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GENE EFFECTS IMPLIED IN MANIFESTATION OF THE SOME QUANTITATIVE TRAITS AT THE TOMATO

EFECTE GENICE IMPLICATE ÎN MANIFESTAREA UNOR CARACTERE CANTITATIVE LA TOMATE

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Abstract. *In the article are presented the results of the research on the genetic effects involved in the manifestation of some quantitative characters to tomatoes. It has been established that the various actions (aditive - a, dominant - d) and epistatic interactions (aa, ad, dd) of the genes vary in their degree and orientation (+/-), and depend on the combination, traits and participate to the inheritance of morphobiological and agronomic traits of tomatoes. Duplicate epistasis play an important role in forming the phenotype of these characters in most combinations. As a result of the clustering analysis of the degree of association of the characters mean in the* F_2 *population with the investigated gene effects, it was found that in all cases, the* F_2 *media displayed a high associative association with epistasis ad. The broad spectrum of gene effects involved in the formation of the phenotype of morphobiological and agronomic features highlights their genetic basis which considerably contributes to the targere of tomato breeding.*
Key words: tomato, quantitative traits, gene effects

Rezumat. *În acest articol sunt prezentate lucrările de cercetare asupra efectelor genetice implicate în manifestarea unor caractere cantitative la tomate. A fost stabilit că acțiuni diferite (aditive-a, dominante-D) şi interacțiunile epistatice (aa, ad, dd) a genelor variază ca grad şi orientare (+/-) şi depind de combinațiile şi caracteristicile pe care le exprimă şi participă la ereditatea caracterelor morfobiologice şi agronomice ale tomatelor. Epistazia duplicată joacă un rol important în exprimarea fenotipului acestor caracteristici în cele mai multe combinații. Ca rezultat al analizei cluster a gradelor de asociere a mediei caracterelor în populația* F_2 *cu efecte genetice demonstrate a fost găsit faptul că în toate cazurile media din* F_2 *a exprimat un grad de asociere ridicat cu epistazie ad. Spectrul larg al efectelor genelor implicate în formarea fenotipului pentru caracteristicile morfobiologice şi agronomice subliniază baza lor genetică care contribuie în mod considerabil la atingerea obiectivelor de ameliorare a tomatelor.*
Cuvinte cheie: tomate, caractere cantitative, efecte genetice

INTRODUCTION

Numerous factors contribute to the formation of genetic and phenotypic variants within a hybrid population. Phenotypic variation within a species or population is extremely complex, often – polygenic and quantitative, being influenced by genetic and environmental factors. In addition, along with allelic variations (dominance), both

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additive actions and non-aditive interactions of the genes play an important role in formation of the quantitative characters in plants (Eckardt, 2008) and their heredity transmission (Holland, 2001; Liberman *et al.*, 2007; Lupaşcu, 2010; Phillips, 2008), for which reason the elucidation of tomato cross combinations with gene effects favorable to obtaining a certain level of character is a safe way of optimizing and accelerating the creation of the new tomato genotypes with the desired traits (Munteanu, 2003; Ciobanu *et al.*, 2009, a).

In control of the quantitative character of tomato fruit, various *Quantitative Trait Loci* (QTL) located on the same chromosome, or on different chromosomes, are involved. For example, for fruit weight (fw), 6 QTLs were detected: on cr.1 (*fw*1.1 and *fw*1.2), cr.2 (*fw*2.1 and *fw*2.2), cr.3 (*fw*3.1), and Cr. 11 (*fw*11.3). The most important QTL – *fw*1.1, *fw*2.2. and *fw*11.3, demonstrated the phenotypic variance values of 17.22 and 37% respectively (Lippman and Tanksley, 2001).

Improving of the size of tomato fruit has been achieved relatively easily, due to the high heritability of the character, but the inheritance patern is quite complex, being determined by the number of loci. A trait correlated with the weight of the fruit – the size of the fruit depends on the number of cells in the ovary to pollination, the number of successful pollination and cell divisions after fertilization, and the extent of the cell size (Ghosh *et al*, 2010).

In tomatoes, the number of fruits *per* plant, the number of fruits *per* sprout, the fruit weight and the fruit yield *per* plant showed high values of the genetic variation coefficient and genetic performance, which revealed the contribution of additive factors and the selectivity efficiency on a the genetic basis for improving these characters (Mohanty, 2003; Saeed *et al*, 2007; Dar and Sharm, 2011; Al-Aysh *et al.,* 2012).

The significant positive association between fruit weight and fruit yield *per* plant indicates a genotypic relationship between these attributes, and the fruit harvest can be increased by simply selecting the plants based on those characters. It should be noted that the significant negative correlation between the number of fruits *per* plant and the fruit weight denotes, in fact, the impossibility of simultaneously improving these attributes within one and the same genotype. For this reason, the improvement must to be oriented towards the formation of large fruit genotypes, with the optimal fruit weight (Mohanty, 2002; Singh *et al,* 2004).

Thus, in order to obtain the high fruit yield tomatoes *per* plant, selecting plants based on the number of fruits per plant and the fruit weight, more precisely selecting based on the positive correlation between these characters, can be performed up to a certain level which does not involve the reciprocal exclusion of factors (Munteanu and Făticeanu, 2008; Ciobanu *et al.*, 2009 b; Ciobanu *et al.*, 2016).

Creating of the high-performance genotypes involves the use of an initial high-capacity hereditary transmission of valuable attributes and the enhanced adaptation to local environmental conditions, able to accumulate a large number of valuable positive gene interactions.

Genetic actions and interactions largely control the phenotype and inheritance of quantitative characters in plants (Liberman *et al*, 2007; Lupascu, 2010).

If the epistatic interactions are subject to the selection factor and the influence of the environmental conditions, their degree of manifestation can also be predicted (Blows and Hoffmann, 1996; Carlborg and Haley, 2004).

The purpose of the research was to elucidate the gene effects involved in the manifestation of quantitative traits in tomatoes and to identify combinations with favorable gene effects that would allow optimization and acceleration of the creation of new genotypes with the desired characteristics.

MATERIAL AND METHOD

Four parental forms – Maestro, Dwarf Moneymaker (D.M.M.), Mihaelia, Irisca, hybrid combinations F_1 and F_2, first-generation backcross (BC) combinations were used as research material.

A number of characters of biological and agronomic importance were analyzed: *fruit length and diameter, thickness of the pericarp, number of seminal locule, fruit weight, number of fruit branches, number of fruits per plant, fruit yield per plant.* The number of fruits analyzed was: 30-40 – for parental forms and hybrid F_1, 120 – F_2 and 60 – backcross populations.

To determine the level and orientation (+/-) of additive (*a*) and nonadditive (*dominant - d, additive x additive - aa, additive x dominant - ad, dominant x dominant - dd*) gene effects, involved in the heredity of biological and productivity traits in tomatoes, was applied the Gamble model (Gamble, 1962).

Construction of the distribution dendrogram was performed based on the iteration algorithm by Ward method in the STATISTICA 7 software package.

RESULTS AND DISCUSSIONS

The obtained results indicate that the gene effects involved in the inheritance of valuable morpho-anatomic and agronomic characters in tomatoes were quite differentiated by level, orientation (+/-) and variance depended largely on the hybrid combination (table 1, table 2).

Fruit length and diametert. Gene effects with the statistical support were found in 100% cases for length and 90% – fruit diameter. With exception of the *ad* epistasis that have always been positive, but with low variance, for all types of effects, significant (+/-) guidelines have been identified to increase or decrease the character.

The thickness of the pericarp. Gene effects with statistical support were confirmed in 17 out of 20 variants (cross combination x gene action / interaction), ie in 85% of cases. Significant additive actions were recorded at the crosses Maestro x D.M.M., Mihaela x Irisca, Mihaela x D.M.M. The effects of dominance, unlike the additive ones, were more influential, both in terms of value and variance, the latter varying within the limits of 23.6 ... 27.7% of the general genetic variation GGV. Positive strong dominance was certified at Maestro x Dwarf Moneymaker (3.17 *), Maestro x Irişca (2.12 *) and Mihaela x Irişca (2.05 *).

Of the epistasis, the interactions *aa* had statistical support in 3 of the 4 combinations, their share in the GGV being quite high: 22.78 ... 24.02. Epistasis *ad* have always been positive, but their low variance of 1.90 ... 2.40 demonstrates the minor role in character formation.

The most important epistasis of the investigated cross combinations were interactions *dd*, the high variance of which demonstrates their major involvement in genetic control of character. However, their practical application has quite different possibilities. Thus, from the four combinations analyzed, only Maestro x D.M.M., by virtue of the manifestation of complementary epistasis (unidirectional orientation of the positive *d* and *dd* forces), presents the chances of obtaining more accelerated genophytes with thick pericarp, while in the other combinations, by epistasis dublicate (the opposite orientation of *d* and *dd* effects), genotypes with the desired character can only be obtained by long-term selection. However, the Mihaela x Irişca cross combinations, due to their positive actions and interactions, and their high variance (50.32%), which contribute to the enhancement of character, present opportunities and chances of obtaining genotypes with thick fruit pericarp.

Locules per fruit. Gene effects, with statistical support, were found in 90.0% of cases. In most combinations, *d* and *aa* effects were recorded, oriented to the decreasing of character, thus increasing the quality of the fruit and reducing the number of seeds. Of the interactions strongly involved in increasing the number of seminal loci, epistasis *dd* can be mentioned.

Fruit weight. Gene effects were found, varying by level, orientation and magnitude of variance, which reveals complexity of the character control. Significant additive actions were found in all hybrid combinations indicating their contribution to increasing the fruit weight. Dominance actions were significant, by level: -29.47 ... 6.67, and a variance that represented 23.52 ... 27.05% of GGV. The strongest dominance effects, aimed at enhancing character, were manifested in Maestro x D.M.M. (6.67 *) and Mihaela x Irisca (4.32 *), and to the diminution of character – at Mihaela x D.M.M. (-29 47 *).

It was found that *ad* interactions had only positive values, indicating that this type of epistase contributes to nonspecific increase of the values of all the surveyed production indices – the fruit yield *per* plant, the number of fruits *per* plant, the weight of the fruit. Strong epistasis in the direction of diminution of character were found at Mihaela x D.M.M. (-25.34 *).

The *dd* epistasis at all combinations acted in the direction of increasing the values of character. It should be noted that interactions *dd* recorded the highest variance, constituting 42.71 ... 49.18% of the GGV. With the exception of the combination, Mihaela x Irisca, in the control of the size of the fruit, there were duplicate epistasis, ie opposite directions (+/-) of *d* and *dd* effects, which puts the process of selecting forms with certain dimensions of the fruit in difficulty.

According to the data obtained, for the creation of large fruit forms there are certain chances for the crosses Maestro x Dwarf Moneymaker, Mihaela x Irişca, which have been certified *a* and *aa* positive effects with the variation sum of 45,91 and 47,32, respectively, in GGV.

Table 1

Gene effects that control the morphobiological and productivity traits of tomatoes

Backcross combination	Gene effects					
	m	***a***	***d***	***aa***	***ad***	***dd***
Length of the tomato fruit						
Maestro x Irişca	43.30*	14.65*	23.12*	27.50*	71.12*	-11.05*
Maestro xD.M.M	77.70*	5.30*	-63.55*	-64.40*	73.45*	92.30*
Mihaela x Irişca	40.60*	3.55*	17.12*	13.30*	42.67*	-24.85*
Mihaela xD.M.M	49.7*	-5.85*	10.30*	13.10*	44.95*	-27.40*
Diameter of the tomato fruit						
Maestro x Irişca	40.15*	-3.45*	-21.07*	-18.70*	33.63*	20.35*
Maestro xD.M.M	33.85*	0.20	3.60*	2.80*	38.10*	12.20*
Mihaela x Irişca	42.05*	6.40*	13.47*	11.00*	42.27*	-21.75*
Mihaela xD.M.M	49.35*	7.6*	-15.15*	-18.2	49.30*	11.90*
Thickness of the pericarp						
Maestro x Irişca	4.85*	-0.15	2.12*	2.30*	5.62*	-1.25*
Maestro xD.M.M	4.75*	-2.70*	3.17*	3.00*	4.92*	5.85*
Mihaela x Irişca	5.45*	0.65*	2.05*	1.90*	5.4*	-6.3*
Mihaela xD.M.M	7.45*	-1.10*	0.45	-0.60	5.50*	-0.10
Locule number						
Maestro x Irişca	2.65*	0.41*	-1.40*	-1.6*	2.90*	3.00*
Maestro xD.M.M	3.15*	0.75*	-1.15*	-1.30*	3.20*	0.10
Mihaela x Irişca	2.45*	0.15*	-1.00*	-0.70*	2.60*	0.80*
Mihaela xD.M.M	2.60*	-0.10	-2.05*	-2.00*	2.30*	3.10*
Fruit weight						
Maestro x Irişca	43.12*	12.90*	0.71	0.33	60.35*	17.40*
Maestro xD.M.M	52.36*	14.29*	6.67*	3.09*	68.07*	6.67*
Mihaela x Irişca	44.47*	30.09*	4.32*	11.43*	84.28*	1.82
Mihaela xD.M.M	62.15*	20.37*	-29.47*	-25.34*	80.90*	35.95*
Branches per plant						
Maestro x Irişca	4.88*	0.15	-1.39*	-1.02*	4.97*	1.07*
Maestro xD.M.M	4.89*	-0.55*	-0.47*	-0.25	4.27*	-0.20
Mihaela x Irişca	4.65*	0.05	-0.82*	-1.32*	4.65*	3.42*
Mihaela xD.M.M	4.64*	-0.05	0.35*	0.15	4.55*	-0.05
Fruits per plant						
Maestro x Irişca	45.9*	-4.10	-9.72*	-13.12*	35.3*	7.06*
Maestro xD.M.M	38.28*	-8.57*	-9.91*	-9.2*	30.7*	20.9*
Mihaela x Irişca	41.27*	-9.53*	-19.27*	-26.02*	25.88*	42.12*
Mihaela xD.M.M	32.61*	-15.53*	5.18*	6.91*	19.75*	-6.54*
Fruit yield per plant						
Maestro x Irişca	1985.90*	360.00*	-242.00*	-634.83*	1978.10*	584.23*
Maestro xD.M.M	1961.17*	-67.04	96.26	-150.22*	1866.48*	682.78*
Mihaela x Irişca	1810.30*	502.17*	-264.52*	-784.62*	1979.97*	1279.42*
Mihaela xD.M.M	1834.01*	-230.53*	-97.95	-139.77*	156.65*	199.87*

p≤0,05.

Table 2

Variants of the gene effects that control the morphobiological and productivity traits of tomatoes

Backcross combination	Gene effects					
	m	***a***	***d***	***aa***	***ad***	***dd***
Length of the fruit						
Maestro x Irişca	21.80	43.13	534.89	521.34	52.07	1093.16
Maestro xD.M.M	119.48	169.30	2662.49	2588.95	180.52	4914.70
Mihaela x Irişca	11.41	18.99	266.76	258.51	23.50	519.33
Mihaela xD.M.M	18.43	22.14	403.02	383.48	28.94	727.37
Diameter of the fruit						
Maestro x Irişca	14.24	23.31	339.10	321.08	27.63	672.89
Maestro xD.M.M	14.55	26.08	350.70	337.20	30.62	704.16
Mihaela x Irişca	10.47	17.83	253.16	238.86	22.62	510.02
Mihaela xD.M.M	11.50	21.30	284.69	269.26	26.32	586.63
Thickness of the pericarp						
Maestro x Irişca	1.92	2.92	43.70	42.47	3.36	82.45
Maestro xD.M.M	2.62	4.69	61.99	60.65	5.23	122.29
Mihaela x Irişca	1.63	3.19	40.15	38.81	3.90	82.41
Mihaela xD.M.M	1.10	1.80	26.34	24.86	2.62	52.43
Locule number						
Maestro x Irişca	0.34	0.31	7.05	6.76	0.38	11.66
Maestro xD.M.M	0.66	1.06	15.11	14.81	1.11	28.74
Mihaela x Irişca	0.26	0.41	6.00	5.80	0.47	11.49
Mihaela xD.M.M	0.25	0.18	5.06	4.78	0.23	8.11
Branches per plant						
Maestro x Irişca	1.11	2.06	27.23	25.95	2.76	55.80
Maestro xD.M.M	0.83	1.51	20.61	19.42	2.14	42.35
Mihaela x Irişca	0.66	1.41	17.47	16.23	2.02	38.07
Mihaela xD.M.M	0.89	1.72	22.09	21.17	2.26	45.51
Fruit weight						
Maestro x Irişca	93.08	137.81	2167.25	2040.56	175.35	4201.05
Maestro xD.M.M	110.40	218.95	2775.80	2642.22	250.63	5804.04
Mihaela x Irişca	101.18	175.61	2401.42	2321.42	231.99	4748.81
Mihaela xD.M.M	394.31	330.64	7817.51	7631.51	381.16	12343.22
Fruits per plant						
Maestro x Irişca	389.6	566.8	8550.9	8404.5	611.1	1579.9
Maestro xD.M.M	257.0	610.1	6887.0	6552.2	693.9	15212.9
Mihaela x Irişca	179.0	331.1	4397.1	4188.7	376.0	8996.5
Mihaela xD.M.M	327.2	446.3	7200.0	7020.4	530.5	13094.0
Fruit yield per plant						
Maestro x Irişca	400.6	766.9	10570.0	9409.6	821.1	2082.9
Maestro xD.M.M	357.9	812.2	8837.0	7772.3	980.9	19223.9
Mihaela x Irişca	285.0	542.3	7399.7	6190.9	888.0	9970.5
Mihaela xD.M.M	528.2	756.3	9238.0	10400.8	938.5	15098.2

Branches per plant. The actions (*a, d*) and the gene interactions (*aa, ad, dd*) had a different role in character formation, casting it to increase or decrease it. The data reflects allelic actions of type *a* and *d* insignificant in the all hybrid cross combinations. Analysis of epistatic allelic interactions showed positive homozygous positive interactions of the type *aa* only at the Mihaela x Dwarf Moneymaker combination, heterozygous of the *ad* type at all combinations and *dd* – at the cross combinations Maestro x Irişca and Mihaela x Irişca.

Fruits per plant. Gene effects with statistical support involved in character formation were found in 95% of cases. Additive forces aimed at enhancing the character have not been attested, but they are interested in the Mihaela x Dwarf Moneymake combination, which due to the manifestation of high-positive (*d, aa* and *ad*) positive gene actions / interactions provide a safe chance of obtaining high- of character, but in the longer term, through the repeated selections.

Fruit yieldt per plant. Significant positive additive actions were found in the cross combination Maestro x Irisca, Mihaela x Irisca. Strong epistatic interactions in the direction of dimishing of character were recorded to all combination. Note that the dominance factor that has great importance in amelioration recorded negative values with statistical support at 2 combinations - Maestro x Irisca and Mihaela x Irisca. All combinations exhibited positive and negative episases *ad* and *dd*.

In the combinations of Maestro x Irisca, Maestro x D.M.M., Mihaela x Irişca, Mihaela x D.M.M., most of the characters in the study were controlled by duplicated epistasis (different orientation of *d* and *dd* effects), which are a serious impediment to the improvement process toward a certain level of character – increased or diminished. This determines individual, long-term selections of plants that have the character of interest. Unlike duplication epistasis, complementary ones offer chances of success in narrower terms. Such epistasis were recorded in the case of fruit yield *per* plant to the Maestro x Irişca, Maestro x D.M.M., Mihaela x Irişca combinations, the fruit yield per plant, the diameter of the fruit and the thickness of the pericarp – the cross combination of Maestro x D.M.M., the positive value of the dominant shares and the interactions *dd* offering opportunities to streamline and accelerate the increase in the values of those characters.

From a practical point of view, it is important to elucidate how the particular gene or association effects contribute to increasing or diminishing a character of interest. In connection with this, for the crosses under study, the clustering analysis of the degree of association of the mean of character in the F_2 population with the gene effects under study was carried out. According to the distribution dendrogram, in all cases the mean of characters in F_2 populations showed a high associative link with *ad* epistasis (fig. 1).

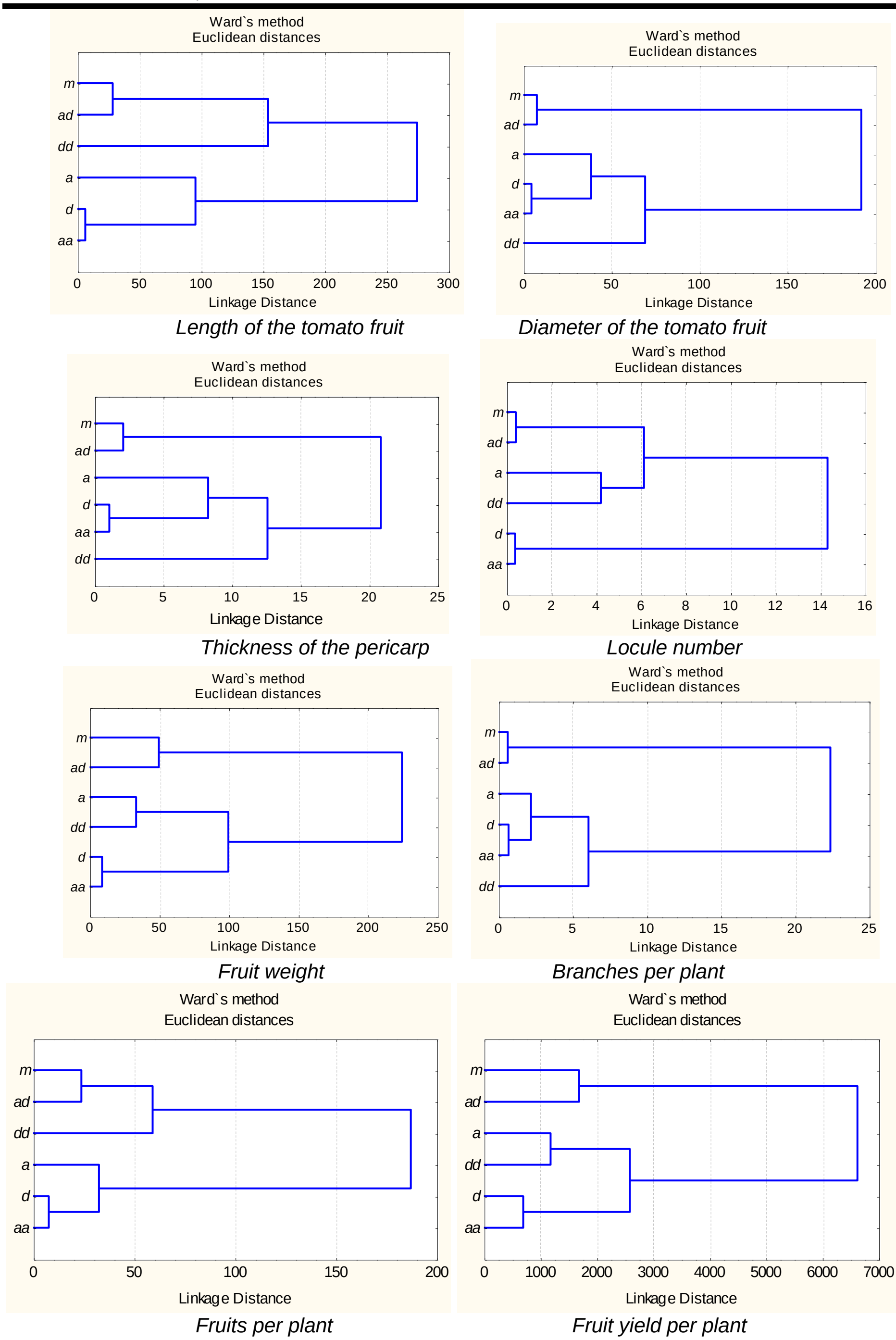

Fig. 1 The repartition dendrogram of the mean F_2 ant genetic effects involved in the control of some quantitative characters in tomatoes (*m* – the mean of character in the F_2 population, *a* – additive, *d* – dominant, *aa* – additive x additive, *ad* – additive x dominant, *dd* – dominant x dominant gene effects)

Taking into account the level of aggregation of the mean of character in F_2 populations and *ad* epistatic interactions, it can be easily observed that in increasing order the ties are as follows: number of locules, fruit branches *per* plant, thickness of the pericarp, fruit diameter, fruit length, number of fruits *per* plant, fruit weight, fruit yield *per* plant. It is worth mentioning that along with epistasis *ad*, the average of characters in F_2 populations also depends on other gene effects: the length of the fruit - the interaction aa, the number of seminal locules – the action *a* and the interaction *aa*, the number of fruits *per* plant – *aa*. So for these characters, gene systems as a control factor are more complex.

CONCLUSIONS

Phenotype and heritability of the morphoanatomic characters (fruit length and diameter, thickness of the pericarp, number of seminal locules, etc.) and agronomic (fruit weight, number of fruit per plant, fruit yield *per* plant,) in tomatoes are determined by different components of genetic variation – *additive, dominant*) and interactions (*additive x additive, dominant x, dominant x dominant additive*), involved in increasing or decreasing character values, and which record a differentiated magnitude in the general genotypic variance of trait. The average of the majority of characters in F_2 populations is most associated with epistasis *ad*, but for some (fruit length, number of fruits) – and *dd* interactions.

In the most tomato cross combinations, the prevalence of duplicate epistasis (the opposite orientation of dominating factors and *dd* epistasis) was recorded in the control of the quantitative character, which makes it difficult to create the genotypes with the desired characteristics in small terms, but the combinations of Maestro x Irişca, Maestro x Dwarf Moneymaker and Mihaela x Irisca present opportunities to accelerate the creation of large-scale genotypes, because they show additive actions and complementary epistasis that favor the enhancement of characters.

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