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INHERITANCE OF YIELD COMPONENTS IN TOMATO

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The aim of the present study was to estimate, on the basis of diallel crossing, superior-parent heterosis, components of genetic variability and trait heritability for three yield components in tomato, and to perform the VrWr regression analysis. Six different tomato inbred lines originating from local and introduced breeding material were selected for the study. The hybrids expressed greater mean values for the majority of the traits than the inbred lines. The value of additive component of variance (D) was higher than the

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value of the dominant variance (H_1 and H_2) for the number of fruits per plant and the average fruit weight, while the value of the dominant component of variance was higher for the fruit weight per plant. Positive values of additive x dominant genetic effect interaction (F) for the observed traits point to a greater participation of dominant alleles in the inheritance of these traits, which was confirmed by the coefficients $H_2/4H_1$ (0.208-0.228) and by the ratio KD/KR being greater than unity (1.129-1.536). The values of the average degree of dominance $\sqrt{H_1/D}$, lower than unity for the number of fruits per plant and the average fruit weight, indicate that these traits were inherited by partial dominance. Furthermore, values of the degree of dominance greater than unity for the fruit weight indicate that this trait was inherited by dominance or superdominance. These conclusions were also confirmed by high values of the broad- and narrow-sense heritability that varied from 98.88% to 99.44%, i.e., from 45.06 to 87.51%, respectively, as well as, by the VrWr regression for the observed traits in the F_1 generation.

Key words: heritability, heterosis, regression analysis, tomato, yield components

INTRODUCTION

The tomato yield is a complex trait that encompasses several components that are quantitative in nature thee inheritance of which is polygenic. Investigation on inheritance of tomato yield and yield components is very important for breeding (ZDRAVKOVIĆ *et al.*, 2010). Phenotypic variability of the quantitative traits is *continuous* and caused by genotypic variability, variability due to the effects of environmental factors and their interaction. The analysis of *continuous* genetic variability cannot be based on the separation and measurement of a great number of individual genes, rather the gene effects have to be measured together in order to obtain basic information on the genetic nature of an observed trait by the use of complex biometric methods. The fruit weight, the number and weight of fruits per plant, and the diameter and the length of the fruits are the most important morphological and quantitative traits of the tomato fruit that directly or indirectly affect the tomato yield. These traits, as well as other quantitative traits, are under the influence of genetic factors, additive ones (KAMRUZZAHAN *et al.*, 2000 and HAYDAR *et al.* 2007), environmental factors, crop density (HIDAYATULLAH *et al.*, 2008), growing practices, mineral nutrition, soil properties, and their also interaction (SAEED *et al.,* 2008).

Estimated heterosis in relation to the average value of the superior parent and named it relative heterosis in contrast to absolute heterosis, where the actual magnitude of a quantitative trait of the F_1 generation was considered. The phenomenon of heterosis is not so frequent, and a case in which a progeny is more superior in all traits than a superior parent is even less frequent.

The correct estimation of the inheritance of traits can be realised only based on genetic variability and heritability. The heritability (h^2) could be considered in a broad and narrow sense. The definition of genetic parameters, which determinate heredity modes is a necessary precondition for establishing the suitable methodology for breeding (ZEČEVIĆ *et al*., 2007). Analysis of genetic variance components as well as regression analysis has been performed by using the methods according to (MATHER and JINKS, 1971).The aim of the present study was to determine heterosis, components of variability and inheritance of traits of the observed tomato genotypes based on mean values, and to perform the Vr/Wr regression analysis.

MATERIAL AND METHODS

The following six tomato inbreds were selected for crossing: 1. B-99 (an inbred originating from a local tomato population from Boljevac) 2. Ma-127 (an inbred originating from a local tomato population from Mali Zvornik) 3. M-29 (an inbred originating from a local tomato population from Mačva), 4. ZJ-17 (an inbred originating from a local tomato population from Zaječar) 5. Kz-13 (an inbred derived from the variety Kazanova) and 6. Az-09 (an inbred derived from the variety Arizona). The inbreds originate from local and introduced breeding material. Crossing was realised after the method of complete diallel crosses without reciprocal crosses. Parents and F_1 hybrids were analysed for the following traits: the average fruit weight, the number of fruits per plant and the fruit weight per plant (g). The average number of fruits per plant and the fruit weight per plant were determined on samples of 10 plants per replication, while the average fruit weight was estimated on samples of 20 fruits per replication for parents and hybrid combinations. The three-replicate trial was set up according to the randomised complete block design in Bijeljina in 2007. Superior-parent heterosis was estimated based on mean values. The components of genetic variance, the regression analysis, the narrow- sense heritability and broad-sense heritability were estimated.

RESULTS AND DISCUSSION

The observed tomato inbreds, originating from local and introduced breeding material, differed in the average values of the studied traits (Table 1 and Table 2).The number of fruits per plant was on average lower in the hybrids and varied from 16.79 (Az-09) to 41.97 (Kz-13) in the parents, while the corresponding values in their hybrids varied from 15.13 to 36.47 (ZJ-17 x Kz-13, Table 1). The average fruit weight varied inversely with the number of fruits. The variation interval in the parental inbreds, *i.e.* hybrids, ranged from 64.66 (Kz-13) to 231.63 g (Az-09), *i.e.* from 84.76 (B-99 x Kz-13) to 181.20 g (Ma-127 x Az-09), respectively. The fruit weight per plant (yield) varied from 2064.50 (ZJ-17) to 3418.24g (Az-09) in the inbreds and from 2027.79 (Ma-127 x ZJ-17) to 3705.59 g (M-29 x Az-09) in the hybrids. The highest values of heterosis were detected in the hybrids: B-99 x Az-09 for the number of fruits per plant, B-99 x Ma-127 for the average fruit weight and in ZJ-17 x Kz-13 for the fruit weight per plant (Table 3). Heterosis for the number of fruits per plant varied from -17.56 (Ma-127 x Az-09) to 19.21% (B-99 x Az-09). Heterosis for the average fruit weight was positive only in four hybrids and ranged from -31.39 (Kz-13 x Az-09) to 12.98% (B-99 x Ma-127). Furthermore, heterosis for the total fruit weight per plant was negative in the majority of tomato hybrids and varied from -22.34 (Ma-127 x Az-09) to 33.45% (ZJ-17 x Kz-13). High values of heterosis are the result of non additive genetic effects and are mainly obtained in cases when a superdominance genetic effect is important in the inheritance of a certain trait (ZDRAVKOVIĆ *et al*. 2000, SEČANSKI *et al.* 2004, HAYDAR *et al.,* 2007 and ŽIVANOVIĆ *et al.* 2007).

Table 1. Mean values of the studied tomato traits

Genotype	No. of fruit per plant	Fruit weight (g)	Fruit weight per plant (g)
B-99	27.01	107.74	2645.48
Ma-127	19.91	170.27	3085.41
M-29	23.42	127.71	2709.66
ZJ-17	21.88	104.64	2064.50
Kz-13	41.97	64.66	2418.40
Az-09	16.79	231.63	3418.24
B-99 x Ma-127	25.65	146.87	3261.36
B-99 x M-29	26.21	112.49	2551.33
B-99 x ZJ-17	23.48	107.27	2319.79
B-99 x Kz-13	28.66	84.76	2245.57
B-99 x Az-09	26.11	168.60	3923.59
Ma-127 x M-29	21.75	131.16	2576.72
Ma-127 x ZJ-17	21.58	102.17	2027.79
Ma-127 x Kz-13	31.51	85.16	2399.35
Ma-127 x Az-09	15.13	181.20	2525.29
M-29 x ZJ-17	24.70	114.56	2588.81
M-29 x Kz-13	28.98	100.63	2651.29
M-29 x Az-09	22.65	176.97	3705.59
ZJ-17 x Kz-13	36.47	91.22	2991.30
ZJ-17 x Az-09	22.84	150.53	3043.28
Kz-13 x Az-09	30.94	101.64	2811.67
LSD 0.05	1.32	9.49	166.38
LSD 0.01	1.76	12.69	222.61

Table 2: ANOVA, mean squares (MS) of tomato traits

Source of variation	df	No. of fruit per plant	Fruit weight	Fruit weight per plant
Replication	2	1.78	83.94	7470.57
Genotype	20	114.55**	4984.46**	763358.38**
Error	40	0.64	33.05	10166.17

** P≤0.01

Table 3. Heterosis (%) of tomato hybrids

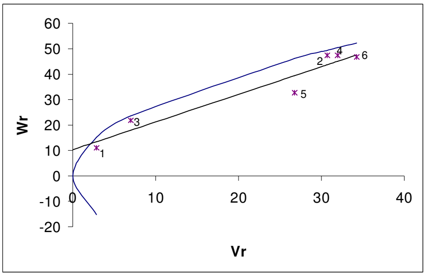
Genotype	No. of fruit per plant	Fruit weight	No. of fruit per plant
B-99 x Ma-127	9.34	12.98	13.82
B-99 x M-29	5.93	-4.44	-4.71
B-99 x ZJ-17	-3.94	1.01	-1.49
B-99 x Kz-13	-16.90	-1.66	-11.31
B-99 x Az-09	19.21	-0.55	29.41
Ma-127 x M-29	0.40	-11.96	-11.07
Ma-127 x ZJ-17	4.11	-25.67	-21.25
Ma-127 x Kz-13	1.84	-27.50	-12.81
Ma-127 x Az-09	-17.56	-9.83	-22.34
M-29 x ZJ-17	9.05	-1.39	8.45
M-29 x Kz-13	-11.36	4.62	3.40
M-29 x Az-09	12.67	-1.50	20.94
ZJ-17 x Kz-13	14.23	7.76	33.45
ZJ-17 x Az-09	18.13	-10.47	11.01
Kz-13 x Az-09	5.32	-31.39	-3.65

Values of the additive components of variance (D) were greater than the dominant ones (H_1 and H_2) for the number of fruits per plant and the fruit weight (Table 4). On the other hand, the dominant variance for the fruit weight per plant was greater than the additive variance. Similar results were obtained by HAYDAR *et al.* (2007). The positive values of the additive x dominant genetic effect interaction (F) for all observed traits indicate that the participation of the dominant genes in the inheritance of these traits was greater. This was confirmed by the coefficients of $H_2/4H_1$, which varied from 0.208 to 0.228, and by the ratios Kd/Kr being greater than unity (1.129, 1.536). Lower than unity values of the average degree of dominance $\sqrt{H_1/D}$ for the number of fruits per plant and the average fruit weight indicate that these traits were inherited by partial dominance. On the other hand, higher than unity values of the degree of dominance for the fruit weight per plant indicates that this trait was inherited by dominance or superdominance. This mode of inheritance for the observed traits could have been expected as the existence of a greater number of genes with a cumulative effect was already established for them in studies perfomed by IBARBIA *et al.* (1995) and BHARDWAY and SHARMA (2005). These conclusions were also confirmed by the high values of the broad-sense heritability, which varied from 98.88% to 99.44% and by the exceptionally low values of the narrow-sense heritability, as well as, by the values of the VrWr regression for the observed traits in the F_1 generation (Graphs 1,3). This was also corroborated by the results on broad-sense heritability for these traits obtained by HIDAYTULLAH *et al.*, (2008). Narrow-sense heritability was remarkably reduced in the fruit weight per plant (45.06%; Table 4). Approximate values and this mode of inheritance for the observed traits were presented by IBARBIA *et al.*, (1995) and HAYDAR *et al.*, 2007 in their studies. The relatively low values of narrow-sense heritability were caused by low additive genetic effects, greater effects of environmental factors and a high frequency of dominant alleles (MOHANTY, 2002). Similar values of heritability for these traits were presented by ZDRAVKOVIĆ *et al.*(2000), HAYDAR *et al.* (2007), HIDAYATULLAH *et al.* (2008) and SAEED *et al.* (2008).

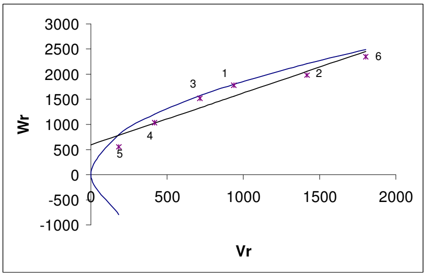
The regression lines are is close to a limiting parabola for the average fruit weight and the number of fruits per plant, which indicate to additive genetic effects for these traits (Graphs 1 and 2). This is in accordance with the calculated value of the average degree of dominance ($\sqrt{H_1 / D}$), which was lower than unity (Table 4). The regression line for the stated traits intersects the *Wr* ordinate above the point of origin (a > 0), which indicates a partial dominant gene action for the inheritance of these traits (Graphs 1 and 2). The scatter of the array points indicates to parental genetic divergence. According to the position of the parental genotypes in relation to the regression line and the remoteness from the point of origin it can be observed that inbreds Kz-13 and ZJ-17 were donors of a greater number of dominant genes for the average fruit weight, while the inbreds Ma-127 and Az-09 were donors recessive genes (Graph 1). The greater participation of dominant, *i.e.* recessive genes for the number of fruits per plant was recorded in inbreds B-99 and M-29, *i.e.* Ma-127, ZJ-17 and Az-09, respectively (Graph 2). The regression line for the fruit weight per plant intersects the *y* ordinate bellow the point of origin indicating superdominance in the inheritance of this trait (Graph 3). This is in accordance with the value of the average degree of dominance $\sqrt{H_1 / D}$ (Table 4), which was higher than unity.

Table 4. Components of genetics variability and heritability for tomato traits

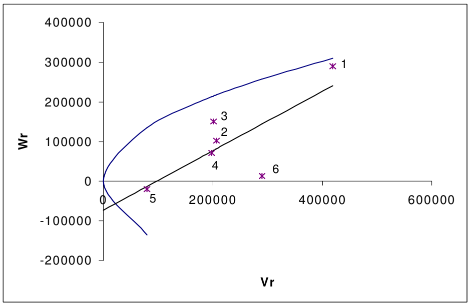
Components of genetics variance	No. of fruit per plant	Fruit weight	Fruit weight per plant
D	79.255	3437.83	226067.20
H1	29.887	925.340	745550.75
H2	27.222	770.473	649714.06
F	20.569	739.153	49850.650
E	0.212	11.017	3388.724
H2/4H1	0.228	0.208	0.218
U	0.649	0.705	0.679
V	0.351	0.295	0.321
$\sqrt{H_1 / D}$	0.614	0.519	1.816
Kd/Kr	1.536	1.523	1.129
Vp	79.470	3448.84	229455.920
Vr	22.270	912.430	232418.580
Wr	34.520	1535.96	101135.730
Vr	15.360	714.300	68296.700
h^2n.s.	0.8138	0.8751	0.451
h^2b.s.	0.9944	0.9932	0.989



Graph 1: VrWr regression for the fruit weight



Graph 2: VrWr regression for No. of fruit per plant



Graph 3: VrWr regression for the fruit weight per plant

CONCLUSION

Based on the diallel crosses (without reciprocal crosses) of six divergent tomato genotypes, the mode of inheritance and components of genetic variance for the number of fruits per plant, average fruit weight and the fruit weight per plant were determined. The studies were based on the data obtained by analyses of the parents and the F_1 generation. The observed genotypes differed significantly from each other. Heterosis for the total fruit weight per plant was negative in the majority of the hybrids. High heterosis is a result of the effects of non-additive genes. The analysis of the components of variance showed that the additive genetic effects mainly participated in inheritance of the number of fruits per plant and the average fruit weight, while the dominant variance for the fruit weight per tomato plant was greater than the additive variance. The number of fruits per plant and the fruit weight were inherited by partial dominance, while the fruit weight per plant was inherited be dominance or superdominance. These conclusions were also confirmed by the high values of the broad-sense heritability and the exceptionally low values of the narrow-sense heritability, as well as, by VrWr regression analysis. The estimated high heritability values also indicate to significant participation of additive genes. According to obtained results following conclusion can be drawn: genotypes with high mean values for the number of fruits per plant and the fruit weight should be selected in tomato breeding for yield.

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NASLEĐIVANJE KOMPONENATA PRINOSA PARADAJZA

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I z v o d

Cilj istraživanja je da se za tri komponenete prinosa paradajza procene: heterozis u odnosu na boljeg roditelja, komponente genetičke varijabilnosti, heritabilnosti osobina na bazi dialelnog ukrštanja i izvrši VrWr regresiona analiza. Odabrano je šest različitih linija paradajza poreklom iz domaćeg i introdukovanog selekcionog materijala. Hibridi su u odnosu na linije ispoljili veće srednje vrednosti za većinu osobina. Vrednost aditivne komponente varijanse (D) veća je od dominantne (H_1 i H_2) za broj plodova po biljci i prosečnu masu ploda, dok je za masu ploda po biljci dobijena veća vrednost dominantne komponete varijanse. Pozitivne vrednosti interakcije aditivni x dominantni efekat gena (F) za ispitivane osobine ukazuju da je u nasleđivanju ovih osobina veće učešće dominantnih alela, a to potvrđuju i koeficijenti $H_2/4H_1$ (0,208-0,228) kao i odnos Kd/Kr koji su veći od jedan (1,129-1,536). Vrednosti prosečnog stepena dominacije $\sqrt{H_1/D}$ manje od jedan (broj plodova po biljci i prosečna masa ploda) ukazuju da se ove osobine nasleđuju parcijalnom dominacijom. Za masu ploda po biljci vrednosti stepena dominacije veći je od jedan, što ukazuje da se ova osobina nasleđuje dominacijom ili superdominacijom. Ove zaključke potvrđuju i visoke vrednosti heritabilnosti u širem i užem smislu koje su varirale od 98,88% - 99,44%, odnosno 45,06-87,51%, kao i VrWr regresije za ispitivane osobine u F_1 generaciji.

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