UDC 575:633.842
DOI: 10.2298/GENSR1102209Z
Original scientific paper

INFLUENCE OF PARENTAL GERMPLASM FOR FRUIT CHARACTERS IN F_1, F_2 AND F_3 GENERATIONS OF PEPPER (*Capsicum annuum* L.)

Bogoljub ZEČEVIĆ[1], Radiša ĐORĐEVIĆ[1], Ahmet BALKAYA[2], Jelena DAMNJANOVIĆ[1], Mladen ĐORĐEVIĆ[1] and Ana VUJOŠEVIĆ[3]

[1]Institute for Vegetable Crops, Smederevska Palanka, Serbia
[2]Ondokuz Mayis University, Faculty of Agriculture. Kurupelit – Samsun, Turkey
[3]Faculty of Agriculture Belgrade – Zemun

Zečević B., R. Đorđević, A. Balkaya, J. Damnjanović, M. Đorđević and A. Vujošević (2011): *Influence of parental germplasm for fruit characters in F_1, F_2 and F_3 generations of pepper (Capsicum annuum L.).* - Genetika, Vol 43, No. 2, 209 -216.

The aim of this research was to determine genetic values for the fruit width and fruit length in F_1 and F_2 generation of diallely crossed pepper genotypes, and to evaluate the effects of applying the *pedigree* and *bulk* breeding method for producing F_3 hybrid populations. Hybrid populations were formed by crossing divergent genotypes belonging to different varieties of species *Capsicum annuum* L. The research of parental lines lasted for three years, experiments with F_1 generation two years, while the

Corresponding author: Bogoljub Zečević, Institute for Vegetable Crops, Karađorđeva 71, 11420 Smederevska Palanka; tel.: 026317170, fax: 026317785; e-mail:bogoljub.zecevic@gmail.com

analysis of results for F_3 hybrid population has been done regarding the data from one year experiment. The heterosis effect in F_1 generation for all researched traits and in all crossing combinations was very low. Genetic analysis of F_2 generation showed that all researched traits were inherited with partial domination. In F_3 generation, hybrid populations formed by using the *pedigree* method of selection had traits which are more valuable for further breeding than the hybrid population formed by using modified *bulk* method.

Key words: bulk method, genetic analysis, pedigree method, pepper

INTRODUCTION

Pepper (*Capsicum annum* L.) is an important vegetable crop around the world and it is very popular in Serbia. Peppers (*Capsicum* spp.) have been grown for several thousand years in the Americas (ZEWDIE and ZEWEN, 1997). Since their introduction into the old world, peppers are cultivated in various environments and a number of different types were developed (GOVINDARAJAN, 1986). There is significant variation in fruit size, fruit shape, colour and the length of time to reach harvest. Variation in yield and quality are major issues and these are determined by genetic and environmental factors. For this reason, determination of the effects of genotypic factors in pepper breeding is a primary concern (CANKAYA *et al*., 2010). Despite the high genetic variability of others C*apsicum* species a large number of traits for almost all studies on this genus have been carried out with *C. annuum* (SOUZA and MALUF, 2003). One of the main characters of pepper production in Serbia is presence an abundance of different pepper types. Diversity of *Capsicum annuum* L. enables applying of various methods of research work (ZECEVIC *et al*., 2007). Genetic divergence existing in the population helps in the selection of suitable parents for utilization in pepper crop breeding programs (THUL *et al*., 2009). One of the basic methodologies of breeding of certain cultivar is a hybridisation since it attains the direct results, such as: genetic variability of progeny, heterosis and fixation of desirable traits, i.e. genes in progeny. Diallel crossing, as one of the methods enables evaluation of parents and gives information regarding the genetic control of quantitative traits which is important for choosing breeding methods (ZEČEVIĆ *et al*., 2003). In addition, diallel crossing gives significant data of heritability and heterosis, and those data are used in predicting the performances of synthetic population. Heterosis has been widely used in agriculture to increase yield and to broaden adaptability of hybrid varieties (MEYER *et al*., 2004). The phenomenon of heterosis is not present in all hybrid combinations of the F1 generation, however, and heterotic effects differ from trait to trait (HLADNI *et al*., 2005). RAJESH and GULSHAN (2001) reported the variation of magnitude of heterosis for different characters of hot peppers in different crosses due to varying extent of genetic diversity of parents involved in crossing. GELETA *et al*. (2004) stated that very closely or distantly related parents showed low heterosis, but crosses between parents of intermediate divergence classes tended to show higher heterosis affect for fruit yield, fruit length and fruit weight. Elite hot pepper genotypes can be utilized in

a systematic breeding program to address the critical hot pepper production constraints (MARAME *et al*., 2009). The program of this study was based on diallel crossing where parent genotypes represent the basic factor for determination of traits in progeny and the possibilities for further breeding. The main aim of the research was to determine the influence of parental germplasm on F_1, F_2 and F_3 progeny.

MATERIALS AND METHODS

The study comprised five genetically different categories of pepper material: inbred lines – parents, F_1 generation, F_2 generation and within F_3 generation two differently formed hybrid populations. Inbred lines of pepper have been chosen for this research from the Institute for Vegetable Crops collection, regarding their agriculturally most important traits:

KP003 – inbred line of Palanacka babura. It belongs to the subspecies *macrocarpum*, variety *grossum* and type *dolma*. This line has bell shaped, hanging fruits and mid early maturity. Fruits are sweet, 5.35 cm wide; 8.60 cm long and the pericarp is 0.51 cm thick. Fruits are milk white in technological and red in biological maturity. Inbred line is early ripening.

KP042 – inbred line of Palanacka kapija. It belongs to the subspecies of *macrocarpum*, variety *longum* and type kapija. This line has hanging, elongated, sweet fruits 3.70 cm wide; 15.20 cm long and the pericarp is 0.40 cm thick. Fruits are green in technological and dark red in biological maturity. Inbred line has mid-season maturity.

KP068 – inbred line of Kobra. It belongs to the subspecies *microcarpum*, variety *shipca*. This line has narrow, elongated, hanging, hot fruits 1.90 cm wide; 13.50 cm long; and pericarp is 0.19 cm thick. Fruits are dark green in technological and red in biological maturity. Inbred line is early ripening.

KP075 – inbred line of Feferona zuta ljuta. It belongs to the subspecies *microcarpum*, variety *shipca*. Fruits are pepperoni type, upright, 0.90 cm wide; 8.30 cm long; and the pericarp is 0.10 cm thick. In technological maturity fruits are dark green and yellow in biological. Inbred line is early ripening.

Experiment was laid down in randomized block design with three replications at the experimental field and greenhouse of the Institute for Vegetable Crops during 2001-2004. Heterosis was calculated regarding mean value of parents (H_1) and regarding better parent (H_2). Analysis of genetic variance components as well as regression analysis has been performed by using the methods according to MATHER and JINKS (1971). In this study were applied bulk and pedigree methods of selection. Selection differential expressed as deviation from middle value to basic population from which a selection was performed. Genetic gain was calculated according to heritability, phenotypic standard deviation and selection differential for percent of individuals in whole population (ALLARD, 1960).

RESULTS AND DISCUSSION

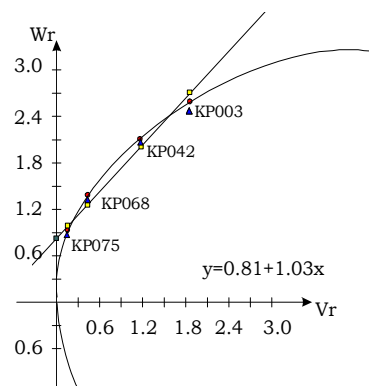
The analysis of data for fruit width shows that developed hybrids almost did not have positive heterosis for this trait. Only one combination of crossing between

KP068 and KP075 showed positive heterosis, when compared to middle value of parents. The registered heterosis was statistically significant. NARASIMHAPRASAD *et al*., (2003) and GELETA and LABUSCHAGNE (2004) found the same results researching heterosis for width in hybrids developed by crossing genotypes from different pepper varieties. Data for fruit length show that heterosis compared to the mean value of one hybrid (KP003 x KP075), it was statistically high. NANDADEVI and HOSAMANI (2003), NARASIMHAPRASAD *et al*., (2003) and SAVITA (2004) agree that the heterosis for fruit length is low. MARAME *et al*., (2009) concluded that various ranges of minimum to maximum better-parent heterosis and corresponding average heterosis were obtained, respectively and included for fruit width (-38.19 to 50.29% and 6.75%) and fruit length (-23.78 to 26.59% and 13.92%).

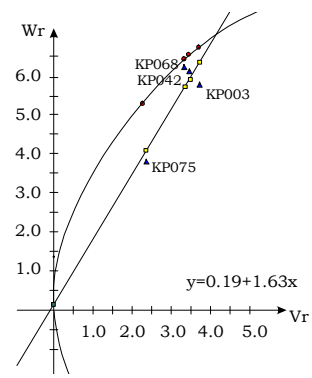
Table 1. - Middle value of F_1 generation and heterosis for fruit width and fruit length

Hybrids	Fruit width			Fruit length		
	$\bar{x}$	Hmp	Hbp	$\bar{x}$	Hmp	Hbp
KP003 x KP042	4.3	- 6.1	- 22.4*	13.7	10.1	- 14.2
KP003 x KP068	3.2	- 15.8*	- 41.9**	12.1	11.5	- 9.8
KP003 x KP075	2.5	- 23.9*	- 54.7**	10.5	26.9*	22.3*
KP042 x KP068	1.8	- 30.3**	- 45.7**	16.0	10.5	6.6
KP042 x KP075	1.8	- 27.2**	- 59.7**	12.6	4.7	- 21.3**
KP068 x KP075	1.4	8.0**	- 24.5**	12.4	15.0	- 4.2

The analysis of fruit width and the analysis for fruit length showed that partial domination is a heredity mode. These results clearly point that in the crossing of genotypes from different pepper varieties should be used only genotypes with high mean values for breeding trait. ZAMBRANO *et al*., (2005), REGO *et al*., (2009), SOH *et al*., (2009) and ZEČEVIĆ *et al*., (1999) found similar results.



Graph 1. - VrWr regression for fruit width



Graph 2. - VrWr regression for fruit length

Our further work was to analyse the F_3 generation and the dynamic of changing after applying two different methods of selection. Regarding the fact that the F_2 generation has the maximum number of gene combinations it is reasonably that the F_2 generation presents a great background where is possible on the best way make a selection of plants for further breeding work.

The selection in mixture, i.e. bulk method, is simple, suitable and rational. Number of generations grown in mixture after hybridization can vary. It can start from F_5 generation (original variant) or F_3 and F_4 generation (modified variants). In our research we tried to go one step forward and select plants from F_2 generation. Mixture of seed of selected plants was grown for one year and the analysis of F_3 generation showed: Generally, fruit width was not improved in F_3 generation. The greatest genetic gain was in hybrid populations KP003 x KP042. The other hybrid populations showed a decreasing value for this trait, except hybrid population KP042 x KP075 where did not registered change regarding to fruit width. Increase of fruit length or realized genetic gain was found in three hybrid populations, KP042 x KP068, KP042 x KP075 and KP068 x KP075. The greatest genetic gain was in combination of crossing between KP042 and KP075. Population KP003 x KP068 had the same fruit length in F_3 generation. Hybrid populations KP003 x KP042 and KP003 x KP075 had decreasing value for fruit length.

Table 2. - Middle phenotype value of parental hybrid populations and genetic gain for fruit width and fruit length in F_3 generation by applying bulk method

Hybrid population	Fruit width			Fruit length		
	A	R_0	R	A	R_0	R
KP003 x KP042	4.0	3.8	0.2	12.8	13.7	- 0.8
KP003 x KP068	2.6	3.1	- 0.5	11.9	11.8	0.1
KP003 x KP075	2.1	2.3	- 0.2	11.0	11.2	- 0.2
KP042 x KP068	2.5	2.6	- 0.1	15.2	15.1	0.1
KP042 x KP075	1.9	1.9	0.0	12.3	11.5	0.8
KP068 x KP075	1.3	1.6	- 0.3	11.5	11.1	0.4

The *pedigree* method is more common method in the research work than *bulk* method. In this research we tried to shorten the *pedigree* method and to keep its efficiency at the same time. Plants from F_2 generation were selected for each researched trait. The F_3 generation from every hybrid population originates from the most expressive plant for certain trait. The greatest genetic gain for fruit width was registered in hybrid population: KP042 x KP068 with 37.31%. Regarding to the data for heritability it can be conclude that hybrid populations KP042 x KP068 (0.91), KP003 x KP075 (0.70) i KP042 x KP075 (0.78) have high values, hybrid population KP068 x KP075 (0.39) has moderate value, while populations KP003 x KP042 (0.19) i KP003 x KP068 (0.25) have low values of heritability for fruit width. The greatest genetic gain for fruit length had combination KP042 x KP075 (19.53%). The lowest genetic gain had KP003 x KP042 (2.62%). Regarding to the mean value for

fruit length it has to be underlined combination between KP042 and KP068 (16.98cm). This hybrid population had the highest value for heritability.

Table 3. - Heritability, genetic gain and middle value for fruit width and fruit length in F3 generation by applying pedigree method

Hybrid population	Heritability		Genetic gain (%)		Middle value (g)	
	f.width	f.length	f.width	f. length	f.width	f. length
KP003 x KP042	0.19	0.29	1.23	2.62	4.27	13.47
KP003 x KP068	0.25	0.55	2.21	8.82	2.78	13.25
KP003 x KP075	0.70	0.29	12.91	3.61	2.04	12.21
KP042 x KP068	0.91	0.49	37.31	8.07	2.75	16.98
KP042 x KP075	0.78	0.81	23.42	19.53	1.97	12.57
KP068 x KP075	0.39	0.39	7.59	6.85	1.29	10.06

General conclusion is that the F_3 generation had greatest middle values for the researched traits when selected by using *pedigree* method. But on the other hand, the F_3 generation selected by *bulk* method also had satisfying characteristics, depending on hybrid population and trait. It is important to point out that the natural selection in early phases of breeding process has a moderate importance on pepper material developed by crossing genotypes from different varieties. Regarding the *bulk* method it can be concluded that this method is suitable for hybrid populations developed by crossing of genotypes from the same pepper varieties.

ALLARD (1960) found that some hybrid populations in F_4 generation grown in mixture had greater yield than their parents. ROMERO and FREY (1966) found that yield constantly increased by applying *bulk* selection in each generation. LEBSOCK and AMYA (1969) found that the stalk height decreased, but number of spiklet per spike and grain weight increased in F_3 generation of wheat grown in mixture, which led to a higher yield.

The best hybrid populations for further breeding, including both researched traits are KP003 x KP068, KP042 x KP068 i KP042 x KP075

Received November 19th, 2010
Accepted June 03th, 2011

REFERENCES

ALLARD, W.R. (1960): Principles of Plant Breeding. John Wiley & Sons Inc., New York.

CANKAYA, S., A. BALKAYA and O. KARAAGAC (2010): Canonical correlation relationships between plant characters and yield components in red peppers [*Capsicum annuum* L. var. *conoides* (Mill.) Irish] genotypes. Span J Agric Res *8* (1): 67-73.

GELETA, L.F. and M.T. LABUSCHAGNE (2004): Comparative performance and heterosis in single, three-way and double cross pepper hybrids. J Agric Sci *142* (6): 659–663.

GELETA, L.F., M.T. LABUSCHAGNE and C.D, VILJOEN (2004): Relationship between heterosis and genetic distance based on morphological traits and AFLP markers in pepper. Plant Breed *123*:467–473.

GOVINDARAJAN, V.S. (1986): Capsicum production technology, chemistry and quality part II – Processed products, standards, world production. Crit Rew Food Nutri *23*: 207-288.

HLADNI, N., D. ŠKORIĆ and M. KRALJEVIĆ-BALALIĆ (2005): Heterosis for seed yield and yields components in sunflower. Genetika *37* (3): 253-260.

LEBSOCK, K.L. and A. AMAY (1969): Variation and covariation of agronomic traits in durum wheat. Crop Sci. *9*: 372-375.

MARAME, F., L. DESSALEGNE, C. FININSA and R. SIGVALD (2009): Heterosis and heritability in crosses among Asian and Ethiopian parents of hot pepper genotypes. Euphytica *168* (2): 235–247.

MATHER, K. and J.L. JINKS (1971): Biometrical Genetics. 2nd edn. Chapman and Hall, London.

MEYER, R.C., O. TORJEK, M. BECHER and T. ALTMANN (2004): Heterosis of Biomass Production in Arabidopsis. Establishment during Early Development. Plant Physiology *134*: 1813 – 1823.

NANDADEVI and R. M. HOSAMANI (2003): Estimation of heterosis, combining ability and *per se* performance in summer grown chilli (*Capsicum annuum* L.) for yield and resistance to leaf curl complex. Capsicum and Eggplant Newsletter *22*: 59-62.

NARASIMHAPRASAD, B. C., K. MADHAVI REDDI and A. T. SADHASIVA (2003): Heterosis studies in chilli (*Capsicum annuum* L.). Indian Journal of Horticulture *60* (1): 69 – 74.

RAJESH, K. and L. GULSHAN (2001): Expression of heterosis in hot pepper (*Capsicum annuum* L.). Capsicum Eggplant Newsl *20*: 38–41.

REGO, E.R., M.M. REGO, F.L. FINGER, C.D. CRUZ and V.W.D. CASALI (2009): A diallel study of yield components and fruit quality in chilli pepper (*Capsicum baccatum*). Euphytica *168* (2): 275–287.

ROMERO, G.E. and K.J. FREY (1966): Mass selection for plant height in oat population. Crop Sci. *6*: 282-287.

SAVITA, M. (2004): Heterosis, combining ability and gene action studies in chilli (*Capsicum annuum* L.). M. Sc. (Agri) Thesis, University of Agricultural Sciences, Bangalore.

SOH, A. C., T. C. YAP and K. M. GRAHAM (2009): Heterosis and combining ability in a diallel cross of chilli (*Capsicum annum* L.). The Journal of Agricultural Science *87* (2): 447 -449

SOUZA, J.A and W.R. MALUF (2003): Diallel analyses and estimation of genetic parameters of hot pepper (*Capsicum chinense* Jacq). Scientia Agricola *60*: 105–113.

THUL, S. T., R. K. LAL, A. K. SHASANY, M. P. DAROKAR, A. K. GUPTA, M. M. GUPTA, R. K. VERMA and S. P. S. KHANUJA (2009): Estimation of phenotypic divergence in a collection of *Capsicum* species for yield-related traits. Euphytica *168* (2): 235–247.

ZAMBRANO, G.M, J.R.A. GONZALES, M.R. MERAZ, A.R. LOERA, and O.P. CAMPODONICO (2005): Efectos genéticos y heterosis em La vida de anaquel Del Chile serrano. Ver Fitotec Mex *28* (4): 327–332.

ZEČEVIĆ, B., D. STEVANOVIĆ, S. PRODANOVIĆ and R. ĐORĐEVIĆ (1999): Inheritance of yield components in diallel crossing of divergent genotypes of pepper (*Capsicum annuum* L.). Genetika *31* (2): 97-105.

ZEČEVIĆ, B., D. CVIKIĆ, T. SRETENOVIĆ-RAJIČIĆ, R. ĐORĐEVIĆ and J. ZDRAVKOVIĆ (2003): Genetic analysis of the earliness in pepper (*Capsicum annuum* L.)., First Symposium on Horticulture, 16-20 October 2002, Ohrid, Republic of Macedonia. Symposium proceedings: 207-213.

ZEČEVIĆ, B., R. ĐORĐEVIĆ, N. PAVLOVIĆ, M. MIJATOVIĆ and Ž. MARKOVIĆ (2007): The Effect of Parent's Germplasm on Yield Components of F1, F2 and F3 Generations of Pepper Hybrids (*Capsicum annuum* L.). Proceedings of the Third Balkan Symposium on Vegetable and Potatoes, Bursa, Turkey, Acta Horticulturae *729*: 95 – 99.

ZEWDIE, Y. and A.C. ZEWEN (1997): Variation in Yugoslavian hot pepper (*Capsicum annuum* L.) accessions. Euphytica *97*: 81-89.

UTICAJA GERMPLAZME RODITELJA NA OSOBINE PLODA F_1, F_2 I F_3 GENERACIJE PAPRIKE (*Capsicum annuum* L.)

Bogoljub ZEČEVIĆ[1], Radiša ĐORĐEVIĆ[1], Ahmet BALKAYA[2], Jelena DAMNJANOVIĆ[1], Mladen ĐORĐEVIĆ[1] i Ana VUJOŠEVIĆ[3]

[1]Institut za povrtarstvo Smederevska Palanka
[2]Ondokuz Mayis University, Faculty of Agriculture. Kurupelit – Samsun. Turkey
[3]Poljoprivredni fakultet Beograd - Zemun

I z v o d

Cilj istraživanja bio je određivanje genetičkih vrednosti za širinu i dužinu ploda F_1 i F_2 generacije dialelno ukrštenih genotipova paprike, kao i ocena efekata primene *pedigree* i *bulk* metoda selekcije kod F_3 hibridnih populacija. Hibridne populacije su formirane od ukrštanja divergentnih genotipova iz različitih varijeteta *Capsicum annuum* L. Ispitivanja roditeljskih linija i F_1 generacije trajala su tri godine, eksperimenti sa F_2 generacijom dve godine, dok je analiza rezultata za hibridne populacije F_3 generacije urađena na osnovu podataka jednogodišnjeg ogleda. Sagledavajući sve kombinacije ukrštanja ocenjeno je da je efekat heterozisa u F_1 generaciji za ispitivane osobine bio veoma mali. Genetička analiza F_2 generacije pokazala je da se proučavane osobine nasleđuju parcijalnom dominacijom. U F_3 generaciji hibridne populacije nastale primenom *pedigree* metoda selekcije ocenjene su kao oplemenjivački vrednije, po osnovu svih osobina, u odnosu na hibridne populacije dobijene modifikovanom *bulk* metodom.

Primljeno 19. XI. 2010.
Odobreno 03. VI. 2011.