UDC 575.630
https://doi.org/10.2298/GENSR1702729P
Original scientific paper

MODE OF INHERITANCE AND AMMI ANALYSIS OF ONION (*Allium cepa* L.) BULB TRAITS

Nenad PAVLOVIĆ[1], Zdenka GIREK[1], Milan ZDRAVKOVIĆ[1], Jelica GVOZDANOVIĆ VARGA[2], Đorđe MORAVČEVIĆ[3], Jasmina ZDRAVKOVIĆ[1]

[1]Institute for vegetable crops, Smederevska Palanka, Serbia
[2]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[3] Faculty of Agriculture, Beograd-Zemun, Serbia

Pavlović N., Z. Girek, M. Zdravković, J. Gvozdanović Varga, Đ. Moravčević, J. Zdravković (2017): *mode of inheritance and AMMI analysis of onion (Allium cepa L.) bulb traits.*-Genetika, vol 49, no.2, 729 - 742.
The success in growing agricultural plants depends on genotype grown, environment and growing technology applied. The impacts of these factors should not be studied separately. Interaction among genotypes and environment was crucial for breeding work and improvement of variety characteristics. Very often in production practice it happens that when comparing the same varieties in different soil and weather conditions they are ranked differently. One of the key aims set at the breeders is breeding for the traits of wide adaptability and calculating of the complex components of genetic variance which is the main condition for successful breeding program such as breeding for increased yield and yield components. Trial was set up at random block system in five repetitions. Ten onion genotypes from the Institute for Vegetable Crops germplasm were used in this trial. After choosing the most stabile genotypes, they were crossed by applying full diallel without reciprocals. Then, a field trial was set up with parents and hybrids of F_1 and F_2 generation. The experiment has been set up at the trial field of the Institute for Vegetable Crops in Smederevska Palanka, for three years. The best adaptability in the experiment, for mass of the onion bulb had genotypes Makoi bronzi and Holandski žuti, while for average yield, it was Jasenički crveni. Also, components of genetic variance in both progeny generations were calculated for mass, yield and height of fresh bulb. The most common heredity mode for mass and yield of the bulb was super-domination and domination of a better parent.
*Key word***s**: interaction G x E, heredity mode, onion

Corresponding author: Nenad Pavlović, Institute for vegetable crops, Karadjordjeva 71, 11420 Smederevska Palanka, npavlovicpb@gmail.com

INTRODUCTION

There are three key factors in agricultural practice: genotype, climate conditions and growing technology. These factors must not be considered separately, since genotypes determine the yield potential, while external conditions determine the degree of realization of that potential (SNIDER *et al.*, 2013). Interaction of genotype and external conditions is crucial for breeding process. When the same varieties are compared in different growing conditions, they are often ranged differently. This phenomenon hardens the breeding process and creates difficulties in selection of superior varieties. The effect interaction of genotype and external condition (GxE) does not give enough information regarding the individual stability, which can cause the decrease of selection productivity (EBERHART and RUSSELL 1966; KHAR *et al*., 2005). It is very common that variation frequency of external conditions in the same region is very high in different years. The same genotypes grown in different regions can have a different reaction to climate conditions, soil characteristics or growing technology. These different growing responses in different regions are known as interaction genotype x region, which enables significant information about genotype for breeders and producers (LACAZE and ROUMET, 2004; GVOZDANOVIĆ VARGA *et al*., 2004; SINGH and RAM, 2012).

Basically, all important economic characteristics of onion, including the yield, are polygenic (SINGH *et al*., 2010). The information regarding the variability of onion yield is of the great importance since that is the most important precondition for the start of the selection program. Other important information about the relations between the yield and its components should be balanced with specific of external conditions (specific climate and edaphic factors), (SINGH *et al.*, 2013). One of the key tasks in selection process is the breeding for traits with high adaptability, as well as genetic divergence and variability as a main condition for successful breeding programs such as breeding for yield and yield components (SINGH *et al.,* 2013).

In order to obtain the best and stabile yield through correct choice of genotypes in wide areal of growing i.e. phenotype stability of genotype in different agro-ecological conditions (MEHTA *et al.,* 2003; HAYDAR *et al.,* 2007; SINGH and RAM, 2012).

Yield is a very complex trait that can be impacted by genetic base and agro/ecological adaptation (PAVLOVIĆ *et al*., 2002), composition of growth media (SUTHAMATHY and SERAN, 2011), planting date (HAMMA, 2013), degree of plant population (KAHSAY *et al*., 2013), fertilization (BRDAR JOKANOVIC *et al.*, 2011) etc. Yield is a very complex trait due to gene action and interaction with the environment, i.e., different reactions of genotypes on changeable environmental conditions (MARJANOVIĆ JEROMELA *et al.*, (2011). The yield of a certain genotype in a specific environment consists of genotype main effects, environment main effects, and genotype by environment interaction. When field trials are carried out in different agro-ecological conditions, usually 80% of onion yield variation is caused by environment, while genotype and genotype by environment interaction cause 10% of variation each (YAN, 2001).

The main component of onion yield is the bulb mass that together with plant density per area unit has a direct impact. Bulb mass is a morphological marker and represents the variety trait impacted by edaphic and ecological factors (PAVLOVIĆ *et al*., 2002; PAVLOVIĆ *et al.,* 2012; PAVLOVIĆ *et al.,* 2015). Bulb height directly determinates its form, which impacts the usage of onion bulbs (markets, industrial proceeding), market value, etc.

The aim of this study was to select genotypes on which environmental factors have low influence. Only these genotypes would significantly help the breeders in their selection, starting from superior, stable genotypes and from complex genetic variability in generations after crossing for yield and yield components.

MATERIAL AND METHODS

Plant material

The trial was set at the Institute for Vegetable Crops, Smederevska Palanka, Serbia experimental field in three years (2005, 2006 and 2007). Ten onion genotypes from the Institute for Vegetable Crops germplasm were used in this study: Athele voroshaguma (AV), Bunkino beo (BB), Holandski žuti (HŽ), Jasenički crveni (JC), Jasenički žuti (JŽ), Kupusinski jabučar (KJ), Makoi bronzi (MB), Piroška (PR), Tetenji rubin (TR) and Zlatno gnezdo (ZG). The researched genotypes were of different geographical origin in order to achieve the full effect of genetic divergence. By applying the method of diallel hybridization without reciprocals, 5 divergent parental types (Makoi bronzi, Piroška, Zlatno gnezdo, Jasenički crveni and Bunkino beo) have been crossed.

Field trial with parents and hybrids F_1 and F_2 has been set in one year in random block system with five replications with 30 plants per replication.

Experimental data

The researched genotypes were sowed in the first week of March, in random block system with five replications. Sets (started from seed the previous year) were planted on 20 cm distance among lines, 10 cm within the line and 50 cm among the blocks. Each replication consisted of 30 plants. Standard technology of growing the onion from sets was applied. Biometric measurements were done after harvesting and natural drying for three months. Onions were harvested at the stage when 2/3 of tops of plants in the trial field fell.

Evaluation of heredity

The evaluation of heredity of height, mass of the bulb and yield for 5 parental genotypes and their F1 and F2 progeny has been done by using significance test of middle values of F_1 hybrids and F_2 generation comparing to parental average according to BOROJEVIĆ (1986). Separation of genetic variance has been done according to HAYMAN (1954) and MATHER and JINKS (1971) in F1 and F1 progeny generations, where:

D - was the variance component due to additive gene reaction;
H_1 and H_2 – was variance component due to dominant gene reaction;
F - was interaction additive x dominant effect;
$F = 0$ if the frequency of dominant and recessive genes was the same;
$F > 0$ if it has more dominant genes;
$F < 0$ if there were more recessive genes;
E – ecological variability from the variance analysis in random block system.

From genetic parameters for analysed traits, an average degree of domination, frequency of dominant and recessive genes and total number of dominant and recessive alleles for all parents was calculated.

$H_2/4H_1$- Average degree of dominance;

- If this quotient was < 1, it is the partial domination;
- If this quotient was = 1 it is a total domination;
- v) if this quotient was > 1 it is a super-domination;

- $\sqrt{H_1/D}$ - Frequency of dominant and recessive genes;
- *Kd/Kr* - Total number of dominant and recessive alleles for all parents.

Heritability of morphological traits in narrow and broad sense (hn^2 and hb^2) was calculated according to obtained values of additive, dominant and ecological variance according to diallel analysis.

Evaluation of stability

Values of bulb mass, yield and bulb height, obtained during three year study, for 10 genotypes, were analyzed by applying AMMI (Additive Mean Effects and Multiactive Interaction), (GAUCH, 1988; ZOBEL *et al.*, 1988) analysis. The AMMI analysis shows which genotypes react similar to different environmental conditions and what environments have similar impact to researched genotypes. PCA model enables easier understanding of influence and connection among different traits, its location and explanations (SINGH *et al.,* 2013).

For analyzes of the residual from interaction model PCA (GAUCH, 1988) was used. AMMI's stability value (ASV) was calculated in order to rank genotypes in terms of stability using the formula suggested by PURCHASE (1997) as shown below:

AMMI stability value (ASV)= $\sqrt{[\mathrm{SSIPCA1/SSIPCA2}\,(\mathrm{IPCA1}\,score]^2 + [\mathrm{IPCA2}\,score]^2}$ Where:

SS= sum of squares

IPCA1= interaction principal component axis 1

IPCA 2 = interaction principal component axis 2

Data was processed in R software (version 2.14.0, A Language and Environment Copyright, 2011).

Weather conditions in the analysis of the years (2005, 2006 and 2007) were downloaded from the official website Hydrometeorological Service of Serbia: http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php

RESULTS AND DISCUSSION

Analysis of variance of AMMI model proved statistically significant differences among the researched genotypes, effect of years (2005, 2006 and 2007) and its interaction to bulb length, mass and yield (Tab 1). Identical results were obtained by MEHTA *et al*., (2003). They explain the divergence of researched genotypes as heterogeneity of years the experiments were set in. CHAVEZ SERVIA *et al*., (2005) found that external conditions determine the phenotype expression and ecological variance which participates in total phenotype variance with at least 85%. Significance of GxE interaction proves that phenotype expression of genotype for the researched traits (length, mass and yield) varied significantly in different years of research (MOHANTI and PRUSTI, 2001; MEHTA *et al.*, 2003). Significant values of bulb length and the average yield have also been reported by HAYDAR *et al*., (2007), while high interaction among genotypes and external factors for onion bulb mass were confirmed by PAVLOVIĆ *et al*., (2002) and SINGH *et al.*, (2010).

Share of square sum of genotypes (49.03%) for bulb length makes a little less than half of total square sum. Also, this value is higher than calculated values of square sums of external factors impact (34.73%). The calculated square sum of interaction (GxE) was lower than square sum of both previous values (Table 1). Similar values were calculated for bulb mass. For this researched trait square sum of genotypes were higher than square sum of external factors and square sum of interaction of genotype and external factors. Also, analysis of variance of AMMI model proved significant values of the first main component (PC1) for both researched traits (bulb length 96.76% and mass 72.70%). Calculated values for the second main component (PC2) for both traits were not significant (Table 1). Slightly different situation was for the third researched trait (bulb yield). For these traits, the calculated value of square sum of external factors (42.19%) was higher than square sum of genotype and its interaction (Tab 1). Value of second main component (PC2) for bulb yield was not significant (Table 1).

Table 1. Analysis of variance for the AMMI model

Source of variation	Bulb length			Bulb weight		Bulb yield	
	df	SS%	MS	SS%	MS	SS%	MS
Genotype (G)	9	49.03	2.53**	50.45	2,916.20**	33.70	138.34**
REP (ENV)	6	1.87	0.14	1.07	92.70	3.10	19.06
Environments (E)	2	34.73	8.07**	31.50	8,194.70**	42.19	779.32**
GxE	18	9.96	0.26**	9.24	267.10**	10.42	21.39**
PC1	10	96.76	0.45**	72.70	349.50	88.68	34.14**
PC2	8	3.24	0.02	27.30	164.02	11.32	5.45
Error	54	4.41	0.04	7.74	74.50	10.59	7.25
Total	89	100.00		100.00		100.00	

PC1 - first principal component; PC2 - second principal component; **-statistical significance at level 0.05 and 0.01

Table 2. Mean AMMI stability values and ranking orders of stability - Genotypes

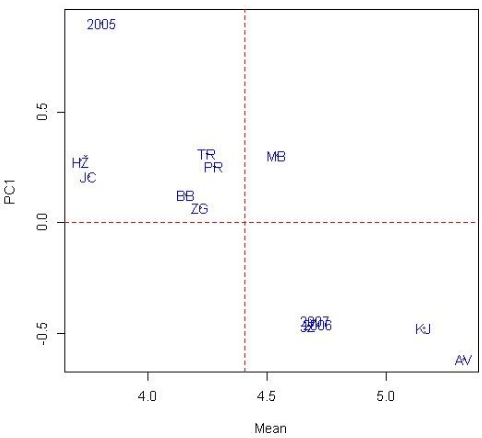
No	Genotype	Bulb length		Bulb mass		Bulb yield	
		ASV		ASV		ASV	
		Value	Rank	Value	Rank	Value	Rank
1	AV	18.43	10	3.02	6	1.60	4
2	BB	3.79	2	3.00	5	0.11	1
3	HŽ	8.41	5	2.99	4	3.78	6
4	JC	6.26	3	2.29	3	0.26	3
5	JŽ	13.82	8	12.04	10	17.93	10
6	KJ	14.28	9	2.01	2	0.24	2
7	MB	9.12	3	0.08	1	8.52	7
8	PR	7.60	4	6.20	9	11.16	9
9	TR	9.30	7	5.37	8	10.75	8
10	ZG	2.06	1	3.82	7	2.60	5

*The names of genotype given in the material and methods.

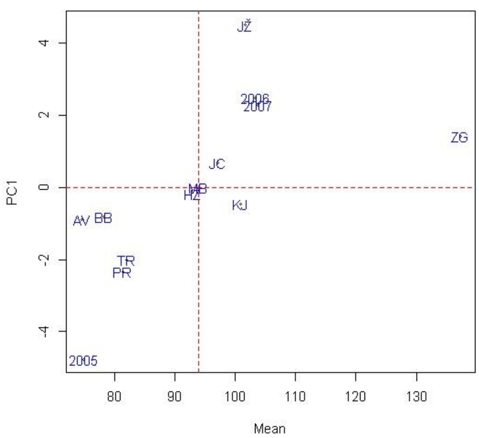
The ASV value (Tab 2) proves that the lowest value for the trait bulb length had genotypes Zlatno gnezdo and Bunkuno beo. This also proves that for both genotypes the impact of interaction (GxE) was the lowest, i.e. they were the most stabile and adaptable to the researched trait. The lowest stability and the highest ASV values had genotype Atteleo voroshaguma and genotype Kupusinski jabučar. Higher ASV values have genotypes with lower stability (SADEGHI *et al*., 2011). Highest stability of trait bulb mass had genotypes Makoi bronzi and Kupusinski jabučar. The lowest stability showed genotypes Jasenički žuti and Piroška. The highest stability for trait total yield of onion bulbs in our research had genotypes Bunkino beo and Kupusinski jabučar. The lowest stability and the highest ASV value were calculated for genotypes Jasenički žuti and Piroška (Table 2).

Genotype stability is considered a reaction to changing environmental conditions, which depends on unpredictable variation components (KANG, 2002). In our experiment, climate conditions in different years of research were the source of variation component. Graphs show

AMMI 2 model of biplot of the first (PC1) and the second main component (PC2), and graphically shown interaction GxE. Our researched genotypes had different interaction with climate conditions in different years. Also, the impact of the climate conditions on researched traits was different for the same genotype. This proves that some genotypes have high stability, however most of them showed specific stability (ATANASOVA *et al.*, 2009; MARJANOVIĆ JEROMELA *et al.*, 2011). Year in which most genotypes had the highest yield was 2007. Values of mass and length of onion bulb were almost the same from 2006 till 2007. Biplot distribution of the researched traits proves that all three studied traits had values of the researched traits above the average in 2006 and 2007. Points for these two years almost overlap on the biplot. Year 2005 had values over the average for the researched traits. Also, on all three biplot the position of the point which marks the year 2005 is further from the PC1 axis in relation to the other examined years, indicating more variable values of observed properties of onion bulbs this year.



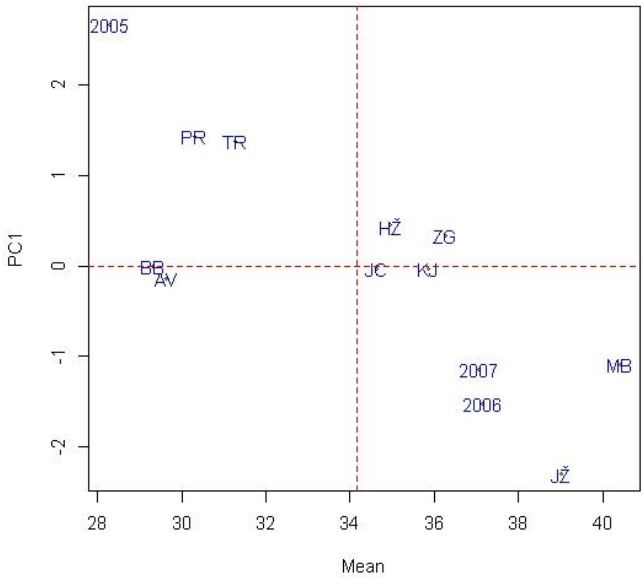
Graph 1. AMMI 1 biplot for bulb length of 10 onion genotypes



Graph 2. AMMI 1 biplot for bulb mass of 10 onion genotypes

AMMI1 biplot (Graph 1) shows that in 2005 most of the researched genotypes grouped for trait length of onion bulb. Separation of genotypes AV and KJ, who have the highest average length in relation to all other genotypes, was clear. Genotype closest to PC1 axis for bulb length was Zlatno gnezdo which proves that it was the most stabile for this trait in three years long study. Bulb mass on Graph 2, clearly points that genotype Makoi bronzi was located at the very centre of PC1 axis, proving it to be the most stabile of all genotypes included in this study. Very close to axis were genotypes Holandski žuti, Kupusinski jabučar and Jasenički crveni. Genotype with lowest stability that improved the interaction (G x E) was Jasenički žuti.

Complex trait average yield of onion bulbs on Graph 3 shows that genotypes: Kupusinski jabučar, Jasenički crveni, Holandski žuti and Zlatno gnezdo were grouped. These genotypes were located very close to the intersection of axis of the first main component (PC1) and average value of the second main component (PC2), which proves their high stability for average bulb yield. The farthest form axis was genotype Jasenički žuti, which proves its stability for analysed traits.



Graph 3. AMMI 1 biplot for total yield of 10 onion genotypes

Partial domination of worse parent had combination MB x JC. Domination of better parent was established in hybrid PR x JC and hybrid combination JC x BB had intermediary heredity. Way and arrangement of heredity in F_2 generation were repeated identically. The average bulb mass of parental lines was from 50.80g in line JC to 88.76g in line ZG. Analysing the average bulb mass in F_1 generation, the lowest fruit mass (48.60g) had hybrid obtained by crossing lines MB x JC, while the hybrid with the greatest mass (165.30 g) was MB x PR. The lowest and the highest bulb mass were repeated in the same crossing combinations in F_2 generation as in F_1 generation. Analysing the variation coefficient, significant variation of this trait (Table 1) was obvious. Parental lines with lowest variability had line PR (9.49%) and the highest line ZG (16.74%). In F_1 generation variability was from 1.66% (MB x BB) to 16.88% (ZG x JC). Dominant heredity mode of bulb mass in F1 generation was the super-domination of better parent and it occurred in three hybrid combinations and then domination of both better and worse parent. Parental line with lowest yield variation coefficient was PR (4.35%), while the highest yield variability had line MB (10.25). Variability in F_1 hybrid generation variation coefficient was from 0.83% (MB x BB) to 9.47% (ZG x JC). Variability in F_2 generation was the highest and in interval from 1.15% (PR x JC) up to 20.60% (ZG x JC) (Table 3). Variability indicators in F_2 generation were higher than in F_1 generation. High values for variability of bulb mass were found by AGIĆ, (1996); PAVLOVIĆ *et al.,* (2002); RIVERA MARTINEZ *et al.,* (2005); HAYDAR *et al.,* (2007); SINGH *et al*., (2010), and the reason for high variability was the environmental. High values for variability of bulb yield were confirmed by PANAJOTOVIĆ, (1986), and PAVLOVIĆ *et al.,* (2003).

Table 3. Mean value ($\bar{x}$), variation coefficient (Cv), heredity mode for bulb height, average mass and yield of researched lines, F_1 and F_2 onion hybrids

Genotype	Bulb height				Bulb mass				Yield			
	F_1		F_2		F_1		F_2		F_1		F_2	
	$\bar{x}$	Cv (%)	$\bar{x}$	Cv (%)	$\bar{x}$	Cv (%)	$\bar{x}$	Cv (%)	$\bar{x}$	Cv (%)	$\bar{x}$	Cv (%)
Makoi bronzi (MB)	6.30	5.32	6.30	5.32	84.73	14.55	84.73	14.55	42.60	10.25	42.60	10.25
MB x PR	8.73	2.88	8.57	2.88	165.33^{Sd+}	14.01	155.33^{Sd+}	5.58	82.63^{Sd+}	7.17	81.16	9.24
MB x ZG	7.63^{Sd+}	1.99	7.50^{Sd+}	1.07	90.50	3.25	88.07^{D-}	5.21	45.26^{Sd+}	1.57	44.13	1.65
MB x JC	5.30^{Pd-}	3.68	5.20^{Pd-}	2.69	48.60^{D-}	4.39	45.97	19.82	24.26	2.17	23.27^{d-}	15.24
MB x BB	5.87	3.61	5.77	2.63	77.33^{Pd+}	1.66	73.10^{Pd+}	6.92	38.66^{Pd+}	0.83	50.66^{Sd+}	15.80
Piroška (PR)	5.83	9.63	5.83	9.63	67.67	9.49	67.67	9.49	33.86	4.35	30.86	4.35
PR x ZG	6.83^{Sd+}	3.10	6.90^{Sd+}	2.61	100.53^{Sd+}	3.29	101.87^{Sd+}	7.81	50.63^{Sd+}	1.31	51.50	4.28
PR x JC	5.80^{d+}	2.16	5.90^{d+}	1.36	90.90^{Sd+}	2.81	89.30^{Sd+}	12.97	45.50^{Sd+}	1.42	45.63	1.15
PR x BB	4.73	2.68	4.87	2.09	58.47^{i}	3.97	56.30^{Pd-}	5.36	29.26^{i}	2.06	29.46	3.91
ZG	4.50	15.44	4.50	15.44	88.77	16.74	88.77	16.74	42.83	6.27	42.83	6.27
ZG x JC	5.43	2.33	5.33	2.38	54.07^{D-}	16.88	52.20^{i}	3.22	28.10^{d-}	9.47	27.70^{d-}	20.60
ZG x BB	6.33^{Sd+}	2.00	6.27^{Sd+}	2.02	93.53^{D+}	3.78	92.53^{d+}	4.25	46.76^{Sd+}	1.90	47.06^{Sd+}	2.13
Jasenički crveni (JC)	4.80	6.67	4.80	6.67	50.80	11.50	50.80	11.50	25.43	5.79	25.43	5.79
JC x BB	5.30^{i-}	1.51	5.17^{i-}	0.90	84.10	5.64	84.53	17.89	42.01	2.94	41.56	6.26
Bunkino beo (BB)	5.97	6.06	5.97	6.06	50.90	12.30	50.90	12.30	25.47	5.84	25.47	5.84
$lsd_{0.05}$	*0.91*		*0.88*		*6.18*		*6.55*		*3.23*		*10.08*	
$lsd_{0.01}$	*1.21*		*1.17*		*8.23*		*8.72*		*4.29*		*13.40*	

Table 4. Absolute and relative heterosis (Ha and Hr) in F1 generation after crossing

Genotype	Bulb height		Bulb mass		Yield	
	Ha	Hr	Ha	Hr	Ha	Hr
MB x PR	2.67**	43.95	89.13**	117	44.40**	116.12
MB x ZG	2.23**	41.35	3.58	4.12	2.55	5.96
MB x JC	-0.25	-4.50	-19.17	-28.3	-9.75**	-28.66
MB x BB	-0.27	-4.34	9.52**	14.03	4.63**	13.61
PR x ZG	1.67**	32.25	22.15**	28.26	12.28**	32.02
PR x JC	0.48	9.09	31.16**	53.46	15.85**	53.45
PR x BB	-1.17*	-19.77	0.82	-1.38	-0.40	-1.34
ZG x JC	0.78	16.85	-15.88	-22.7	-6.03**	-17.67
ZG x BB	1.10*	21.01	23.53**	33.62	12.62**	36.94
JC x BB	-0.08	-1.55	33.25**	65.39	16.55**	65.03

Heterosis for bulb height was highest in F_1 hybrid obtained by crossing lines MB x PR (41.20%), MB x ZG (38.80%) and PR x ZG (33.54%). Significant heterosis had hybrids PR x BB (17.51%) and ZG x BB (19.74%). In F_2 generation significant heterosis had the same hybrid combinations. High values for heterosis were found in combinations MB x PR. This hybrid had highest average bulb mass. Significant heterosis was also found in another five hybrids in both researched generations. Super-domination as a heredity mode is the most common way of heredity and it was found in five hybrids of F_1 generation. However, partial domination of better parent, domination of a parent with lower yield and intermediary inheritance appeared in one F_1 generation. Statistically significant percentage of heterosis appeared in eight hybrid combinations of F_1 generation, of which two combinations had negative values (Table 4).

Heterosis in hybrid combinations for total bulb yield in its research was found by PANAJOTOVIĆ, (1986); SUCIU *et al*., (1985); SUCIU *et al*., (1986); PAL *et al*., (1998); PAL e*t al.*, (1999); PAVLOVIĆ *et al.*, (2003); SINGH *et al*., (2010) and for bulb mass.

Table 5. Genetic variance components for height, mass and yield of onion bulb

Components	Bulb height		Bulb mass		Yield	
	F_1	F_2	F_1	F_2	F_1	F_2
D	0.511	0.517	319.713	319.125	73.249	61.861
H_1	4.466	4.110	3380.539	3031.667	831.449	789.146
H_2	3.490	3.150	3051.187	2752.742	755.071	713.358
F	0.200	0.219	-47.651	-16.982	-22.472	-32.108
E	0.103	0.097	4.781	5.369	1.301	12.690
$H_2/4H_1$	0.195	0.192	0.226	0.227	0.227	0.226
$\sqrt{H_1/D}$	2.957	2.819	3.252	3.082	3.369	3.572
Kd/Kr	1.142	1.163	0.955	0.983	0.913	0.865
hn^2	0.397	0.415	0.31	0.31	0.311	0.307
hb^2	0.936	0.936	0.99	0.99	0.995	0.954

Genetic variance components of bulb height were lower than dominant (H_1 and H_2) which proves that bigger part of genetic variability belongs to dominant gene influence. The F value was positive in both researched generations, which proves that in gene expression of bulb height to more dominant than alleles were included. Also, this proves the ratio of total number of dominant to recessive alleles (1.142 for F_1 and 1.163 for F_2 generation). Dominant and recessive alleles were not equally distributed in parents ($H_2/4H_1$=0.195 and 0.192). Average domination degree ($\sqrt{H_1/D}$ = 2.957) was higher than one in both generations, which proves super-domination as bulb height heredity mode considering all crossing combinations. Considering all crossing combinations, heritability in narrow sense in F_1 generation was 0.39, and in broader sense 0.93. In F_2 generation, heritability in narrow sense was 0.41 and 0.93 in broader (Table 5). Similar results in its researches were found by PAVLOVIĆ, (1999); PAVLOVIĆ *et al.*, (2003); HAYDAR *et al.*, (2007). Similar values for heritability of bulb height in its research were confirmed by RAJALINGAM and HARIPRIYA, (1998); MOHANTY *et al.*, (2001a); SINGH *et al.*, (2010); PAVLOVIĆ *et al*., (2003); PAVLOVIĆ *et al*., (2015).

Additive component of genetic variance (D) was lower than dominant (H_1 and H_2) in both generation levels, which proves that in inheriting of bulb mass dominant genes have high impact. Negative F (interaction additive x dominant gene effect) value, proved that in inheriting of this trait, the impact of recessive genes was the strongest. Also, this proves the ratio of total number of dominant towards recessive alleles (Kd/Kr = 0.95 and 0.98) that was lower than one. Recessive and dominant alleles were not evenly distributed ($H_2/4H_1$ = 0.22). The average level of domination ($\sqrt{H_1/D}$ = 3.25 and 3.08) was higher than one, which implies to super-domination as heredity mode of bulb mass, considering all crossing combinations. Heritability in narrow sense for F_1 generation was 0.31, and in wider 0.99. Similar values were calculated for F_2 generation. High values of heritability for researched trait point to higher level of gene factors in inheriting average bulb mass (Table 5). High levels of heritability was also confirmed by SINGH *et al.*, (1995); NEYKOV *et al.*, (1997); MOHANTY *et al.*, *(*2001a); PAVLOVIĆ *et al.*, (2002); PAVLOVIĆ (2010).

Additive component of genetic variance (D) for bulb yield was lower than dominant (H_1 and H_2), and in F_1 and F_2 generation, which proves that dominant genes have high impact in inheriting this trait. The F value, which shows interaction additive x dominant gene effect was negative which proves that in inheriting yield components, alleles have higher impact. This fact can be proved by the relation of total number of dominant toward recessive alleles (Kd/Kr = 0.91 and 0.86), which is lower than one. Distribution of dominant and recessive alleles in parental lines was not equal ($H_2/4H_1 = 0.22$). The average degree of domination ($\sqrt{H_1/D}$ = 3.37 and 3.57) was higher than one, which means that super-domination was the heredity mode for bulb yield, considering all crossing combinations. Heritability in narrow sense was 0.31 and in wider 0.99 for F_1 generation. Heritability values in F_2 generation were also high, (Table 5).

High heritability values for bulb yield were found by RAJLANGAM and HARIPRIYA, (1998); SINGH *et al.*, (1995); SIDHU *et al*., (1986).

Following the results of MOHANTY, (2001a); MOHANTY, (2001b); MOHANTY and PRUSTI, (2002); PAVLOVIĆ *et al.*, (2003), which proved similar results of genetic variance component on divergent genotypes and different traits of onion bulb, the results of this study are in coordination with most.

A criterion for selection of parent pairs for crossing was a high rang of genotype stability for researching genetic variability components and for recombination that would be the most successful in process of onion selection, respectively. Having that in mind, Jasenički crveni (JC) was used for crossing since it was on the third place regarding stability for all three researched traits. Genotype Bunkino beo (BB) was on second place in range regarding bulb height, fifth regarding bulb mass, while it was the first regarding the yield, according to ASV stability coefficients (Table 2). This choice of parental pairs genetic variability components are the most precise. They differed in parameter F for bulb height, which points to prevailing effect of dominant alleles, while the recessive alleles (negative sign) prevailed for bulb mass and the yield, which is in accordance with component Kd/Kr which was higher, lower than one, respectively (Table 5).

CONCLUSION

In this study, among the analyzed genotypes for the researched traits, genotypes BB and ZG distinguished for good adaptability in different environment, which was the consequence of the impact of different years. Genotypes BB and ZG had good, while genotypes KJ and AV had low adaptability for bulb height. In our research, genotypes MB and HŽ had the highest adaptability for bulb mass, while genotypes TR, PR and JŽ had low adaptability. The best adaptability for the average bulb yield had genotype JC, while genotypes MB, PR and TR had low adaptability.

Selection process, based on the results of this research, will be relatively complicated due to different heredity modes of certain traits. Highly correlated traits (mass and yield of bulb) comparing to less correlated (bulb height) will complicate the breeder process do desirable clean line, regardless to individual genetic stability.

ACKNOWLEDGEMENT

Financial support for this research was provided by Ministry of Education, Science and Technological Development through grant TR31059.

Received November 22nd, 2016
Accepted March 25th, 2017

REFERENCES

AGIČ, R. (1996): Sporedbeni ispituvana introduirani poluluti sorti kromid vo uslovi na skopsko. Magistarski rad, Zemjodelski fakultet, Skopje, Makedonija. str. 88.

ATANASOVA, D., V. DOCHEV, N., TSENOV, I. TODOROV (2009): Influence of genotype and environments on quality of winter wheat varieties in Northern Bulgaria. Agricultural Science and Technology *1*(4): 121-125.

BOROJEVIĆ, K. (1986): Genes and Population. Forum, Novi Sad (in Serbian)

BRDAR JOKANOVIĆ, M., M. UGRINOVIĆ, D. CVIKIĆ, N. PAVLOVIĆ, J, ZDRAVKOVIĆ, S. ADŽIĆ, M. ZDRAVKOVIĆ (2011). Onion yield and yield contributing characters as affected by organic fertilizers. Field. Veg. Crops Res. *48*:341-346.

CHAVEZ SERVIA, J.L., L.A. COLLADO-PANDURO, R. PINEDO RAMIREZ, R. SEVILLA PANIZO, W. GUILLEN HUACHUA, J. MORI CASTRO (2005): Environmental effect and genotypic variation of maize on–farm in Peruvian Central Amazon. Enhancing the use of crop genetic diversity to manage abiotic stress in agricultural production system, Budapest, Hungary. 39-47.

EBERHART, S.A., W.A RUSSEL (1966): Stability parameters for comparing varieties. Crop Science *6:*36-40.

GAUCH, H.G. (1988): Model selection and validation for yield trials with interaction. Biometrics *44*(3): 705-715.

GVOZDANOVIĆ VARGA, J., M. VASIĆ, J. ČERVENSKI, D. BUGARSKI (2004): Genotype and enviroment effects on yield and quality of winter garlic. Genetika *36*(2): 161-170.

HAMMA, H.L, (2013). Growth and yield of onion as influenced by planting dates and mulching types in Samaru, Zaria. International Journal of Advance Agricultural Research. *1*:22- 26.

HAYDAR, A., N. SHARKER, M.B. AHMED, M.M. HANNAN, M.A. RAZVY, M. HOSSAIN, A. HOQUE, R. KARIM (2007): Gentic variability and interrelationship in onion (*Allium cepa* L.). Middle-East Journal of Scientific Research *2*(3-4):132-134.

HAYMAN, B. I**.** (1954): The theory and analysis of diallel crosses. Genetics *39*, 787-809.

KAHSAY, Y., D. BELEW, F. ABAY (2013). Effect of intra-row spacing on yield and quality of some onion varieties (*Allium cepa* L.) at Aksum, Northern Ethiopia. Afr J Plant Sci. *7*(12):613-622.

KANG, M.S. (2002): Genotype-environment interaction: Progress and prospects. In: M.S. Kang (Ed.), Quantitative genetics, genomics and plant breeding, CAB International: Wallingford: England, 221-243.

KHAR, A., A. ASHA DEVI, V. MAHAJAN, K. E. LAWANDE (2005): Genotype x environment interactions and stability analysis in elite lines of garlic (*Allium sativum* L.). Journal of Spices and Aromatic Crops *14*(1):21-27.

LACAZE, X., P. ROUMET (2004): Environment characterization for the interpretation of environmental effect and genotype x environmet interaction. Trheoretical and Applied Genetics *109*: 1632-1640.

MARJANOVIĆ JEROMELA, A., N. NAGL, J. GVOZDANOVIĆ VARGA, N. HRISTOV, A. KONDIĆ ŠPIKA, M. VASIĆ, R. MARINKOVIĆ (2011): Genotype by environment interaction for seed yield per plant in rapeseed using AMMI model. Pesq. agropec. bras., Brasília. *46*(2):174-181.

MATHER, K., J.L. JINKS (1971): Introduction to biometrical genetics. Sec. Ed., Champan and Hall, London

MEHTA, D.R., I.J. GOLANI, M.A. VADDORIA, K.L. DOBARIYA (2003): Stability analysis for bulb yield and its attributes in onion. Vegetable Science *30*(1): 33-36.

MOHANTY, B.K (2001a). Genetic variability, inter relationship and path analysis in onion. J. Tropical Agriculture *39*: 17-20.

MOHANTY, B.K (2001b): Analizis of Genetic Divergence in Kharif Onion. Indian J. Hortic. *58*:260-263

MOHANTY, B.K., A.M. PRUSTI (2001). Performance of common onion varieties in Kharif seasons. Journal of Tropical Agriculture *39*:21-23.

MOHANTY, B.K., A.M. PRUSTI (2002). Mahalanobis generalized distance analysis in onion. Res. Crops. *3*(1):142-144.

NEYKOV, S., I. CESCHMEDZIEV (1997): Biodiversity, distribution and preservation of *Allium* spp. in Bulgaria. IPGRI on *Allium*. 80-83.

PAL, N., N. SINGH, B. CHOUDHURY (1988): Heterosis for yield and its components, dehydration qualities and storage in onion (*Allium cepa*). Indian Journal of Agricultural Sciences *58*(9): 687-692.

PAL, N., N. SINGH, N. SINGH (1999): Heterosis for yield and storage parameters in onion (*Allium cepa*). Indian Journal of Agricultural Sciences *69*(12): 826-829

PANAJOTOVIĆ, J. (1986): Ispitivanje kombinacionih sposobnosti inbred linija i ispoljavanje heterozisa kod crnog luka (*Allium cepa* L.). Doktorska teza, Beograd. str. 91

PAVLOVIĆ, N, J. ZDRAVKOVIĆ, T. SRETENOVIĆ RAJIČIĆ (2002): Variability of onion bulb fresh weight. Book of Abstracts 1st Symposium on horticulture, p. 152,

PAVLOVIĆ, N. (1999): Ocena selekcione vrednosti i divergentnosti germplazme u kolekciji crnog luka (*Allium cepa* L.). Magistarska teza, Univerzitet u Beogradu, Poljoprivredni fakultet str. 81.

PAVLOVIĆ, N. (2010): Nasleđivanje kvantitativnih svojstava crnog luka (*Allium cepa* L.). Doktorska disertacija, Univerzitet u Beogradu, Poljoprivredni fakultet, 96 str.

PAVLOVIĆ, N., M. ZDRAVKOVIĆ, M. IVANOVIĆ, M. DAMJANOVIĆ (2003): Variability heritability of average yield of onion bulb (allium cepa L.). Genetika *35*(3):149-154

PAVLOVIĆ, N., J. ZDRAVKOVIĆ, D. CVIKIĆ, M. ZDRAVKOVIĆ, S. ADŽIĆ, S. PAVLOVIĆ, G. ŠURLAN MOMIROVIĆ (2012): Characterization of onion genotypes by use of RAPD markers. Genetika *44* (2):269-278.

PAVLOVIĆ, N., D. CVIKIĆ, J. ZDRAVKOVIC, R. ĐORĐEVIĆ, M. ZDRAVKOVIĆ, J. GVOZDANOVIĆ VARGA, Đ. MORAVČEVIĆ (2015): Bulb fresh weight mode of inheritance in onion (*Allium cepa* L.). *52*(1): 24-28.

PURCHASE, J.L. (1997): Parametric analysis to describe G xE interaction and yield stability in winter wheat. PhD thessis. Department of Agronomy, Faculty of Agriculture. University of the Orange Free State Bloemfontein, South Africa. pp 120.

RAJALINGAM, G.V., K. HARIPRIYA (1998): Genetic variability in onion. Madras Agricultural Journal 85(5-6):248-250.

REPUBLIČKI HIDROMETEOROLOŠKI ZAVOD SRBIJE (2015). Dostupno na: http://www.hidmet.gov.rs/ciril/meteorologija/klimatologija_godisnjaci.php

RIVERA MARTINEZ, A., P.J. FERNANDEZ, J.L. ANDRES ARES (2005): Evaluation of local onion lines from northwest Spain. Spanish Journal of Agricultural Research *3*(1):90-97

SADEGHI, S. M., H. SAMIZADEH, E. AMIRI, M. ASHOURI (2011): Additive main effects and multiplicative interactions (AMMI) analysis of dry leaf yield in tobacco hybrids across environments. African Journal of Biotechnology *10*(21): 4358-4364.

SIDHU, A.S., S. SINGH, M.R. THAKUR (1986): Variability and correlation studies in onion. Indian Journal of Horticulture *43*(3-4):260-264.

SINGH, A., H.H. RAM (2012): Estimates of stability parameters for yield and its components in cucumber (*Cucumis stivus* L.). Vegetable Science *39*(1):31-34.

SINGH, D.N., A. NANDI, P. TRIPATHY, A. SAHU (1995): Genetic variability and correlation in onion (*Alliumcepa*). Indian Journal of Agriculture Sciences *65*(11):793-796.

SINGH, R.K., B.K. DUBEY, S.R. BHONDE, R.P. GUPTA (2010): Variability studies for some quantitative characters in white onion (*Allium cepa* L.) advance lines. Vegetable Science *37*(1):105-107.

SINGH, S.R., N. AHMED, S. LAL, S.A. GANIE, M. AMIN, N. JAN, A. AMIN (2013): Determination of genetic diversity in onion (*Allium cepa* L.) by multivariate analysis under long day conditions. African Journal of Agricultural Research *8*(45):5599-5606.

SNIDER, J.L., D.C. GUY, J. WHITAKER, J.W. DAVIS (2013): Quantifying genotypic and environmental contributions to yield and fiber quality in Georgia: data from seven commercial cultivars and 33 yield environments. The Journal of Cotton Science *17*:285–292.

SUCIU, Z., R. MARGEA, E. BOJAN, M. ONCU (1986): Heterozis in onion. Lucrari stiintifice-I.A.T. *21*: 73-78.

SUCIU, Z., V. BERAR, S. SIMON, B. KATONA, M. RODICA (1985): The effect heterosis on yield in onion. Lucrari stiintifice, Institutul Agronomic, Timisoara, Agronomie. *20*: 105-107.

SUTHAMATHY, N., T.H. SERAN (2011). Growth and yield response of red onion (*Allium ascalonicum* L.) grown in different potting media. Journal of Phytology *3*(1):50-58.

YAN, W. (2001): GGE biplot–a windows application for graphical analysis of multienvironment trial data and other types of two-way data. Agronomy Journal *93*: 1111-1118.

ZOBEL, R.W., M.J. WRIGHT, H.G. GAUCH (1988): Statistical analysis of a yield trial. Agronomy Journal *80*: 388-393.

NAČIN NASLEĐIVANJA I AMMI ANALIZA NEKIH OSBINA SVEŽE LUKOVICE CRNOG LUKA (*Allium cepa* L.)

Nenad PAVLOVIĆ[1], Zdenka GIREK, Milan ZDRAVKOVIĆ, Jelica GVOZDANOVIĆ VARGA[2], Đorđe MORAVČEVIĆ[3], Jasmina ZDRAVKOVIĆ

[1]Institut za povrtarstvo, Smederevska Palanka, Srbija
[2]Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija
[3]Poljoprivredni fakultet, Beograd-Zemun, Srbija

Izvod

Gajenje useva u poljoprivrednoj praksi je limitirano od strane gajenog genotipa uticaja faktora spoljne sredine i primenjene tehnologije gajenja useva. Uticaj ovih faktora nikako ne treba da se posmatra odvojeno. Interakcija koja se javlja između genotipa i faktora spoljne sredine je od krucijalne važnosti za oplemenjivački rad i unapređenje karakteristika varijeteta. Vrlo često se u proizvodnoj praksi dešava da poređenjem istih varijeteta u različitim ekološkim uslovima gajenja dolazi do njihovog različitog rangiranja. Jedan od ključnih ciljeva koji se postavlja pred oplemenjivače jeste oplemenjivanje osobina na široku adaptibilnost i izračunavanje kompleksnih komponenti genetičke varijanse što je osnovni uslov za uspešnost oplemenjivačkih programa kao što je oplemenjivanje na povećani prinos i komponente prinosa.

Eksperiment je izveden na ogledom polju Instituta za povrtarstvo, Smed. Palanka u trajanju od četiri godine. Ogled je izveden po pricipu slučajnog blok sistema u pet ponavljanja. U ogledu je korišćeno 10 genotipova iz kolekcije germplazme crnog luka Instituta za povrtarstvo. Nakon odabira najstabilnijih genotipova izvedeno je njihovo ukrštane metodom punog dialela bez recipročnog. Zatim, postavljen poljski ogled sa roditeljima i hibridima F_1 i F_2 generacije.

U eksperimentu najbolju adaptibilnost od svih ispitivanih genotipova za osbinu masa sveže lukovice crnog luka imali su genotipovi Makoi bronzi i Holandski žuti, dok za prosečan prinos to je bio Jasenički crveni. Izračunate su komponente genetičke varijanse u obe generacije potomstva za masu, prinos i visinu sveže lukovice. Utvrđeno je da preovlađijući načini nasleđivanja za masu i prinos lukovice predstavlja superdominacija i dominacija boljeg roditelja.

Primljeno 22. XI 2016.
Odobreno 25. III. 2017.