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THE IMPORTANCE OF EARLINESS FOR CREATING NEW *ms* F_1 PEPPER HYBRIDS

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Breeding new line pepper genotypes is an important goal for the Institute for Vegetable Crops, Smederevska Palanka. Years of selection resulted in great number of varieties, however, the selection of F_1 pepper hybrids started recently. Pepper F_1 hybrids have proved to be better than cultivars in the terms of earliness, yield, plant uniformity, pathogen resistance etc. Considering significant heterosis values for earliness, this paper deals with the genetic analysis of F_1 and F_2 pepper hybrids, obtained by crossing four lines, including *ms* line HM-6.

Key words: pepper, selection, hybrid, earliness, *ms* line

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INTRODUCTION

Glass and plastic greenhouse vegetable production has increased in the last ten years in Serbia. Pepper, as one of the most important vegetables, occupies a significant percentage of the area. The increasing demand for early high-quality varieties adapted to greenhouse production motivated the breeders from the Institute of Vegetable Crops, Smederevska Palanka to create commercial F_1 hybrids with improved morphological and production characteristics, by creating sterile *ms* lines with *ms3* gene.

Heterotic effects noted for the number of pepper traits (earliness, number of fruits per plant, fruit length, yield) should be utilized, especially in terms of creating F_1 hybrids intended for greenhouse production (MAK 1987**,** MAMEDOV and PYSHNAJA 1995).

Since early flowering can substantially enhance yield in various types of pepper (RAO *et al***.** 2003), one of the most important traits included in the great majority of pepper breeding programs is the length of the vegetation period (BERNARD**,** 1973). The trait is considered as quantitative and controlled by major genes. The better performance of F_1 hybrids created on the basis of genetic male sterility of mother line (*ms8* gene) justifies the efforts and the invested funds. The hybrids may demonstrate significantly higher heterosis values for earliness and yield (25-36 and 22-72%, respectively) comparing to cultivars (CVIKIĆ *et al.* 2006a). Registered hot pepper hybrid Sirena F_1, created at the Institute for Vegetable Crops, is characterized by high heterosis values for earliness, number of fruits per plant, pericarp thickness and yield (CVIKIĆ *et al***.** 2006b).

The study was undertaken in order to investigate earliness inheritance pattern in genotypes obtained by crossing five lines of pepper.

MATERIAL AND METHODS

Five genetically divergent pepper lines (KP-01, KP-03, S-15, CH-1 and HM-6), differing in earliness, have been intercrossed (full diallel, without reciprocal crosses). The genotypes are pure lines, created at the Institute for Vegetable Crops, Smederevska Palanka. HM-6 is nuclear male sterile line, obtained by self-pollination of a foreign hybrid. The line is classified in subspecies *macrocarpum*, variety *longum*.

Both F_1 and F_2 generations have been produced in greenhouse conditions, in 2005 and 2006 growing seasons. Comparative field trial including parents, F_1 and F_2 hybrids was set in random block design, with three replications. The trial was conducted in the pepper growing season of 2007. Standard agrotechnical procedures have been applied.

Earliness is expressed as the number of days from initial stage of emergence to initial stage of flowering. Flowering date was recorded as the date when opening of the first flower has been observed for 50% plants from the plot.

Standard deviation (*Sx*) and coefficient of variation (*Cv*) have been calculated for parents, F_1 and F_2 generation. Earliness inheritance pattern was determined using scheme given by BOROJEVIĆ (1992). Absolute (*Ha*) and relative

(*Hr*) heterosis was estimated on the basis of parental mean values. Genetic variance was partitioned by MATHER AND JINKS (1971) statistical method. Combining ability of the parental lines that have been included in the study was analyzed using Method 2, Mathematical model 1 (GRIFFING 1956). The method includes parents and *F1* or *F2* generation.

RESULTS AND DISCUSSION

Earliness is a very important pepper trait. Introducing early genotypes in greenhouse production may enlarge pepper growing area and therefore provide greater economic gains. There are three main groups of pepper cultivars, formed on the basis of the length of the vegetation period: early (120 days between emergence and physiological maturity), medium early (120-140 days) and late (>140 days), according to HRISTOV *et al.* (1966).

Mean values, standard deviations, coefficients of variation and heterosis values for earliness of the tested genotypes are listed in Table 1. Among parents, the earliest initial flowering occurred for S-15 (80.1 days) and the latest for CH-1 (90.4 days). The earliest (S-15 x HM-6) and latest (KP-03 x S-15) *F1* hybrid flowered 78.6 and 87.8 days after emergence, respectively. For F_2 generation, initial flowering was recorded in the range from 78.7 (KP-01 x S-15) to 86.5 days (KP-03 x S-15).

Coefficient of variation was in the range from 0.63 (KP-03) to 1.39% (HM-6) for parents. The low coefficient of variation values imply uniformity and stability, concerned with high homozygosity. Slightly higher values of coefficients of variation were noted for F_1 generation (from 1.40 to 3.02%, SP-15 x HM-6 and CH-1 x HM-6, respectively), whereas genotypes belonging *F2* generation varied to the greatest extend (from 3.03 to 6.20%, KP-01 x KP-03 and S-15 x HM-6, respectively).

Mode of the inheritance pattern was analyzed on the sample of ten F_1 pepper hybrids. Superdominance of the earlier parent was confirmed for four hybrids, dominance of the earlier parent for three hybrids, whereas intermediate inheritance pattern occurred for one hybrid. For nine of the ten studied hybrids the estimated heterosis values were negative, which is a favorable from breeder's point of view. Pepper fruit traits are mostly inherited independently from plant growth characteristics (including earliness), offering large degree of freedom in breeding different early ideotypes (BARCHI *et al.* 2009). The highest value of negative heterosis (-6.80%) was noted for KP-01 x CH-1 cross combination. The estimated heterosis values for F_2 generation were insignificant. Heterosis for earliness in pepper was confirmed in studies performed by JOSHI (1986), MAC (1987), MISHRA *et al.* (1988), KORDUS (1991) and CVIKIĆ ***et al.*** (2006). Similarly, MARAME *et al.* (2009) reported negative heterosis for number of days to maturity in hot pepper.

Table 1. Mean values ± standard deviations (X± Sx), coefficients of variation (Cv), absolute (Ha) and relative (Hr) heterosis for earliness in full diallel of five pepper genotypes

Genotypes	**F_1**		F_2		*Ha*		**Hr**	
	X ±*Sx*	*Cv* (%)	*X* ±*Sx*	*Cv* (%)	F_1	F_2	F_1	F_2
KP-01	83.4 0.44	0.91	83.4 0.44	0.91				
KP-01x KP-03	82.6^{d-} 0.96	2.02	82.9 1.97	4.13	-3.25*	-2.95	-3.78	-3.44
KP-01x S-15	79.2^{Sd-} 1.28	2.80	78.7 1.38	3.03	-2.55	-3.05	-3.12	-3.73
KP-01x CH-1	80.1^{Sd-} 0.92	1.99	82.1^{Sd-} 1.89	3.98	-6.80**	-4.80	-5.02	-5.52
KP-01x HM-6	80.4 0.65	1.40	82.2 2.61	5.50	-4.15*	-2.35	-4.91	-2.78
KP-03	88.3 0.32	0.63	88.3 0.32	0.63				
KP-03 x S-15	84.8^{i} 0.95	2.05	86.5^{i} 2.57	5.15	0.60	2.30	0.71	2.73
KP-03 x CH-1	87.8 1.11	2.19	83.5 2.31	4.80	-1.55	-5.85	-1.73	-6.55
KP-03 x HM-6	81.9 0.85	1.78	82.4 1.86	3.91	-5.10**	-4.60	-5.86	-5.29
S-15	80.1 0.52	1.12	80.1 0.52	1.12				
S-15 x CH-1	81.8^{d-} 0.99	2.11	82.2^{Pd-} 2.53	5.33	-3.45*	-3.05	-4.05	-3.58
S-15 x HM-6	78.6^{Sd-} 0.63	1.40	79.2^{d-} 2.84	6.20	-4.30**	-3.70	-5.19	-4.46
CH-1	90.4 0.33	0.63	90.4 0.33	0.63				
CH-1 x HM-6	83.9^{Sd-} 1.47	3.02	85.8 2.46	4.97	-4.15*	-2.25	-4.71	-2.55
HM-6	85.7 0.69	1.19	85.7 0.69	1.19				

F_1 $lsd_{0.05} = 3.12$ F_2 $lsd_{0.05} = 6.64$

$lsd_{0.01} = 4.16$ $lsd_{00.1} = 8.83$

[i] intermediary inheritance, [Pd] partial dominance, [d] dominance, [Sd] superdominance

The results of the analysis of the components of genetic variance are given in Table 2. For F_1 generation, higher values for dominant (H_1 and H_2) comparing to additive (D) components of variance were estimated, implying dominant gene action as the main source of genetic variability. In addition, additive x dominance gene interaction (F) was positive and dominant/recessive allel ratio (Kd/Kr) was higher than 1, implying the prevalence of dominant allels. Dominant and recessive allels were unevenly distributed among parents ($H2/4H1$ = 0.22).

Table 2. Components of genetic variance for earliness in pepper

Components	Value F_1	Value F_2
D	15.236	10.951
H_1	18.713	11.082
H_2	16.842	12.840
F	1.460	1.249
E	1.221	5.505
$H_2/4H_1$	0.225	0.290
$\sqrt{H_1/D}$	1.108	1.006
Kd/Kr	1.090	1.120
hu^2	0.590	0.313
hs^2	0.910	0.566

The average dominance level ($\sqrt{H_1/D}$) was higher than 1, implying superdominance as the mode of inheritance of earliness in pepper, considering all cross combinations. The estimated narrow and broad sense heritability values were 0.59 and 0.91, respectively.

Similar results have been obtained analyzing F_2 generation. Dominance genetic variance prevailed additive. Positive F value and Kd/Kr ratio that is higher than 1 clearly demonstrate the higher frequency of dominant allels. The average dominance level was higher than 1, confirming superdominance as mode of inheritance for earliness in pepper; however, additive gene effects were also significant. The prevalence of dominant allels over the additive in inheritance of pepper earliness was reported by ZEČEVIĆ *et al.* (2003).

Analysis of variance of combining abilities provides precise analysis of the components of genetic variance and gene effects (Table 3). Significant general combining abilities were confirmed for both F_1 and F_2 generation. Special combining abilities were significant for F_1 generation only. The estimated general combining ability values were 4.12 and 2.97 (for F_1 and F_2 generation, respectively) times higher than the corresponding special combining ability values, implying the prevalence of additive gene effect.

Table 3. Analysis of variance of combining abilities of five pepper genotypes for earliness

Source of variation	df	SS		MS		F-exp	
		F_1	F_2	F_1	F_2	F_1	F_2
GCA	4	109.869	81.435	27.467	20.359	22.50**	3.69*
SCA	10	66.699	68.597	6.670	6.860	5.46**	1.24
Error	28			1.220	5.505		
GCA/SCA				4.12	2.97		

GCA $F_{0.05} = 2.71$ $F_{0.01} = 4.07$

SCA $F_{0.05} = 2.19$ $F_{0.01} = 3.03$

Among the five studied pepper genotypes and two filial generations, the highest general combining ability value was noted for line S-15. General combining ability value was significant also for F_1 generation of line KP-01, at the 0.05 level of probability. The lowest general combining ability value had CH-1 (Table 4).

Table 4. General combining ability (GCA) values of pepper parental lines for earliness

Parents	Value of SCA F_1	Rank	*Se*	Value of SCA F_2	Rank	*Se*
KP-01	-1.494*	2		-1.226	2	
KP-03	2.024	4		1.508	4	
S-15	-2.156**	1	0.591	-2.092	1	1.254
CH-1	2.115	5		1,865	5	
HM-6	-0.489	3		-0.054	3	

$lsd_{0.05}$= 1.18 $lsd_{0.05}$=2.51

$lsd_{0.01}$= 1.57 $lsd_{0.01}$=3.34

Se - standard error

For F_1 generation, the highest special combining ability had KP-01 x CH-1 combination. Significant special combining ability value was also noted for KP-03 x HM-6 hybrid, at the 0.05 level of probability. Negative special combining ability values were noted for another six cross combinations, however, the values were insignificant. For F_2 generation, eight cross combinations had negative, however insignificant, special combining ability values. The results may be explained by the effect of additive genes (Table 5).

Table 5. Special combining ability (SCA) values of F_1 and F_2 generations obtained by crossing five pepper lines, for earliness

Genotypes	SCA F_1	*Se*	SCA F_2	*Se*
KP-01 x KP-03	-1.235		-0.973	
KP-01 x S-15	-0.420		-1.506	
KP-01 x CH-1	-3.759**		-2.097	
KP-01 x HM-6	-0.887		-0.078	
KP-03 x S-15	1.660	1.320	3.493	2.804
KP-03 x CH-1	0.389		-3.463	
KP-03 x HM-6	-2.840*		-2.578	
S-15 x CH-1	-1.430		-1.130	
S-15 x HM-6	-2.025		-2.244	
CH-1 x HM-6	-0.997		0.465	
	$lsd_{0.05} = 2.64$		$lsd_{0.05} = 6.61$	
	$lsd_{0.01} = 3.51$		$lsd_{0.01} = 7.46$	*Se* - standard error

CONCLUSION

Considering all studied pepper cross combinations and two filial generations, superdominance is the earliness mode of inheritance pattern. The best general combining abilities were noted for lines S-15 and KP-01, therefore, the lines should be exploited in further breeding programs aimed to short the period between emergence and flowering. Significant heterotic effects were noted for 7 F_1 hybrids. Heterotic effects were insignificant for F_2 generation. Two F_1 hybrids with significant special combining abilities imply the exploitation of heterosis as a promising method for creating early pepper genotypes. Hybrid combination KP-03 x HM-6 is currently in the process of registration.

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ZNAČAJ RANOSTASNOSTI U KREIRANJU NOVIH *ms* F_1 HIBRIDA PAPRIKE

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I z v o d

U Institutu za povrtarstvo iz Smederevske Palanke započet je program selekcije F_1 hibrida paprike. Prednosti hibrida su u ranostasnosti, većem prinosu, ujednačenosti habitusa biljaka i plodova, većoj otpornosti prema bolestima i dr. Obzirom na značajno ispoljavanje heterozisa za osobinu ranostasnosti u ovom radu prikazana je genetička analiza za navedenu osobinu F1 i F2 hibrida u ukrštanjima četiri linije paprike sa *ms* linijom HM-6. Na taj način, pokušali smo da damo odgovore poljoprivrednim proizvođačima koji se u poslednje vreme sve više bave proizvodnjom paprike u zaštićenom prostoru. To su upravo nove sorte i hibridi paprike ranijeg stasavanja, čiji plodovi znatno ranije pristižu za berbu.

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