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HERITABILITY OF THE TOMATO GENOTYPES RESISTANCE TO THE HIGH AIR TEMPERATURES

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Abstract

Since the resistance of plants to stressful temperatures is a quantitatively controlled polygenetic feature, the manifestation and particularities of its inheritance in the system of the other quantitative characters, which usually have correlative relationships, are of interest. The aim of the research was to evaluate the heritability of the tomato genotypes resistance to the heat and to highlight the most prospects for use in breeding programs. Based on the growth capacity of the P1 and F1 hybrids, at optimal (25ºC) and high temperature (43ºC), it was found that at the sporophytic level, the resistance of tomatoes at high temperature is controlled by dominant factors, with varying degrees of expression and orientation (+/-) that most directly depend on the hybridization components. By calculating the multiple regression coefficient β regarding the contribution of the maternal and paternal form in the formation of the resistance of high temperature tomato hybrids F1 (+ 43°C), it was found that the analyzed parameter for the maternal parent is ~ 2 times higher than that of the paternal form, which reveals that resistance to heat stress in the case of tomato sporofite is inherited in particular by the maternal way.

Key words: *tomato, heritability, resistance, high temperature.*

INTRODUCTION

Lately, the effects of high temperature, known as thermal shock, exceed the specific level of normal temperature for agricultural plant species, including tomatoes, for which reason they have become a topical topic for fundamental and applied research (Hazra et al., 2007; Mihnea et al., 2011).

More and more obvious and alarming climate changes in the world, which frequently cause decline at crop yields, including tomatoes, have led to increased efforts to increase resistance in the breeding programs (Hazra P. et al., 2007). Although the tomatoes exhibit a high adaptability to environmental conditions, the heat stress can become a major limiting factor for the growth, reproduction and plant production level, the optimal temperature for cultivation of tomatoes being framed within the limits of 25-30ºC/20ºC - day/night (Camejo et al., 2005).

Most crop plants are subject to high temperature stress (HTS) at certain stages of development, this phenomenon being more and more frequently lately (Sato et al., 2000). Plant exposured to HTS reduces harvesting and its quality at many crop plants, including leguminous crops (Boote et al., 2005).

According to some opinions, heat stress can also be considered as the temperature level of 28-29°C which is only a few degrees higher than the optimal range of 21-24°C. Increasing the temperature to such a level does not lead to severe disturbances of the biochemical reactions in the plant that would affect the cell's functionality, the plants still developing normally, but the reduction in the number of fruits is the general response to this factor, the main cause being the various distortions of the reproductive processes.

The high temperature (32/26ºC - day/night), and in particular its association with drought, greatly affects the growth, development and productivity of tomatoes. This situation requires the orientation of tomato improvement programs towards the creation of heat-tolerant varieties (Venema et al., 2005; Hazra et al., 2007). Increasing the temperature even at 2-4ºC above the optimal level negatively influences the development of gametes and inhibits the ability of pollinated flowers to form fruit, thus significantly reducing the yield (Firon et al., 2006).

At higher temperatures - than 35°C, germination, flowering, meiotic processes, large fruit formation, egg development, its viability, and embryo development (Wahid et al., 2007) are affected to the majority of tomato varieties, and resistant tomato genotypes have the ability to form a much greater number of fruits than those sensitive under these conditions (Comlekcioglu et al., 2010).

MATERIALS AND METHODS

As a research material they have served varieties of different ecological and geographical origin and their F_1 hybrids.
High temperature reaction testing was carried out according to the method proposed by Ivakin (1979), based on plant growth capacity after maintaining it at elevated temperatures for 6 hours. For the analysis of the high temperature influence on the germination and the length of the plants, the thermal level of 43^0C was used. According to the method, between the resistance of the sporophyte and the tomato gametophyte there is a positive correlation.
The degree of domination (h_p) was calculated based on the formula (Briubeiker, 1966):
$h_p = F_1 - 0.5\ (P_1+P_2)/\ H_p - 0.5\ (P_1+P_2)$, in which: F_1 - the mean value of the character in the F_1 generation; P_1, P_2 - the mean value of the character in the parental forms; H_p - average value of character rated at best parental component.
Clusterian analyzes were performed by constructing dendrograms based on the Ward method and the *k*-means method (Savary et al., 2010). In the *k*-means method, 3 clusters were programmed after the possible values of the characters: small, medium and high. The main purpose of these procedures is to find the similarities and differences between objects (genotypes) according to the parameters used and their distribution in groups so that objects in the same group are similar and those in different groups - special.
Multiple regression analysis. The overall importance of this analysis is to elucidate the links between several (or more) independent variables and a dependent variable. Independent variables can correlate with each other and this is to be taken into account when determining regression coefficients to avoid misinterpretations caused by false correlations. The mathematical equation of multiple regression is as follows:

$$y = \beta_1 \bullet x_1 + \beta_2 \bullet x_2 + \ldots + \beta_n \bullet x_n + a,$$

where: *y* - dependent variable; *β* - the regression coefficient for each independent variable (x_1, $x_2 \ldots x_n$); a - constant.
After evaluating criterion (test) F, it is important to estimate the regression coefficient *β* which can be positive or negative, significant or insignificant. If the *β* coefficient is positive, it can be interpreted that for each increase of the predictor variable with 1 unit, the increase of the dependent variable will be equal to the value of the non-standardized coefficient *β* (Nathans et al., 2012).
The data obtained were statistically processed in the software package STATISTICA 7.

RESULTS AND DISCUSSIONS

One of the basic genetic indices that demonstrates the type of inheritance in F_1 generations is the degree of domination (h_p). To obtain F_1 hybrids, crossbreeds were made between parental forms with varying degrees of resistance / sensitivity to high temperatures.
The obtained data on the reaction of high-temperature hybrids of tomato populations show that hybrid combinations F_1 have values that show increased resistance of the obtained hybrids compared to the genitors, in some combinations the F_1 values are lower than the average of the parents. The analysis of the genitors and F_1 hybrids resistance at t = 42-43^0C showed a considerable variability of the studied character: 23.6 ... 56.0% (Table 1).
The degree of resistance of high temperature plants was high to the hybrids F_1: Visas x Sunmark, Katerina x Sunmark, A 90/7 x Gusar, Katerina x Danna, the values of which constituted 57.5, 53.6, 52.6, 52.2%, respectively.

Table 1. Heritability of the resistance/sensitivity of tomato genotypes at high temperature at the juvenile plant level

Nr.	Combination	Resistance of the plant to t=43^{0}C, %			
		P_1	P_2	F_1	h_p
1.	Onix x Saladette	28.9	31.3	33.6	2.92
2.	Katerina x Burnley Metro	41.8	38.1	35.5	-2.31
3.	A 90/7 x Gusar	38.6	20.4	52.6	2.54
4.	Narvic x Zastava	34.3	56.0	39.4	-0.53
5.	Cal J THM x Saladette	28.1	31.3	42.7	8.12
6.	Katerina x Zastava	41.8	56.0	49.6	0.09
7.	Nistru x Onix	30.9	28.9	40.9	11.0
8.	A 90/7 x Kredo	38.6	35.3	46.9	5.9
9.	Viza x Burnley Metro	38.5	38.1	23.6	-73.5
10.	Katerina x Danna	41.8	40.0	52.2	12.5
11.	Katerina x Sunmark	38.6	47.2	53.6	2.5
12.	A 90/7 x Costral	30.9	31.3	46.2	75.5
13.	Nistru x Saladette	38.5	64.0	46.4	-0.37
14.	Viza x Sunmark	41.8	64.0	57.5	-0.4

The appreciation of the high temperature influence on the growth of tomato plants has revealed considerable variability in both parental and hybrid combinations ranging from 2.2 ... 5.5 cm and 2.4 ... 5.8 cm, respectively (Figure 1).

At high temperatures, F_1 hybrids showed advanced positive resistance compared to the best genitor at the combinations: Onix x Saladette, A 90/7 x Gusar, Cal J THM x Saladette, A 90/7 x Kredo, Katerina x Danna, A 90/7 x Costral, Nistru x Onix.

The values of the h_p coefficient for the length of the plantlets reveal the overdominance of the resistance to 11 combinations: Onix x Saladette, Katerina x Burnley Metro, Narvic x Zastava, Cal J THM x Saladette, Katerina x Zastava, Nistru x Onix, A 90/7 x Kredo, A 90/7 x Credo, A 90/7 x Costral, Katerina x Sunmark, Nistru x Saladette, of the 14 studied. Dominance of sensitivity was recorded at the A 90/7 x Gusar combinations, and the intermediate sensitivity inheritance at Viza x Burnley Metro.

Considering that the phenomenon of overdominance is not inherited (because it is a result of allelic interactions), we can deduce that in the descendants of the combinations in which F_1 manifested resistance much higher than that of the best parent, more probably will not be found genotypes with this level of character manifestation.

The success of the selections will be determined only by the possibility of identifying homozygous resistance forms.

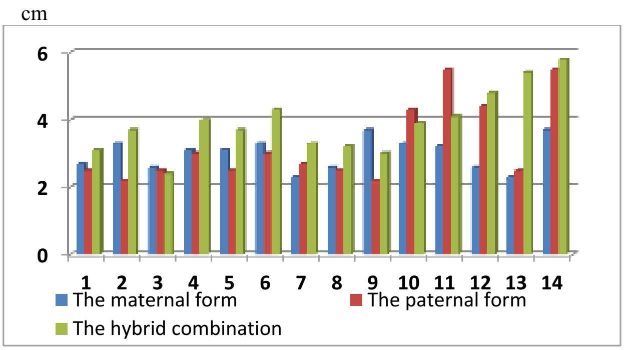
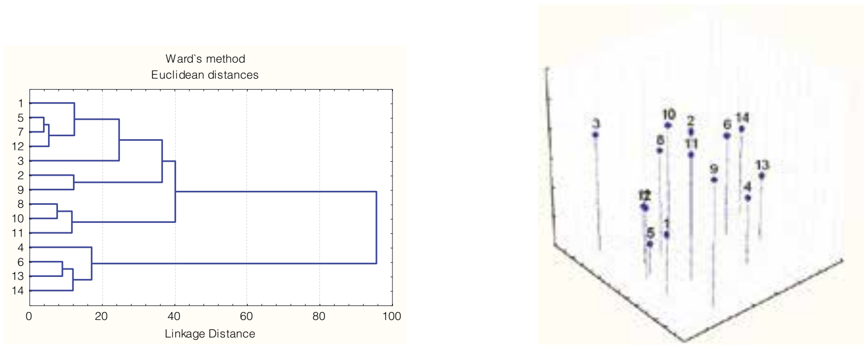


Figure 1. Comparative data of growing parental formulas and F_1 hybrids at high temperature (43°C):
1 - Onix x Saladette; 2 - Katerina x Burnley Metrou; 3 - A 90/7 x Gusar; 4 - Narvic x Zastava; 5 - Cal J THM x Saladette; 6 - Katerina x Zastava; 7 - Nistru x Onix; 8 - A 90/7 x Kredo; 9 - Viza x Burnley Metrou; 10 - Katerina x Danna; 11 - Katerina x Sunmarк; 12 - A 90/7 x Costral; 13 - Nistru x Saladette; 14 - Viza x Sunmark

By cluster analysis (A) and multidimensional scaling (B), it was found that the investigated combinations differ greatly from the reaction of plantlets at + 43°C, forming clusters at different levels of aggregation or different location in the three-dimensional space (Figure 2).



Germination *Length of radicle, mm*

Figure 2. The dendrogram for the distribution of tomato combinations based on the reaction of parent plants (P_1, P_2) and high temperature hybrids F_1

The *k*-means clustering analysis of the combinations studied (based on the parental and hybrid F_1 reactions) in 3 clusters according to the possible values of the length of the plantula - large, medium, small, highlighted that the greatest differentiation capacity they showed the paternal form of the combination (Table 2, Figure 3).

Thus, the intercluster variance determined by the parental form (P_2) recorded the highest value: 2149.821.

Table 2. Analysis of cluster variance

Genotype	Intercluster variance	df	Intracluster variance	df	F	p
P_1	210.959	2	118.196	11	9.817	0.0004
P_2	2149.821	2	295.512	11	40.012	0.0001
F_1	221.282	2	872.150	11	1.396	0.2883

*- $p \leq 0,05$.

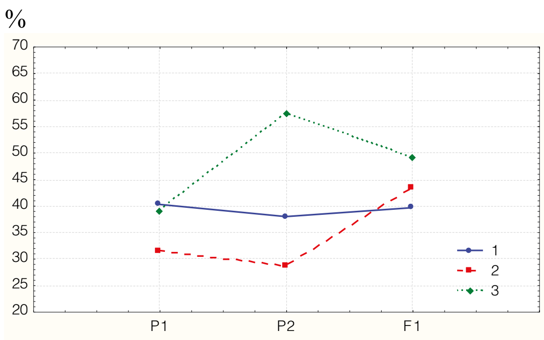


Figure 3. The ability to differentiate clusters (*k*-means method) by parental forms and tomato hybrid F_1

It should be noted that by calculating the multiple regression β coefficient regarding of the maternal and paternal form contribution in the formation of the phenotype of hybrid F_1 plants, the following regression equation was found: $y = 0.289\ P_1 + 0.139\ P_2$, in which: y - hybrid F_1; P_1 - maternal form; P_2 - paternal form. As it can be seen, the β coefficient in the case of the maternal is ~ 2 times higher than that of the paternal parent, which shows that the high temperature resistance in tomato plants is inherited in particular by the mother.

CONCLUSIONS

Based on the growth capacity of the P_1 and F_1 hybrids, at optimal temperature (25ºC) and high (43ºC), it was found that at the sporophytic level, the resistance of tomatoes at high temperature is controlled by dominant factors, with degrees variation of expression and orientation (+/-) that most directly depend on the hybridization components.

By calculating the multiple regression coefficient β regarding of the maternal and paternal form contribution in the resistance of high temperature tomato hybrids F_1 (+ 43ºC), it was found that the parameter analyzed for the maternal parent is ~ 2 times higher than the paternal parent, which reveals that the level of resistance of the maternal form as a hybridization component has to be taken into consideration in the elaboration of tomato improvement programs, especially the resistance to high temperatures.

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