Studii şi Cercetări Ştiinţifice. Biologie 2025, 34 (1), 63-69
Scientific Study & Research. Biology
Print ISSN 1224-919X Online ISSN 2457-5178

DEGREE OF DOMINANCE AND EFFECT OF HETEROSIS BY ECONOMICALLY VALUABLE TRAITS IN F_1 TOMATO HYBRIDS WITH MUTANT MARKER GENES

Milania MAKOVEI*

Moldova State University, Institute of Genetics, Physiology and Plant Protection Chisinau, Republic of Moldova

KEY WORDS
Tomato,
F_1 hybrids,
Mutant marker genes,
Inheritance,
Heterosis effect,
Economically valuable traits

ABSTRACT
The article presents the features of inheritance of the main economically valuable traits of F_1 tomato hybrids and the manifestation of heterosis effect on them in combinations from crossing mutant, semi-mutant forms with genotypes of cultural type. The ambiguous influence of mutant marker genes on the character of inheritance of traits and manifestation of heterosis effect on them is shown. The F_1 hybrids (*rin, nor, Ln,* Wo^m) inherited components and subcomponents of productivity, total yield and fruit marketability with simultaneous manifestation of high heterosis effect on them by the type of positive and overdominance. The trait "duration of vegetation period" was inherited by the intermediate type. Negative dominance and overdominance of the main economically valuable traits are observed in combinations with sterility genes (*ps-2* and *ps*), including pollen quality and its response to high and low temperatures. The highest heterosis effect on all studied traits is observed in combinations of intermutant F_1 hybrids. F_1 hybrids were identified: L186(*rin*) × Mo 835(*Ln*); L8/234(*nor*) × Mo 835(*Ln*); L201(*nor*) × Mo341(Wo^m) with stable high heterosis effect on productivity subcomponents, total yield, fruit marketability, with high adaptive potential to the action of high and low temperature stress factors in three different years of research (2020-2022).

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an economically important and widely cultivated vegetable crop in the Republic of Moldova. Due to its nutritional, technological and flavor advantages, tomato can be classified as a crop that contributes to the conservation of the gene pool and health of the nation. However, global climate change, including in Moldova, where every 2nd year there is a severe drought, leads to intensification of its genetic erosion. As a result, it is a decrease in the adaptability of modern varieties and F_1 hybrids of tomato in relation to biotic, abiotic and anthropogenic stresses, as well as in the level of productivity and its quality. This necessitates a more active search for and involvement in the breeding process of new sources of germoplasm with more pronounced genetic divergence. Of particular interest in this regard are mutations obtained by different methods (Stubbe, 1966; Zhucenco, 1973; Rich, 1986). In recent years, they have become the object of close attention of scientists from different countries (Avdeev, 2014; Kuzeminskii, 2004; Makovei, 2022) and are used for genetic improvement of the existing varietal diversity and obtaining new tomato forms with an unusual combination of mutant marker traits with the main economically valuable ones. Mutant forms of tomato crossed with other biotypes in the process of splitting lead to the expansion of the spectrum of recombination transgressive variability in F_2 populations, which makes it possible to obtain genotypes with an unusual combination of traits and their stable manifestation in the following generations F_3, F_4, etc. They are basic objects for the creation of tomato lines homozygous for certain mutant marker genes and are also of particular interest as sources of resistance to abiotic stress factors (Makovei, 2022; 2023). Mutant forms when crossed with conventional varieties and lines often show heterosis effect in productivity, early maturity and fruit quality

* Corresponding author: Makovei M.
E-mail address: milania.makovei@igfpp.usm.md
https://doi.org/10.29081/scsb.2025.34.1.07

(Avdeev, 2014), which is due to the presence of recessive genes (Singh at el., 2002). Heterozygous organisms have not only the traits of parental forms, but also new traits that were not present in the original components. On the question of the manifestation of economically valuable traits in F_1, the opinions of researchers are quite contradictory, both with regard to the degree of dominance and the direction of dominance. It depends on both hybrid combination and ecological conditions in the area of plant cultivation. It should also be noted that heterosis, as the phenomenon of superiority of a hybrid over parental forms for specific traits, cannot be predicted in advance (Dowker, 1983). Heterosis is manifested in specific hybrid combinations and is affected by environmental factors (Khotyleva at el., 2016). Despite the lack of a unified theory revealing the mechanism of heterosis, the creation of F_1 hybrids is the most priority direction of breeding and genetic research not only in tomato, but also in other agricultural crops. This is primarily due to the fact that F_1 hybrids are more productive and ecologically plastic. In hybrids it is easier to combine the desired set of traits. The success of their creation depends to a large extent on a scientifically justified choice of source material. Our research in this regard is quite interesting and original with a large share of novelty. Heterozygous F_1 populations are obtained using genotypes carrying mutant genes that control traits valuable not only from the economic point of view, but also give the plant a high degree of decorativeness with incredibly beautiful and different in color and shape fruits.
Purpose of the research: To study the inheritance of the main economically valuable traits by F_1 hybrids obtained using mutant and semi-mutant tomato lines with marker genes and the manifestation of the effect of heterosis on them in the offspring of the first generation.

MATERIALS AND METHODS

The source material for research was 8 hybrid combinations of tomato F_1 obtained using mutant forms of Mo 835 (*Ln – Lanata*), Mo 341 (*Wo^m – Wooly*), homozygous for *rin* (*ripening inhibitor)* and *nor (non ripening)* genes lines – L 186, L 8/234, L 201 and high-tech tomato varieties of own selection Stefani, Fakel, MaKrista. The work was carried out in several stages: selection of donors and genetic sources of the most important traits by studying their general and specific combinatory ability (Khotyleva at el., 2016); carrying out crosses; studying the inheritance of the main economically valuable traits by F_1 hybrids (Zhuchenco, 1973); determining the effect of heterosis on them (Ganeva at el., 2015). The degree of phenotypic expression of mutant genes in F_1 hybrids controlling marker traits was determined using the nomenclature of genes and their classification (Zhuchenco, 1973). Plants were grown in the greenhouse of the experimental site of the Institute of Genetics, Physiology and Plant Protection in three different climatic years (2020-2022), in 10 m^2 plots of 40 plants from each hybrid combination (Orzan at el., 1989). Quantitative indices of such traits as: type of plant growth, inflorescence type, number of flowers on plants, number of fruit set, fruit weight, pericarp thickness, total yield, fruit marketability and length of the growing season were taken into account. Phenological observations, morphological description and biometry of the main plant parameters of F_1 hybrids were carried out following the recommendations of UPOV (16). Under laboratory conditions, parental forms and their F_1 hybrids were tested for tolerance to high and low temperatures using artificially modeled stress backgrounds (Makovei, 2018). For this purpose, pollen from experimental tomato genotypes was studied and collected in the morning from fully opened flowers. Fresh pollen from each sample was divided into 3 parts, one of which was immediately sown on artificial nutrient medium consisting of 15% sucrose and 0.006% boric acid and germinated under in vitro conditions, for 3 h at 25°C. Pollen viability-germination (*p*, %) and pollen tube length (*l*, µm) in ocular-micrometer divisions were determined; this served as a control (K). The second part of pollen was used to assess heat resistance by treating it at 45°C for 8 hours, followed by germination for 3 hours. Viability (*p*, %) was then determined and pollen tube length (*l*, µm) was measured. The cold tolerance of F_1 hybrids and their parental forms was determined by sowing the third part of pollen on nutrient medium, which was germinated in a cold-thermostat (HT - 3/70) at +6°C for 24 hours. At the end of the time exposure (24 h), its viability (*p*, %) and pollen tube length (*l*, µm) were determined. For each F_1 hybrid and in each study variant, at least 500 pollen grains were evaluated. All pollen preparations were viewed under a Zeiss light microscope. Stability was judged by the ratio of pollen parameters in the experiments (O) to the control (K).

$$P = O : K \times 100\%$$

Genetic and statistical analysis of the studied quantitative traits allows determining the degree of genetic stability of relative each trait, individually for each F_1 combination depending on the characteristics of the original parental forms and conditions of plant cultivation.

RESULTS AND DISCUSSION

Dominance is the predominance in the offspring of a trait of one parent or the suppression in hybrids of some traits by others. For quantitative traits, the degree of dominance indicates how many times the value of a particular trait exceeds in F_1 the average value of its parental forms or the value of the best parent. The degree of dominance can take a value from minus – ∞ to + ∞ (Zhucenco, 1973). It is assumed that dominant genes have an additive, or summative effect on many quantitative traits for which heterosis is manifested. Therefore, the more loci with dominant favorable genes a hybrid has, the more powerful its development will be.

Degree of dominance and heterosis effect in F_1 tomato hybrids by components and subcomponents of productivity (1 group of traits)

Components and subcomponents of productivity are traits, the nature of which manifestation determines the value and quality of yield of F_1 hybrids obtained in crosses with mutant and semi-mutant forms of tomato. The quantitative value of these traits will allow us to obtain information about the mechanism of their formation in the first-generation offspring. Indicators of the degree of dominance and heterosis effect will allow us to identify F_1 hybrids with the maximum value of the main economically valuable quantitative traits and their successful combination in different hybrid combinations depending on the genotypic features of the original parental forms used in crosses. Positive and overdominance in the number of flowers per plant, fruit set, fruit weight and pericarp thickness was found in combinations of F_1 hybrids L 186 × Mo 835, Stefani × Mo 835 and L 8/234 × Mo 835 with the mutant line Mo 835(*Ln*) and homozygous for the genes *rin* (L186) and *nor* (L 8/234), as well as varieties Stefani and MaKrista. In these combinations, a high effect of heterosis on these traits was also observed (Table 1). This indicates the absence of a negative influence of such a combination of mutant genes, carried by their parental forms, on the manifestation of these traits in the descendants of the first generation F_1.
A somewhat different character of traits manifestation is observed in the combination of F_1 hybrid - L 33/16(*ps-2*) × Mo 835 (*Ln*), where the maternal form (L33/16 *ps-2*) is characterized by a high degree of flower sterility (from 57 to 81%). In this F_1 combination, intermediate inheritance of all traits was observed (Table 1), indicating additive action of genes in this combination. Heterosis effect is not observed, the indices of the studied traits are at the level of the average index of their parental forms. Similarly, stable character of traits manifestation is observed in three different years of research (2020-2022).
The analysis of the second group of hybrids with the mutant line Mo 341(Wo^m) also showed a different character of manifestation of traits, which is determined by the features of their parental forms.

Table 1. Degree of dominance (hp) and heterosis effect (X) by components and subcomponents of productivity in F_1 tomato hybrids obtained in crosses with mutant forms

Hybrid combinations F_1	Number of flowers per plant		Fruit set		Fruit weight		Pericarp thickness	
	hp	X	hp	X	hp	X	hp	X
	1 group of combinations: indeterminate × indeterminate							
L 186 (*rin*) × Mo 835 (*Ln*)	+ 1,36	163	+ 2,1	247	+ 1,61	172	+ 1,47	177
Stefani × Mo 835 (*Ln*)	+ 1,06	146	+ 1,27	204	+ 2,3	201	+ 1,52	136
L 8/234 (*nor*) × Mo 835 (*Ln*)	+ 1,71	240	+ 1,74	222	+ 2,0	216	+ 1,67	192
L 33/16(*ps-2*) × Mo 835 (*Ln*)	+ 0,24	96,6	+ 0,41	96,4	+ 0,15	97,5	+ 0,30	96,4
	2 group of combinations: determinate × determinate							
L 45/16 (*ps*) × Mo 341 (Wo^m)	- 3,1	87,6	- 1,2	90,6	- 1,8	92,4	- 0,65	93,5
L 201 (*nor*) × Mo 341(Wo^m)	+ 2,2	201	+ 1,62	198	+ 1,37	149	+ 0,76	124
Fakel × Mo 341 (Wo^m)	+ 0,54	116,4	+ 0,56	101,4	+ 1,0	105	+ 0,82	109
MaKrista × Mo 341 (Wo^m)	+ 1,0	137	+ 1,41	163	+ 1,31	154	+ 1,04	110

Negative overdominance for all traits, that is, depression is observed in the combination of hybrid F_1 – L 45/16 (*ps*) × Mo 341 (Wo^m) and, accordingly, negative heterosis (Table 1). While the other combinations of F_1 hybrids with the mutant line Mo 341(Wo^m) show positive dominance and overdominance with high heterosis effect on all traits (Table 1). The data of Table 1 show that the greatest effect of heterosis on the studied traits is observed in the hybrid with the line L201 homozygous for the *nor* gene with the corresponding index of the coefficient of the degree of dominance. Positive and overdominance for this group of traits is also observed in combinations of F_1 hybrids with varieties Fakel and MaKrista (Table 1). The highest results were obtained for components and subcomponents of productivity in combinations of F_1 intermutant hybrids regardless of the type of plant growth of their parental forms.

Degree of dominance and heterosis effect in F_1 tomato hybrids in terms of total yield and fruit marketability (traits group 2)

Studies by different authors (Avdeev, 2014; Kuzeminsky, 2004; Khotyleva at el., 2016) show the advantage of heterosis hybrids of tomato over varieties in terms of “total yield”. According to their data, the yield increase in heterosis F_1 tomato hybrids on average can range from 25 to 100% depending on the characteristics of the parental forms and their combinatory ability. The results obtained by us and presented in Table 2 fully confirm the conclusions of these authors.

Almost all the studied F_1 hybrids show positive dominance and overdominance in terms of total yield and marketability of fruits (shape, size, uniformity, etc.) (Table 2). The average dominance coefficient over three years of research in the F_1 hybrid combinations: L 186 × Mo 835; Stefani × Mo 835; L 8/234 × Mo 835, L 201 × Mo 341 and MaKrista × Mo 341 was higher than one, which characterizes them as truly heterotice, including in terms of components and subcomponents of total productivity (Tables 1 and 2). The yield increase in these F_1 hybrid combinations, depending on the conditions of the year and the genotypic characteristics of their parental forms, varied from 27 to 92%. The highest average heterosis effect across the years of research was observed in the inter-mutant combinations F_1: (L 186(*rin*) × Mo 835(*Ln*); L 8/234(*nor*) × Mo 835(*Ln*); L 201(*nor*) × Mo 341(*Wo^m*) (Table 2). Whereas in the F_1 combinations with the sterility genes L 33/16(*ps-2*) × Mo 835(*Ln*) and L 45/16(*ps*) × Mo 341(*Wo^m*), the heterosis effect for all traits was negative (Table 2). A pronounced negative dominance and negative heterosis for the overall yield and marketability of fruits (Table 2), as well as for the first group of traits (components and subcomponents of productivity – Table 1), is observed in the F_1 hybrid L45/16 × Mo 341 in three different years of research (2020-2022).

Table 2. Degree of dominance (hp) and manifestation of the heterosis effect (X) in F_1 tomato hybrids for the traits of total yield and marketability of fruits

Hybrid combinations F_1	Total yield			Marketability of fruits,%		
	Average indicators by characteristics for 2020-2022.					
	X_{av}	hp	x	X_{av}	hp	x
	kg/m²	1 group of combinations: indeterminate × indeterminate				
L 186 (*rin*) × Mo 835 (*Ln*)	26,1	+ 3,23	260	95,8	+ 2,04	214
Stefani × Mo 835 (*Ln*)	20,7	+ 1,64	148	93,6	+ 1,33	162
L 8/234 (*nor*) × Mo 835 (*Ln*)	28,9	+ 2,84	244	96,8	+ 2,37	301
L 33/16 (*ps-2*) × Mo 835 (*Ln*)	11,2	+ 0,27	90	83,3	+ 0,43	87
	kg/plant	2 group of combinations: determinate × determinate				
L 45/16 (*ps*) × Mo 341 (*Wo^m*)	1,7	- 0,72	82	89,1	- 0,44	84
L 201 (*nor*) × Mo 341 (*Wo^m*)	4,1	+ 2,34	185	94,7	+ 1,90	206
Fakel × Mo 341 (*Wo^m*)	2,7	+ 0,68	133	94,3	+ 1,4	167
MaKrista × Mo 341 (*Wo^m*)	3,8	+ 1,57	161	95,6	+ 1,71	183

The average heterosis effect in F_1 hybrids for the "total yield" trait was 148% in 2020, 194% in 2021, and 137% in 2022. This indicates the influence of environmental conditions during the plant growth period on the heterosis effect, the indicator of which is significantly higher under more favorable climatic conditions in 2021. Intermutant F_1 tomato hybrids demonstrated a consistently high heterosis effect in three different years of research (Tables 1 and 2). The heterosis effect was somewhat lower in combinations with the Stefani, Fakel, and MaKrista varieties. The average dominance coefficient of the "total yield and marketability of fruits" traits varied across the years of research, but remained within the normal range characteristic of each hybrid, determined by the genotypic characteristics of their parental forms.

Peculiarities of heterosis manifestation by the duration of vegetation period in F_1 tomato hybrids with mutant marker genes (3rd group of traits)

The nature of inheritance of the duration of the vegetation period by F_1 tomato hybrids with the *rin* and *nor* genes, which control the quality and timing of fruit ripening, and the manifestation of heterosis in them simultaneously depends on both the parental forms and the environmental conditions in which the plants were grown. However, both under more favorable (2021) and unfavorable (2020 and 2022) environmental conditions, F_1 hybrids show positive dominance and overdominance of parental forms with a longer vegetation period (Table 3). This may be the result of complementary interaction of late-ripening genes. Mutant lines Mo 835 and Mo 341 are characterized by a long vegetation period – 120 and 124 days, respectively. Crossing them with lines with a short vegetation period (L33/16 – 101 days; L45/16 – 104 days; Fakel – 106 days; L186 – 107 days) showed dominance and heterosis towards late ripening (Table 3). The reason for this may be the linkage of mutant genes *Ln* and *Wo^m* with polygenes controlling late ripening. It can also be assumed that the late ripening

of the mutant forms Mo 835 and Mo 341 is due not only to the linkage of its recessive genes with the genes of late ripening, but also with the genes controlling sterility, which negatively affected the setting of fruits, the weight of fruits, their quality and the overall yield. In general, all F_1 tomato hybrids are characterized as mid-season. In combinations with the *rin* and *nor* genes, intermediate inheritance is noted (the indicator of the trait at the level of the average of the two parental forms). This can serve as a guide for the selection of parental pairs when crossing, to obtain hybrids with a shorter ripening period. Hybrids with mutant genes show the ability to heterosis for early ripening under high-temperature environmental conditions (2020 and 2022) (Table 3). High temperatures accelerate the onset of fruit ripening, contributing to the reduction of the phenophase “beginning of ripening and first fruit harvest”. This was reflected in the average value of the "length of the vegetation period" trait, which was 114 days in hybrids in 2020 and 2022 and 118 days in 2021, which was more favorable in terms of a set of climatic conditions (Table 3). Despite the variability of this trait across years of research, genetic determinism contributed to the preservation of the general trend of its manifestation in intermutant tomato hybrids F_1 (Table 3).
Thus, the original material shows that the degree of dominance and the effect of heterosis in terms of the length of the vegetation period in F_1 tomato hybrids are determined by the genotypic diversity of the parental forms used in the crosses and their interaction with environmental conditions.

Table 3. Degree of dominance (hp) and heterosis effect (X) in F_1 tomato hybrids by vegetation period, in three different research years (2020-2022)

Hybrid combinations F₁	**Vegetation period, days**			**hp**			**X**		
	2020	**2021**	**2022**	**2020**	**2021**	**2022**	**2020**	**2021**	**2022**
	1 group of combinations: indeterminate × indeterminate								
L 186 (*rin*) × Mo835 (*Ln*)	111	119	114	+1,00	+1,24	+1,11	104	121	108
Stefani × Mo 835 (*Ln*)	117	119	117	+1,80	+1,08	+2,1	114	108	112
L 8/234 (*nor*) × Mo 835 (*Ln*)	115	118	112	+1,00	+2,04	+0,94	102	116	104
L 33/16 (*ps-2*) × Mo 835 (*Ln*)	118	116	119	-0,26	-1,00	-0,78	90	99	93
	2 group of combinations: determinate × determinate								
L 45/16 (*ps*) × Mo 341 (*Wo^m*)	115	118	114	-0,44	-1,00	-0,56	101	96	92
L 201 (*nor*) × Mo 341 (*Wo^m*)	114	120	111	+1,48	+2,10	+1,54	106	131	114
Fakel × Mo 341 (*Wo^m*)	110	117	109	+0,87	+1,00	+0,75	103	106	102
MaKrista × Mo 341 (*Wo^m*)	116	119	117	+0,64	+1,21	+0,83	104	110	107
Average indicators of the trait and the heterosis effect by year	**114**	**118**	**114**				**103**	**111**	**104**

Resistance of F_1 tomato hybrids to high and low temperatures based on male gametophyte traits (4th group of traits)

In the conditions of climate change, one of the key tasks of breeding programs is to create tomato varieties and hybrids F_1 with a lower response to environmental stress. It is important to take into account that the sensitivity of the generative sphere of the plant to unfavorable environmental conditions is higher than the vegetative one, and favorable temperature ranges for the development of reproductive organs are narrower than for vegetative ones. Therefore, to determine the adaptive potential of the studied F_1 tomato hybrids to the action of temperature stress factors, we conducted an assessment at one of the most vulnerable stages of ontogenesis – the stage of mature male gametophyte. The male gametophyte is most sensitive to the influence and change of environmental conditions, unlike the female (which is covered with thick layers of somatic tissues). Therefore, pollen quality can serve as a criterion for the reproductive capacity of plants (Kruglova, 2020; Makovei, 2023) and the basis for the formation of a large number of high-quality seeds (Demurin et al., 2021), which is especially important in heterotice tomato breeding and in the production of hybrid seeds.
The results of the studies showed a complex nature of the manifestation of male gametophyte traits in F_1 tomato hybrids, depending on the mutant marker traits they carry. Significant differences were established between F_1 hybrids in the reaction of their pollen to high (45 C/8 hours) and low temperatures (+6 C/24 hours).
The pollen grain populations of the parental lines L 33/16 and L 45/16, carriers of the sterility genes (*ps-2* and *ps*), were highly heterogeneous in shape and size, with a large number of small, puny grains with damaged integrity. This was reflected in the nature of the manifestation of traits in hybrids with their participation (L 33/16 × Mo 835 and L 45/16 × Mo 341) (Figure 1). At the same time, pollen grains of the genotypes of the cultivated type – Stefani, Fakel, MaKrista and lines homozygous for the *rin* and *nor* genes – L 186, L 8/234 and L 201, were sufficiently aligned in shape, size and fertility. Similar results were obtained in the F_1 tomato hybrids obtained on their basis.
Evaluation of the fertilization ability of F_1 hybrid pollen – viability-germination and pollen tube length in fresh pollen (control) and pollen exposed to high- and low-temperature stress (experiments), also showed significant

differences between them regarding the nature of manifestation of both traits (Figure 1). Pollen of F_1 hybrids – L 186 × Mo 835, L 8/234 × Mo 835 and L 201 × Mo 341 practically did not react to high-temperature exposure. After treating their pollen at 45°C for 8 hours, pollen grains quickly and actively germinated on an artificial nutrient medium *in vitro*, simultaneously forming very long pollen tubes (Figure 1). This indicates their high adaptive potential in relation to the action of this stress factor.

The pollen of the hybrid L 201 × Mo 341 responded differently to the low-temperature factor, against which it germinated very weakly (17.7%), while forming very short pollen tubes (11-20 µm). Whereas in the hybrids F_1 – L 186 × Mo 835, 8/234 × Mo835, the indices of both traits remained high even against the background of low temperature (Figure 1).

Pollen of F_1 tomato hybrids – L 33/16(*ps-2*) × Mo 835(*Ln*) and L 45/16(*ps)* × Mo 341(*Wo^m*) (Figure 1) turned out to be highly sensitive to the action of both temperature stress factors, both in pollen germination and in the ability of germinated pollen grains to form tubes of sufficient length for fertilization (three diameters of a pollen grain). This indicates a complex nature of the interaction of mutant genes in such a combination in the genomes of F_1 hybrids. This is confirmed by the results obtained on the nature of the manifestation of economically valuable traits from the previous groups (Tables 1, 2 and 3).

An ambiguous reaction of pollen to high and low temperatures is also observed in F_1 hybrids with the Stefani and Fakel varieties. The pollen of the Stefani × Mo 835 hybrid showed a high response to the high-temperature stress, but at the same time it germinated well, forming very long tubes against the background of low temperature (Figure 1). Conversely, pollen obtained from the flowers of the Fakel × Mo 341 hybrid plants does not react to high temperature (45 C/8 hours), demonstrating a high degree of resistance, but turned out to be very sensitive to low temperature. Similar results were revealed for the L 201 × Mo 341 combination (Figure 1). It is important to note here that the pollen of all F_1 hybrids in combinations with the mutant line 341 (*Wo^m*) showed high sensitivity to the low temperature stress factor (+6 ° C) (Figure 1).

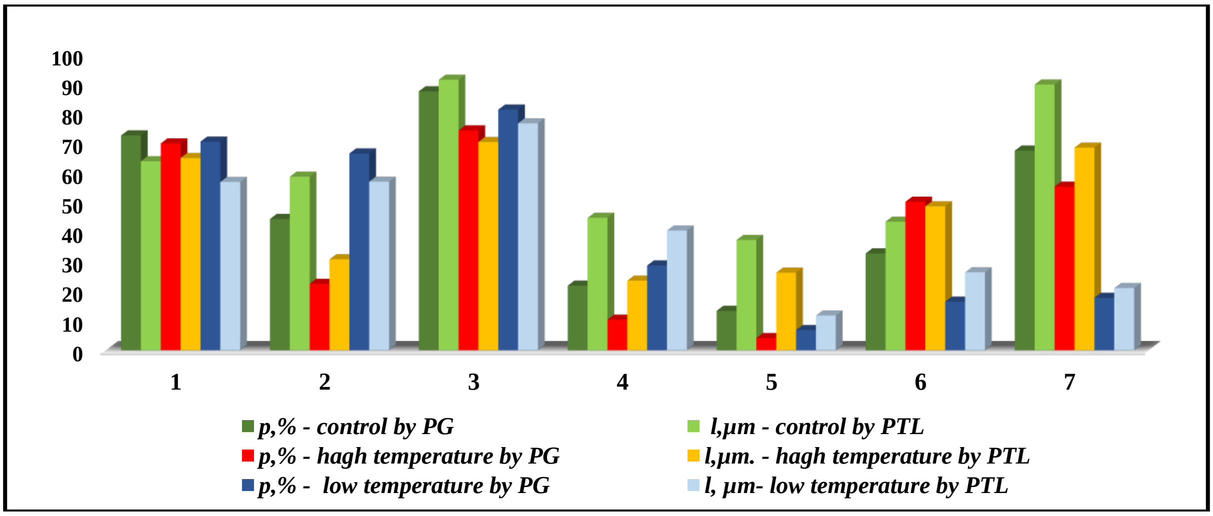

Figure 1. Resistance of hybrids to high and low temperatures according to male gametophyte traits

Note: Hybrids F_1: **1.** L 186(*rin*) × Mo 835(*Ln*); **2**. Stefani × Mo 835(*Ln*); **3**. L 8/234(*nor*) × Mo 835(*Ln*); **4.** L 33/16(*ps-2*) × Mo 835(*Ln*);
5. L 45/16(*ps*) × Mo 341(*Wo^m*); **6.** Fakel × Mo 341 (*Wo^m*); **7**. L 201 × Mo 341 (*Wo^m*).
Traits: *R*esistance to high temperature by pollen germination (*p,% - PG*); Resistance to high temperature by pollen tube length (*l, µm – PTL*); Resistance to low temperature by pollen germination (*p,% - PG*); Resistance to low temperature in pollen tube length (*l, µm – PTL*).

This approach to research allowed us to identify the individual reaction of F_1 hybrid pollen to high and low temperature based on the nature of the manifestation of two traits of the male gametophyte (pollen germination and pollen tube length), including depending on the characteristics of their parental forms. These results can form the basis for a more in-depth study of the mechanisms of action and interaction of parental form genes for the effective selection of pairs for hybridization. Also, for determining the effect of different combinations of mutant genes in heterozygous offspring on the nature of the manifestation of traits that are of fundamental importance for the creation of heterotice hybrids, including those resistant to temperature stress factors.

CONCLUSION

Positive dominance and overdominance with a high heterosis effect were established in intermutant tomato hybrids F_1 – L 186 × Mo 835; L 8/234 × Mo 835; L 201 × Mo 341 with the *rin, nor, Ln* and *Wo^m* genes for the following traits: number of flowers per plant, number of set fruits, fruit weight, pericarp thickness, total yield, marketability of fruits and resistance to high and low temperatures in three different years of research (2020-2022). It is possible that the high polygenicity of the parental forms of these F_1 hybrids for these traits in combination with their genetic heterogeneity ensured the corresponding result.

An ambiguous effect of the sterility genes *ps*-2 and *ps* in combination with the *Ln* and *Wo^m* genes on the nature of the manifestation of traits in the heterozygous F_1 offspring was revealed, where negative dominance and overdominance are noted, both for the components and subcomponents of productivity, and for the quality of pollen and its response to high- and low temperature stress factors.

The nature of the inheritance of the duration of the vegetation period by F_1 hybrids with the genes *rin* and *nor*, controlling the quality and timing of fruit ripening, and the manifestation of heterosis in them simultaneously depend both on the parental forms and on the environmental conditions in which the plants were grown. These hybrids are characterized as medium-ripe with high quality fruits.

The F_1 – L186 × Mo835; L8/234 × Mo835 tomato hybrids with a high effect of heterosis were identified for all studied traits with stable manifestation in three different years of research (2020-2022). They are characterized by a high adaptive potential to the action of high- and low temperature stress factors and can be recommended for cultivation in high-tech greenhouses of the Republic of Moldova.

ACKNOLEDGMENTS

The research was carried out within the Subprogram 011102 "Increasing and conservation genetic diversity, agricultural crop breeding in the context of climate change", financed by the Ministry of Education and Research.

REFERENCES

1. Avdeev A.Y. *Spontaneous mutations of tomato in fruit size, shape, and weight and trait evolution.* Reports Russian Academy of Agricultural Sciences, 2014, 1, 16-19.
2. Demurin Y.N., Rubanova O.A. *Pollen analysis of plants of various sunflower genotypes*. Journal of Oilseed Crops, 2021, 2 (186): 10-17.
3. Dowker B.D., Driscoll C.J., Gordon G.H. *Heterosis*, Berlin, 1983.
4. Ganeva D., Danailov J. *Successes of Bulgarian heterosis breeding of tomato*. In: *Breeding and seed production of vegetable crops*. Moscow, 2015.
5. Khotyleva L.V., Kilchevsky A.V., Shapturenko M.N. *Theoretical aspects of heterosis.* Vavilov Journal of Genetics and Breeding, 2016, 20 (4): 482-492.
6. Kruglova N.N. *Assessment of the pollen grains quality in flowering plants (overview).* Journal of the State Nikita Botanical Garden, 2020, (135): 50-56.
7. Kuzeminsky A.V. *Breeding and genetic studies of mutant forms of tomato.* Kharkov, 2004.
8. Makovei M. *Pollen quality as a criterion for selection of tomato genotypes resistant to stress abiotic factors*. International Journal of Agriculture & Environmental Science, 2023, 10 (6): 1-9.
9. Makovei M. *Pollen reaction of mutant tomato forms to abiotic stress factors.* Journal Plant Breeding and Seed Production, 2023, 124, 6-20.
10. Makovei M.D. *Tomato selection on resistance to stress abiotic factors with gamete technologies*. Chisinau. 2018.
11. Makovei M.D. *The potential of mutant tomato forms for breeding and genetic research*. Chisinau, 2022.
12. Orzan V., Ionescu C. *Experimental methodology and technique for testing field vegetable varieties.* Bucharest, 1989.
13. Rick C.M. *Tomato mutants, freaks, anomalies, and breeders' resources.* Horticultural Science, 1986, 21 (4): 918-919.
14. Singh J., Aradhana J., Singh V. *Heterosis breeding in tomato: a review*. Progressive Horticulture, 2002, 34 (2): 161-167.
15. Stubbe H. *On the relations between natural and artificially obtained diversity of mutant forms and on some experimental studies on the evolution of cultivated plants.* Genetics, 1966, 11, 9-30.
16. Tomato – UPOV (*Solanum lycopersicum* L.) V 2012 0007 TG/44/11 Rev. Geneva.
17. Zhuchenco A.A. *Genetics of tomatoes*. Chisinau, 1973.