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MANIFESTATION OF VARIABILITY AND HERITABILITY OF SOME QUANTITATIVE CHARACTERS IN TOMATO

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Abstract

The paper was aimed to present the results of study of variability and heritability of some tomato characteristics: plant height, number of branches, number and weight of fruits per plant, size, length and diameter of the fruit, thickness of pericarp, number of locules which were presented for four tomato hybrids 'Maestro' x 'Irişca', 'Maestro' x 'Dwarf Moneymaker', 'Mihaela' x 'Irişca', 'Mihaela' x 'Dwarf Moneymaker'. Analyzing the coefficient of variability of quantitative characters of parents, hybrid combinations F_1, F_2 and backcrosses, it was found that the coefficient for the number and weight of fruits per plant for both, parents and all hybrid combinations was high, the average being 36.5 and 37.1%, respectively. Small variability was demonstrated for the plant height and diameter of the fruit. The heritability of quantitative characters depended significantly on parental forms. The highest values of heritability for the number and weight of fruits per plant were registered for 'Maestro' x 'Irişca' and 'Mihaela' x 'Dwarf Moneymaker' hybrid combinations. The combination 'Maestro' x 'Irişca' was highlighted as having high coefficient of variability for the most characters.

Key words: *tomato hybrids, breeding, variability, heritability.*

INTRODUCTION

The tomatoes Solanum lycopersicum L. were the second crop after potato in respect of the consumption level as well as the most popular garden crop (http://faostat.fao.org.). This was largely due to taste, special dietary and medicinal properties (Avdeev, 1982).

After FAO data, tomatoes were grown worldwide in the area of 4 million hectares. The most significant areas were in China (974, 000 ha) and India (520,000 ha). There was obviously a considerable increase in interest to this crop. In 2009 Moldova produced 84,070 tons of tomatoes (http://faostat.fao.org/).

The increase of agricultural plants harvests in agrocenoses was due to both, optimizing their growth conditions and the use of more productive and resistant genotypes. Under these conditions varieties and hybrids of cultivated plants played the crucial role in agriculture innovation progress which resulted in obtaining a sufficient product quantity of high quality.

Optimization and efficiency progressive programmes for tomato improvement were inconceivable without knowledge of the genetic basis of characters for which research was conducted and hence, technologies for genotypes with desirable characters were developed (Agong et al., 2000). In relatively recent studies it was shown that there existed a high genotypic and phenotypic variability of fruit weight, number of flowers in inflorescence, number of branches (Haydar et al., 2007, Mohamed et al., 2012), that offered opportunities for creating valuable genotypes with successful combination of characters, elucidating the impact of environmental conditions on character manifestation and hereditary transmission capacity. Of particular importance was knowledge on variability of characters that were determined by both, the genotype and environmental factors.

The degree of characters variability indicated genotype response norm peculiarities under different environmental conditions (Haydar et al., 2007, Mohamed et al., 2012 Mohanty, 2002).

The coefficient of variation was widely used while studying regularities of organisms'

adaptive responses. The information about characters' variation driven by the variety of genotypes demonstrated possibility of changing the parameter in the direction required at this stage of selection. Establishing peculiarities of characters' variability and heritability provided possibility for optimizing the selection programme optimization (Fasoulas, 1973).
Most characters valuable for tomatoes were quantitative and that was why evaluation of their variability and heredity attracted great attention primarily for development of genetic and improving programmes and successful completion of the improvement process (Agong et al., 2000, Mihnea, 2008). The aim of the research was complex evaluation of quantitative characters in new intra-specific hybrid combinations and study of variability and heredity of these characters for effective forecasting of the improvement process.

MATERIALS AND METHODS

The experiments were conducted in year 2010 under field conditions in the experimental plot of the IGFPP. Six components (P1, P2, F1, F2, BC1, BC2) in 4 hybrid combinations obtained under intraspecific hybridization (Maestro x Irişca, Maestro x Dwarf Moneymaker, Mihaela x Irişca, Mihaela x Dwarf Moneymaker) were used as a starting material for the intended research. Field experiments were conducted in triplicate in randomized blocks of seedlings cultivation without irrigation. The sowing took place in greenhouses in the first decade of April according to the scheme 7 x 10 cm and field planting - in the scheme of 70 x 30 cm. Field planting was performed in the second decade of May, and harvesting was done gradually (4-6).
Determination of heritability of quantitative characters was effectuated basing on Borojevic (1990). Morphological descriptt-ion was done according to the general principles and methodology of carrying out tests on Distinctness, Uniformity and Stability TG / 44/11 UPOV (2011). The data were statistically processed by the software package STATISTICA 7. Graphical representation, tabular and textual, was performed through the Microsoft Office and Microsoft Excel software.

RESULTS AND DISCUSSIONS

According to the relevant data biological characters and elements of productivity of the parental varieties and hybrids F_1, F_2 and backcrosses in year 2010 varied largely (Figure 1, 2, 3).
Plant height (Figure 1.A) Varied within 45,2 ... 75,0 cm in parents; 57,4…68,4 cm in hybrids F_1 and 51,1…68,3 cm in offspring hybrids F_2 and backcrosses. Significant differences were found for BC_1 F_1 (Maestro x Dwarf Moneymaker) x Maestro and BC_2 F_1 (Maestro x Dwarf Moneymaker) x Dwarf Moneymaker.
Number of branches (Figure 1.B) Presented were values within 4.4 ... 4.9 in parents, which showed that parents did not differ essentially by this character. Significant differences were certified only in BC_2 F_1 (Maestro x Dwarf Moneymaker) x Dwarf Moneymaker and F_1 Mihaela x Iriș ca.
Number of fruits per plant (Figure 1.C) Recorded were values 20,3 ... 50,5 in parents; 33,6…42,8 and 32,6…45,9 in F_2 and BC. Hybrids BC_1 F_1 (Mihaela x Iriș ca) x Mihaela, BC_2 F_1 (Mihaela x Iriș ca) x Iriș ca showed significant values.
Weight of fruits per plant (Figure 2.A) Included were values within 1236,9…1999,4 g in genitors; 1835,0…2180,0 g in F_1 and 1363,1…2007,0 g in F_2 and BC. Significant differences were established in F_1 Maestro x Dwarf Moneymaker, Mihaela x Irişca and BC_1 F_1 (Mihaela x Irişca) x Mihaela, BC_2 (F_1 (Mihaela x Irişca) x Irişca.
Weight per fruit (Figure 2.B) Recorded were values within 24,7…83,7 g in parental forms; 47,1…62,1 in F_1 and 32,3…66,0 g in segregating populations F_2 and BC. No significant differences were recorded either in a hybrid combination.
Pericarp thickness (Figure 2. C). Varied within 3,6…7,9 mm in parents; 4,9…7,8 in F_1 and 4,1…7,8 mm in F_2 and BC.

Significant differences were found in F_1 Mihaela x Dwarf Moneymaker, BC_1 F_1 (Mihaela x Irişca) x Mihaela, BC_2 F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymake].

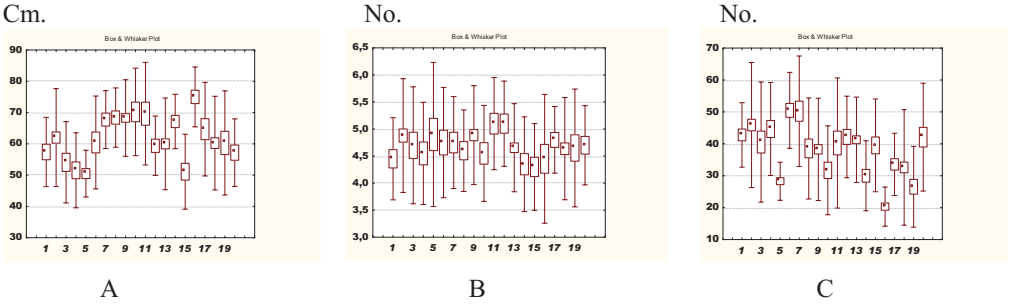

Fig. 1. Comparative data on plant height (A), number of branches (B), number of fruits per plant (2010)
1 - F_1 Maestro x Irişca, 2 - F_2 Maestro x Irişca, 3 - BC_1 F_1 (Maestro x Irişca) x Maestro, 4 - BC_2 F_1 (Maestro x Irişca) x Irişca, 5 – Maestro, 6 - Irişca, 7 - Dwarf Moneymaker, 8 - F_1 Maestrox Dwarf Moneymaker, 9 - F_2 Maestro x Dwarf Moneymaker, 10 - BC_1F_1 Maestro (x Dwarf Moneymaker) x Maestro, 11 - BC_2 F_1 (Maestro x Dwarf Moneymaker) x Dwarf Moneymaker], 12 - F_1 Mihaela x Irişca, 13 - F_2 Mihaela x Irişca, 14 - BC_1 [F_1 (Mihaela x Irişca) x Mihaela, 15 - BC_2 F_1 (Mihaela x Irişca) x Irişca, 16 – Mihaela, 17 - F_1 Mihaela x Dwarf Moneymaker), 18 - F_2 Mihaela x Dwarf Moneymaker, 19 - BC_1 F_1 (Mihaela x Dwarf Moneymaker) x Mihaela, 20 - BC_2 F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymaker.

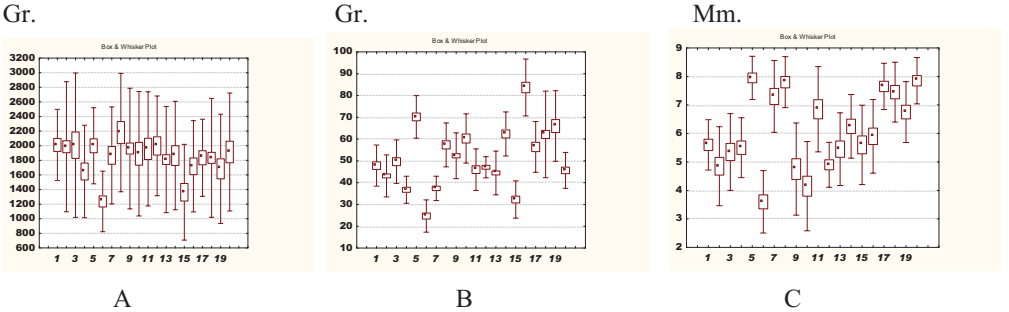

Fig. 2. Comparative data of fruit weight per plant (A), weight per fruit (B), pericarp thickness (C) parents and hybrid populations (year 2010)
1 - F_1 Maestro x Irişca, 2 - F_2 Maestro x Irişca, 3 - BC_1 F_1 (Maestro x Irişca) x Maestro, 4 - BC_2 F_1 (Maestro x Irişca) x Irişca, 5 – Maestro, 6 - Irişca, 7 - Dwarf Moneymaker, 8 - F_1 Maestrox Dwarf Moneymaker, 9 - F_2 Maestro x Dwarf Moneymaker, 10 - BC_1 F_1 (Maestro x Dwarf Moneymaker) x Maestro, 11 - BC_2 F_1 (Maestro x Dwarf Moneymaker) x Dwarf Moneymaker, 12 - F_1 Mihaela x Irişca, 13 - F_2 Mihaela x Irişca, 14 - BC_1 F_1 (Mihaela x Irişca) x Mihaela, 15 - BC_2 F_1 (Mihaela x Irişca) x Irişca, 16 – Mihaela, 17 - F_1 Mihaela x Dwarf Moneymaker, 18 - F_2 Mihaela x Dwarf Moneymaker, 19 - BC_1 F_1 (Mihaela x Dwarf Moneymaker) x Mihaela, 20 - BC_2 F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymaker.

Fruit height (Figure 3. A). Presented values within 35,7…77,2 mm in parents; 42,9…69,0 mm in F_1 and 40,6…77,7 mm in segregating populations F_2 and BC. Significant differences were established in BC_1 F_1 (Mihaela x Irişca) x Mihaela.

Fruit diameter (Figure 3. B). Included values within 34,2…47,5 mm in parents; 34,7…44,7 in hybrid combinations F_1 and 33,7…49,3 in hybrids F_2 and BC. Significant differences were recorded in F_2 Mihaela x Dwarf Moneymaker) and BC_1 F_1 (Mihaela x Dwarf Moneymaker) x Mihaela

Number of locules (Figure 3. C). Varied within 2,9…2,0 in plant varieties; 2,1…2,7 in hybrids F_1 and 2,0…3,2 in hybrids F_2 and BC. Significant differences were established in segregating populations - F_2 Maestro x Dwarf Moneymaker, BC_1 F_1 (Maestro x Dwarf Moneymaker) x Maestro.

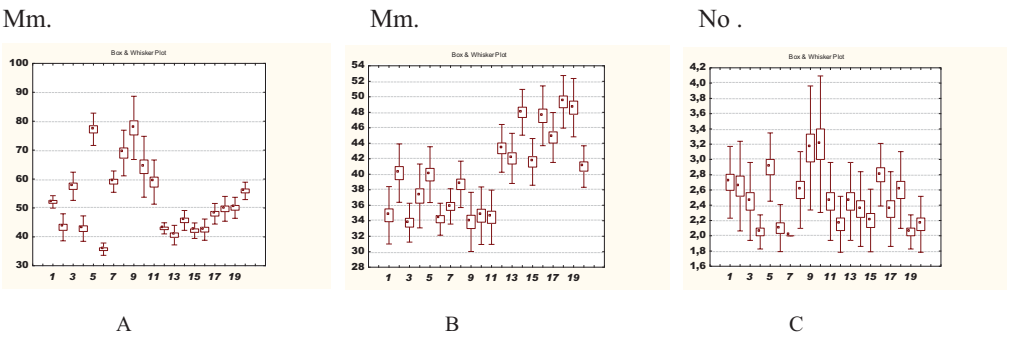

Fig. 3. Comparative data of fruits per plant height (A), fruit diameter (B), the number of locules (C) in parental and hybrid populations (2010)

1 - F_1 Maestro x Irişca, 2 - F_2 Maestro x Irişca, 3 - BC_1 F_1 (Maestro x Irişca) x Maestro, 4 - BC_2 F_1 (Maestro x Irişca) x Irişca, 5 – Maestro, 6 - Irişca, 7 - Dwarf Moneymaker, 8 - F_1 Maestrox Dwarf Moneymaker, 9 - F_2 Maestro x Dwarf Moneymaker, 10 - BC_1 F_1 Maestro (x Dwarf Moneymaker) x Maestro, 11 - BC_2 F_1 (Maestro x Dwarf Moneymaker) x Dwarf Moneymaker, 12 - F_1 Mihaela x Irişca, 13 - F_2 Mihaela x Irişca, 14 - BC_1 F_1 (Mihaela x Irişca) x Mihaela, 15 - BC_2 F_1 (Mihaela x Irişca) x Irişca, 16 – Mihaela, 17 - F_1 Mihaela x Dwarf Moneymaker, 18 - F_2 Mihaela x Dwarf Moneymaker, 19 - BC_1 F_1 (Mihaela x Dwarf Moneymaker) x Mihaela, 20 - BC_2 F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymaker.

Analysis of the data presented in Table 1 demonstrated essential differences of genotypes / populations by variability of evaluated characters. A rather sufficient diversity was revealed in plant height depending on both, genotype and climatic conditions, which gave us possibility to choose genotypes for creating new varieties more suitable to carry out mechanized tillage. The average variation coefficients for characters of the plant height and number of branches were 21,0 and 19,5%, which showed that the characters were environmental variables. *The number of fruits per plant and weight of fruits per plant* in analyzed tomato forms were 36,5 and 37,1 which demonstrated the pronounced variability of characters. Variability in the number of fruits per plant was more pronounced in varieties of Dwarf Moneymaker (34,4%), Mihaela (30,1%) while hybrid populations were within 23,6… 47,7%.

Table 1. Variability of some biological and productive tomato characters

Hybrid combinations and parental forms	Variation coefficient, %			
	Plant height, cm	Number of branches	Number of fruits per plant	Weight of fruits per plant
F_1 Maestro x Irişca	19,3	17,1	23,6	24,2
F_2 Maestro x Irişca	25,2	21,5	42,6	44,9
BC_1 (F_1 (Maestro x Irişca) x Maestro	24,0	23,0	46,4	49,2
BC_2 F_1 (Maestro x Irişca) x Irişca	23,3	20,6	32,6	38,4
Maestro	14,8	27,1	21,1	26,1
Irişca	24,5	21,5	23,6	33,5
Dwarf Moneymaker	13,6	17,9	34,4	35,6
F_1 Maestrox Dwarf Moneymaker	13,8	16,3	41,1	37,2
F_2 Maestro x Dwarf Moneymaker	17,9	18,6	41,9	42,1
BC_1 (F_1 Maestro x Dwarf Moneymaker) x Maestro	19,5	19,6	44,0	45,1
BC_2 (F_1 Maestro x Dwarf Moneymaker) x Dwarf Moneymaker	23,6	16,7	35,5	39,9
F_1 Mihaela x Irişca	15,9	15,5	30,3	34,2
F_2 Mihaela x Irişca	24,4	17,4	32,4	40,2
BC_1 (F_1 (Mihaela x Irişca) x Mihaela	12,9	20,2	36,6	39,8
BC_2 (F_1 (Mihaela x Irişca) x Irişca	23,4	18,6	40,7	48,1
Mihaela	12,7	26,3	30,1	18,9

Hybrid combinations and parental forms	Variation coefficient, %			
	Plant height, cm	Number of branches	Number of fruits per plant	Weight of fruits per plant
F_1 Mihaela x Dwarf Moneymaker	22,3	12,7	29,1	14,1
F_2 Mihaela x Dwarf Moneymaker	24,8	20,3	55,5	44,4
BC_1 (F_1 (Mihaela x Dwarf Moneymaker) x Mihaela	27,6	23,4	47,7	44,4
BC_2 (F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymaker	18,8	15,5	40,1	42,2
Environment	20,1±1,1	19,5±0,8	36,5±2,0	37,1±2,1

Among many features of the fruit the main feature was its weight, as it represented the economic value of the character. Requirements for the fruit size were different and determined by their use specificity and the trend towards tomatoes improvement. Big fruits were used mainly for fresh consumption and making juice. Lately, more attention was given to improving tomato plants with small and medium fruits, because they could be used both, fresh and for the food industry to prepare various products. Variability of the *fruit weight* was more pronounced in cultivar Irişa (29,9%) and segregating populations F_2 Maestro x Irişca (22,4%), Mihaela x Irişca (22,6%), BC_1 [F_1 (Maestro x Irişca) x Maestro] (26,5%), F_2 (Mihaela x Dwarf Moneymaker). The average variation coefficient of evaluated character was 20,1 indicating that the character was environmentally variable.

Requirements for the fruit shape were also different depending on the use and destination. The character had a special importance for mechanized cultivation. It's known that the degree of damage to the fruit as a result of mechanical cultivation depended both, on fruit density and form (length and width). Therefore, it was recommended to use egg shaped samples as they easily detached from the pedicel. The data obtained (Table 2) demonstrated slight variability of these characters. This allowed the character to be qualified of low variability, demonstrating its strong genetic determinism. Pericarp thickness was very important for determining the shape and quality of the fruit. Lately, improvements were targeted at obtaining tomatoes with medium or thick pericarp, which provided their safety when shipping for long distances. The forms assessed on this character differed essentially. Calculation of the variation coefficient showed a strong variability of the evaluated character where the average variation coefficient was 24.2%. Pericarp thickness variability was more pronounced in the cultivars Irişa (30,2%), Mihaela (21,3%), in hybrid combinations F_2 Maestro x Dwarf Moneymaker (34,1), (Maestro x Irişca) (28,6), backcrosses [F_1 Maestro (x Dwarf Moneymaker) x Maestro] (37,6%), [F_1 (Maestro x Irişca) x Maestro] (25,2%), [F_1 (Mihaela x Irişca) x Irişca] (24,8%).

The number of seminal locules was a very important feature. Depending on the need of seeds quantity might be creates cultivars with small or big seminal locules Experimental results showed a wide range of variability in the number of locules in the analyzed cultivars / populations ranged within 0 to 27,8%. The average variation of this character was 18,7% which showed a rather high variability.

Table 2. Variability of some quantitative indices of tomato fruit in parents and hybrids

Hybrid combinations and parental forms	Variation coefficient, %				
	Fruits weight	Fruit height	Fruit diameter	Pericarp thickness	Number of locules
F_1 Maestro x Irişca	19,7	4,1	10,7	15,7	17,4
F_2 Maestro x Irişca	22,4	10,8	9,2	28,6	22,3
BC_1 (F_1 (Maestro x Irişca) x Maestro	20,0	8,5	7,4	25,2	20,8
BC_2 F_1 (Maestro x Irişca) x Irişca	16,9	10,2	11,1	19,1	10,7
Maestro	13,9	7,2	9,0	9,5	15,5

Hybrid combinations and parental forms	Variation coefficient, %				
	Fruits weight	Fruit height	Fruit diameter	Pericarp thickness	Number of locules
Irişca	29,9	5,9	6,0	30,2	14,8
Dwarf Moneymaker	14,9	6,3	6,3	17,3	0,0
F_1 Maestrox Dwarf Moneymaker	17,6	11,4	7,7	11,4	19,2
F_2 Maestro x Dwarf Moneymaker	20,1	14,1	11,2	34,1	25,7
BC_1 (F_1 Maestro x Dwarf Moneymaker) x Maestro	18,8	16,4	10,7	37,6	27,8
BC_2 (F_1 Maestro x Dwarf Moneymaker) x Dwarf Moneymaker	20,7	13,0	10,1	21,9	20,8
F_1 Mihaela x Irişca	10,3	4,5	7,1	16,1	17,2
F_2 Mihaela x Irişca	22,6	8,3	7,7	23,5	20,8
BC_1 (F_1 (Mihaela x Irişca) x Mihaela	16,2	7,5	6,1	17,9	20,8
BC_2 (F_1 (Mihaela x Irişca) x Irişca	26,5	6,3	7,2	24,8	18,6
Mihaela	15,6	8,6	8,1	21,3	14,6
F_1 Mihaela x Dwarf Moneymaker	20,6	7,4	7,2	10,6	20,8
F_2 Mihaela x Dwarf Moneymaker	31,9	8,6	6,9	14,1	19,2
BC_1 (F_1 (Mihaela x Dwarf Moneymaker) x Mihaela	24,6	7,2	7,7	15,8	10,7
BC_2 (F_1 (Mihaela x Dwarf Moneymaker) x Dwarf Moneymaker	18,0	5,4	6,5	10,3	17,2
Environment	20,1±1,2	8,6±0,7	8,1±0,4	20,2±1,8	18,7±1,0

One of the basic genetic indices that demonstrated the type of inheritance in F_1 generations was the degree of domination (hp). Study of the dominance degree of the biological elements and tomato productivity showed that the most of F_1 hybrids manifested intermediary domination and positive supra-domination of the character (Table 3). Our research showed that in 36 variants (4 hybrids F_1 x 9 characters) hp were positive for 67% of cases. This revealed predominant manifestation of the parents with high character values.

Table 3. The degree of dominance of tomato quantitative indices

Characters	Hybrid combinations			
	Maestro x Irişca	Maestro x Dwarf Moneymaker	Mihaela x Irişca	Mihaela x Dwarf Moneymaker
Plant height	+0,40	+1,10	-1,14	-1,74
Number of branches	-4,00	-2,00	+3,67	+1,67
Number of fruits per plant	+0,31	-0,07	+0,45	-0,11
Weight of fruits per plant	+1,03	+3,74	+2,16	+0,56
Fruit weight	+0,01	+0,22	-0,24	-0,18
Fruit length	-0,07	+0,67	+0,13	+1,43
Fruit diameter	-0,21	+0,09	+1,12	-0,34
Pericarp thickness	-0,82	+0,41	+0,37	+0,52
Number of seed locules	+0,50	+0,33	-1,00	-0,25

Heritability coefficient was a genetic trait that allowed determining the contribution of the genetic factor to the total phenotypic variability. In selection practice it is important to determine at the initial stages of hybrid combinations in which selection can be more effective. The heritability coefficients of the main quantitative characters of the studied combinations were shown in Table 4. The analysis of the obtained data showed a considerable variability of the heritability coefficient of the studied hybrids which, in a broad sense, ranged from 0.01 to 0.76%, and, in the narrow sense, - from 0.00 to 0.94. The highest heritability values at most characters were recorded in Maestro x Irişca combination.

Table 4. Heritability coefficient in large (H) and narrow (h^2) senses of tomato quantitative characters

Characters	Hybrid combinations							
	Maestro x Irişca		Maestro x Dwarf Moneymaker		Mihaela x Irişca		Mihaela x Dwarf Moneymaker	
	H	h^2	H	h^2	H	h^2	H	h^2
Plant height	0,50	0,30	0,40	0,10	0,58	0,49	0,06	0,12
Number of branches	0,45	0,04	0,25	0,06	0,14	0,00	0,55	0,05
Number of fruits per plant	0,73	0,26	0,02	0,18	0,08	0,07	0,71	0,32
Weight of fruits per plant	0,70	0,13	0,04	0,02	0,12	0,07	0,58	0,08
Fruit weight	0,04	0,26	0,01	0,00	0,76	0,10	0,65	0,58
Fruit length	0,79	0,01	0,48	0,29	0,67	0,17	0,31	0,40
Fruit diameter	0,03	0,18	0,39	0,10	0,09	0,15	0,09	0,19
Pericarp thickness	0,58	0,24	0,69	0,11	0,62	0,03	0,36	0,18
Number of locules	0,35	0,54	0,62	0,94	0,50	0,23	0,04	0,64

CONCLUSIONS

As a result of the analysis of the complex of 16 hybrid combinations created on the base of intraspecific hybridization there were obtained genotypes which differed by productivity, shape and size of the fruit and the pericarp thickness that might be used for obtaining new cultivars with valuable traits and high transportability.

Statistical calculations proved the veridity of differences between parents and F_1, F_2 hybrids and BC for 8 of 9 evaluated characters.

As a result of the analysis of the variation coefficient of quantitative characters from parents and hybrid combinations F_1, F_2 and BC it was found that in all hybrid combinations in respect of the number and fruit weight per plant the variation coefficient was high and more pronounced in the combination BC_1 F_1 (Maestro x Iriș ca) x Maestro (46,4 and 49,2%), F_2 Mihaela x Dwarf Moneymaker (55.4 and 44,4%), BC_1 F_1 (Mihaela x Dwarf Moneymaker) x Mihaela (47,7 and 44,4%, respectively).

The heritability coefficient of quantitative characters in broad and narrow senses depended largely on parental forms. The highest heritability values were recorded for the number and fruit weight per plant in combinations of Maestro x Iriș ca și Mihaela x Dwarf Moneymaker. High values of heritability for the pericarp thickness being within the limits of 0,39 to 0,69 demonstrated possibility to obtain forms with high transportability.

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EX·TERRA·AVRVM