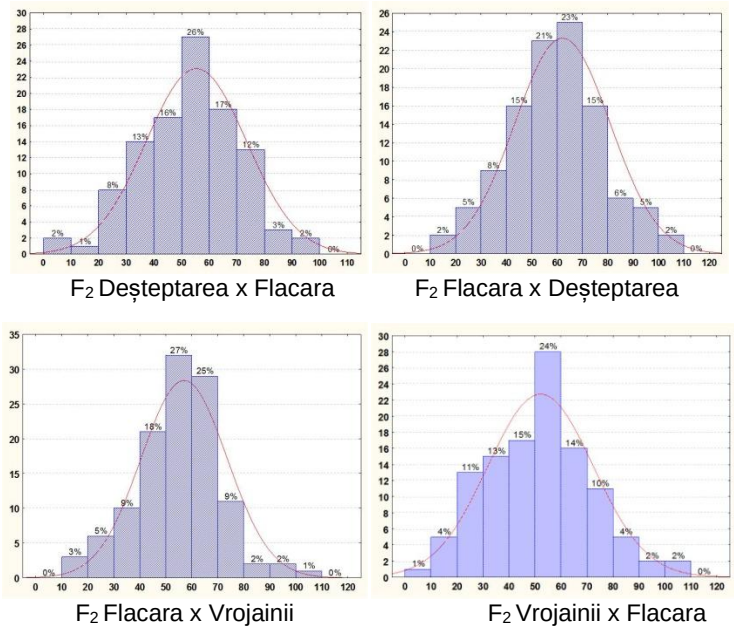


Fig. 2. Distribution histograms of tomato plants based on radicle length in reciprocal segregating populations F_2 under optimal conditions (25 ºC)
Vertically: the number of seedlings, horizontally: phenotypic classes (mm)

By researching the influence of the 41ºC temperature on the distribution of plants in phenotypic classes in the segregating populations F_2 Desteptarea x Flacara / F_2 Flacara x Desteptarea and F_2 Vrojainii x Flacara / Flacara x Vrojainii, it was found that the peak of the distribution of values differed greatly between both pairs of reciprocal hybrids (Fig. 3).

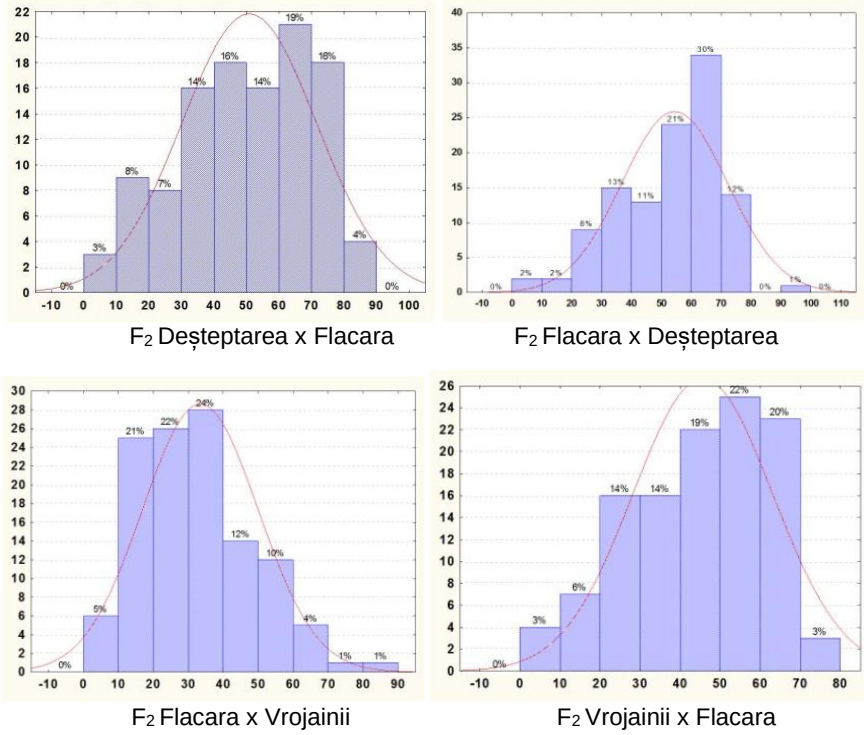


Fig. 3. Distribution histograms of tomato plants based on radicle length in reciprocal segregating populations F_2 under stressful temperature (41°C)
Vertically: the number of seedlings, horizontally: phenotypic classes (mm)

Regarding the temperature of 43°C, it can be seen that in the combinations F_2 Flacara x Desteptarea and F_2 Flacara x Vrojainii the maximum of the frequency distribution compared to the optimal conditions was shifted to the left, while in the combinations in which the variety was used as the paternal form Flacara, the rate of plants that developed relatively long embryonic radicle (40-80 mm) was much higher than in their counterparts (Fig. 4).

So, obtaining a larger number of segregants with reduced sensitivity to high temperatures is more likely when using the F_2 Flacara x Deșteptarea and F_2 Flacara x Vrojainii combinations.

As can be seen from the distribution histograms, the phenotypic classes based on the radicle length in early ontogeny in the reciprocal F_2 populations were influenced by the temperature level and the parental factor selected as the hybridization component.

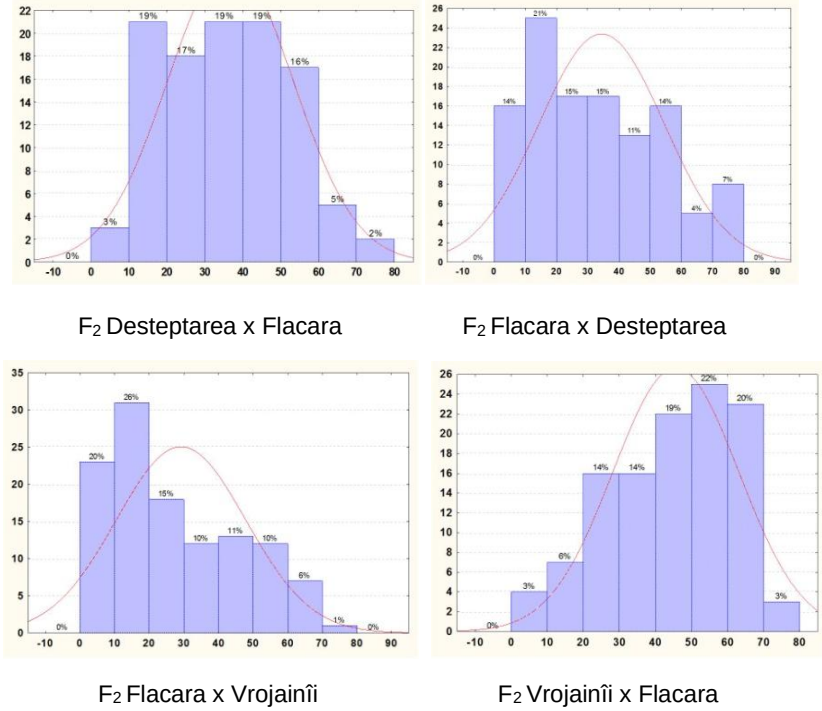


Fig. 4. Distribution histograms of tomato plants based on radicle length in reciprocal segregating populations F_2 under stressful conditions (43°C)
Vertically: the number of seedlings, horizontally: phenotypic classes (mm)

CONCLUSIONS

The analysis of the growth characteristics – of the radicle, the stem, the seedling in the varieties and reciprocal combinations, at different temperature levels highlighted the differentiated character of their reaction to limiting temperatures. In the most cases, stressful temperatures produced a significant inhibition of growth organs in tomato.

Through cluster analysis (*k*-means method), the most resistant genotypes/hybrids were identified at 41°C – F_2 Deșteptarea x Flacara / F_2 Flacara x Deșteptarea and at temperature 43 °C – Exclusiv, Prestij, Deșteptarea, Flacara and F_2 Deșteptarea x Flacara with the highest values of the evaluated characters, which provides opportunities for their use in breeding programs as reliable sources of resistance.

The research of the influence of stressful temperatures on the distribution of plants in phenotypic classes demonstrated that obtaining a greater number of segregates with reduced sensitivity to high temperatures is more likely in the case of the combinations F_2 Deșteptarea x Flacara and F_2 Vrojainii x Flacara.

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