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Original scientific paper

Evaluation of grain yield and its components of some experimental, registered and commercial ZP maize (*Zea mays* L.) hybrids

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Abstract

The grain yield and its components of eighteen experimental, one registered and two commercial maize hybrids were examined in six different environments. The main objectives were to identify the best performing experimental and registered hybrids and to select appropriate hybrids for approving and commercialization. Based on the results, many decisions are made. Experimental hybrid Exp.15 is submitted for testing to the Variety Commission of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. This hybrid, as a high-yielding and a stable one, could enrich the assortment of registered medium-late maize hybrids in Serbia. First year of its testing for the purpose of being registered is going to be 2020. Further, registered hybrid ZP 685 is suggested for commercialization as one of the best performing in present study. In addition, the goal of this study was also identification of the superior inbred lines for use in future breeding programs. Inbred lines L1 (BSSS) and L4 (Independent heterotic group) are chosen for crossing with an aim to create a new origin population - source for deriving new recombinant inbred lines. Cross L1 x L4 will be a part of maize breeding program at Maize Research Institute "Zemun Polje" in 2020. Lines L1 and L4 are also suggested for crossing with all others Lancaster lines from MRIZP (which are not parental components of tested hybrids) for deriving new experimental F1 hybrids. As well, Lancaster lines L5, L6 and L7 should be crossed between themselves for creating new origin populations for deriving new recombinant Lancaster inbred lines. Hybrid Sister 1 had very high and stable grain yield and as such it is the most cost effective for seed production.

Key words: maize, experimental hybrids, grain yield, yield components, variety registration

Introduction

The main task of maize breeders is constant development of new maize hybrids more productive and more adaptable than all hybrids created so far. In order to examine their value, phenotypes of newly developed hybrids must be compared with registered hybrids in multi-environments. Multi-locational and multi-year field trials are required for this purpose. Only the best experimental hybrids are submitted for testing for the purpose of being registered by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. After registration, more extensive field trials follow in order to commercialize some of the registered hybrids. According to Čamdžija et al. (2012), it is important for commercial hybrid that a high yield is accompanied by maximum stability in favorable and unfavorable conditions. Such hybrids must be superior in all environments, i.e. capable of accomplishing stable and high yield under various environmental conditions (Finlay and Wilkinson, 1963; Eberhart and Russel, 1966). Only genotypes with a minimal variance for yield across environments are considered stable (Mohammadi et al., 2009). For development of superior hybrids and lines it is important to have a good knowledge of traits which have significant association with grain yield as the most important goal of all breeding programs (Malik et al., 2005). For that reason, it is necessary for breeders to take into consideration these traits when they create new origin population for development of new inbred lines (Ojo et al., 2006). As the grain yield is highly influenced by environmental factors, in order to develop high-yielding desirable maize genotypes, yield components with stable expression and highly correlated with grain yield could be useful (Panwar et al., 2013; Stanković, 2016). Filipović et al. (2014) also state that those yield components as agronomically important traits that mostly determine the yield can be used as important breeding criteria. During inbred lines development breeders pay attention to their combining ability and yield components of their hybrids and themselves per se. The correct choice of initial material having a high frequency of desirable alleles, good agronomic traits and good combining abilities is crucial for the success of any breeding program (Mišević, 1996). Since for future breeding programs inbred lines are selected based on the performance of their hybrids, elite inbred lines are the best source material for developing of new superior inbred lines (Hallauer, 2000). Maize breeders at Maize Research Institute “Zemun Polje” work hard on development of new high-yielding and adaptable maize hybrids. Out of the thousands of newly created hybrids, only a few dozens of the best apply for approving and registration. This study was undertaken to assess grain yield and its components of some experimental, registered and commercial maize hybrids. The objectives were (i) to identify the best performing experimental and registered hybrids, (ii) to select appropriate hybrids for approving (registration) and for commercialization, (iii) to choose some parental inbred lines which should be crossed in order to create a new origin population for development of new inbred lines.

Material and Methods

Twenty-one single-cross maize hybrids from Maize Research Institute "Zemun Polje" (MRIZP) were chosen as a material for this experiment (Table 1). Out of these twenty-one, fifteen hybrids are experimental (Exp.1 – Exp.15) and are currently in the process of being examined in order to make a decision to initiate a process of their possible registration. Hybrids ZP 606 and ZP 666 are commercial and already have been widely grown in Serbia. They were used as standard checks in this study. ZP 606 is the best-selling hybrid of the MRIZP. Hybrid ZP 685 is registered but it has not yet been commercialized. The other three hybrids, Sister 1, Sister 2 and Sister 3 are female parental components (mothers) of many registered and commercial three-way cross hybrids of MRIZP. All hybrids have the same kernel type – yellow dent and belong to FAO 500 and FAO 600 maturity groups.

Table 1. Twenty-one maize hybrids and their status, formula, pedigree and maturity group

No.	Hybrid	Status	Formula	Pedigree data	Maturity group
1	Exp.1	Experimental	L1 x L2	BSSS x Iodent	FAO 600
2	Exp.2	Experimental	L1 x L3	BSSS x BSSS	FAO 600
3	Exp.3	Experimental	L1 x L4	BSSS x Independent	FAO 600
4	ZP 606	Registered - Commercial	L1 x L5	BSSS x Lancaster	FAO 600
5	ZP 666	Registered - Commercial	L1 x L6	BSSS x Lancaster	FAO 600
6	Exp.4	Experimental	L1 x L7	BSSS x Lancaster	FAO 500
7	Exp.5	Experimental	L2 x L3	Iodent x BSSS	FAO 500
8	Exp.6	Experimental	L2 x L4	Iodent x Independent	FAO 600
9	Exp.7	Experimental	L2 x L5	Iodent x Lancaster	FAO 500
10	Exp.8	Experimental	L2 x L6	Iodent x Lancaster	FAO 500
11	Exp.9	Experimental	L2 x L7	Iodent x Lancaster	FAO 500
12	Exp.10	Experimental	L3 x L4	BSSS x Independent	FAO 600
13	Exp.11	Experimental	L3 x L5	BSSS x Lancaster	FAO 600
14	Exp.12	Experimental	L3 x L6	BSSS x Lancaster	FAO 500
15	Exp.13	Experimental	L3 x L7	BSSS x Lancaster	FAO 500
16	ZP 685	Registered (Not Commercial)	L4 x L5	Independent x Lancaster	FAO 600
17	Exp.14	Experimental	L4 x L6	Independent x Lancaster	FAO 500
18	Exp.15	Experimental	L4 x L7	Independent x Lancaster	FAO 500
19	Sister 1	Mother of TWC hybrids	L5 x L6	Lancaster x Lancaster	FAO 600
20	Sister 2	Mother of TWC hybrids	L5 x L7	Lancaster x Lancaster	FAO 500
21	Sister 3	Mother of TWC hybrids	L6 x L7	Lancaster x Lancaster	FAO 500

All twenty-one hybrids used in this study were derived from seven inbred lines crossed according to incomplete diallel method (without reciprocal hybrids) (7x6/2=21). These seven parental lines were developed in breeding programs at Maize Research Institute "Zemun Polje" and belong to different heterotic and maturity groups (Table 2).

The phenotypes of the selected hybrids were tested at three locations in Serbia (Pančevo, Bečej and Zemun Polje) in 2018 and 2019 (total six environments). At all three locations the same soil type – chernozem was present. Field trials were set up according to the randomized complete block design (RCBD) with two replications. Mechanical planting of the trials was done in the two-rowed plots. The length of the plot was 5 m and the inter-row distance amounted to 75 cm forming a plot area of 7.5 m^2. Sowing density was 67000 plants per hectares for all hybrids. Standard maize production technology was used. Harvesting of the trials was done by hand.

Table 2. Heterotic groups, origins and maturity groups of the parental lines of the tested hybrids

Line	Heterotic group	Origin/Source	Maturity group
L1	BSSS – *Iowa Stiff Stalk Synthetic*	MRIZP	FAO 600
L2	Iodent	MRIZP	FAO 500
L3	BSSS – *Iowa Stiff Stalk Synthetic*	MRIZP	FAO 600
L4	Independent (Unknown)	MRIZP	FAO 600
L5	Lancaster - *Lancaster Sure Crop*	MRIZP	FAO 600
L6	Lancaster - *Lancaster Sure Crop*	MRIZP	FAO 500
L7	Lancaster - *Lancaster Sure Crop*	MRIZP	FAO 500

Grain yield and following yield components were examined: ear length (cm), kernel depth (cm), number of kernel-rows, number of kernels per row and 1000-kernel weight (kg). The grain yield is converted to tones per hectares (t/ha) at 14 % moisture level. The yield of all ears per every plot was measured immediately after harvesting. Moisture measurement was done immediately after harvesting, as well, on the samples of five ears taken from each plot. Observations of the yield components were recorded from ten representative ears selected from each plot. Recorded data from the trials were statistically analyzed by one-factorial analysis of variance (ANOVA) for all six traits. After that, data were further analyzed using Least Significant Difference (LSD) test (student's t-test) at 99% and 95% probability levels. Pearson's simple correlation coefficients among all examined traits were also calculated. Statistical processing was done by Microsoft Office Excel 2016.

Results and Discussion

Grain yield of tested hybrids in 2018 and 2019

The analysis of variance (ANOVA) showed a statistically significant influence ($p<0.01$) of genotype on grain yield in both years (Table 3).

Table 3. One-factorial analysis of variance (ANOVA) – significance of factor genotype influence on all investigated traits in both years

GY18	GY19	KRN 18	KRN 19	KD18	KD19	KW18	KW19	NKPR18	NKPR19	EL18	EL19
**	**	**	**	**	**	**	**	**	**	**	**

(GY= grain yield; KRN= kernel-rows number; KD= kernel depth; KW= 1000-kernel weight; NKPR= number of kernels per row; EL= ear length; 18= year 2018; 19= year 2019; ns- no significant; *-significant at p=0.05; ** -significant at p=0.01)

Environmental conditions in 2018 were almost ideal for maize production in Serbia, while they were less favorable in 2019 thanks to drought and strong winds (Republic Hydrometeorological Service of Serbia, 2020). As a consequence, average grain yields of all tested hybrids in our experiment was higher in 2018 than in 2019 (Table 4). In 2018 grain yield ranged from 7.569 t/ha (Sister 3) to 16.776 t/ha (ZP 606) (average in 2018 was 13.453 t/ha), and in 2019 from 6.204 t/ha (Sister 3) to 14.770 t/ha (ZP 606) (average in 2019 was 11.375 t/ha).

Table 4. Average grain yields of tested hybrids and significance of differences (t-test) in grain yield of each hybrid between two years

Hybrid	Grain yield (t/ha)		Significance of differences between 2018 and 2019	Pedigree data
	2018	2019		
Exp.1	14.324	13.130	*	BSSS x Iodent
Exp.2	14.136	12.112	**	BSSS x BSSS
Exp.3	14.562	12.551	**	BSSS x Independent
ZP 606	16.776	14.770	**	BSSS x Lancaster
ZP 666	16.169	13.887	**	BSSS x Lancaster
Exp.4	14.073	12.945	*	BSSS x Lancaster
Exp.5	12.757	8.772	**	Iodent x BSSS
Exp.6	13.889	9.351	**	Iodent x Independent
Exp.7	13.991	11.339	**	Iodent x Lancaster
Exp.8	13.267	11.258	**	Iodent x Lancaster
Exp.9	12.408	11.908	ns	Iodent x Lancaster
Exp.10	13.905	9.917	**	BSSS x Independent
Exp.11	13.915	10.995	**	BSSS x Lancaster
Exp.12	14.779	11.932	**	BSSS x Lancaster
Exp.13	13.764	10.368	**	BSSS x Lancaster
ZP 685	15.515	14.332	ns	Independent x Lancaster

Hybrid	Grain yield (t/ha)		Significance of differences between 2018 and 2019	Pedigree data
	2018	2019		
Exp.14	14.999	13.622	*	Independent x Lancaster
Exp.15	15.301	14.420	ns	Independent x Lancaster
Sister 1	8.279	8.046	ns	Lancaster x Lancaster
Sister 2	8.135	7.014	*	Lancaster x Lancaster
Sister 3	7.569	6.204	**	Lancaster x Lancaster
LSD (0.05)	0.654	0.723		
LSD (0.01)	0.827	0.921		

(ns- no significant; *-significant at p=0.05; ** -significant at p=0.01)

The most yielding tested hybrid in both years was commercial ZP 606 which had 16.776 t/ha and 14.770 t/ha, in 2018 and 2019, respectively (Table 4). The second highest grain yield in 2018 (16.169 t/ha) and the forth in 2019 (13.887 t/ha) showed commercial hybrid ZP 666. These two hybrids have the same female parent line which belongs to BSSS heterotic group (L1) and two Lancaster male parents (L5 and L6). This is an evidence supporting the claim that a long-established heterotic couple BSSS x Lancaster is still widely used in selection and it represents the basis for planning maize breeding programs (Čamdžija, 2014). ZP 606 and ZP 666 showed a statistically significantly higher grain yield in 2018 than in 2019, which means that they can only reach their genetic potential under the best conditions which were characteristic for year 2018. However, their results of grain yield in 2019 also showed they were superior in different environments. These results confirmed the statement of Čamdžija et al. (2012) that only high-yielding and stable hybrids should be commercialized. Crevar et al. (2011) also detected highest average grain yield in ZP 606 and highest adaptation to more favorable growing conditions in ZP 666.

Registered hybrid ZP 685 was in the third place in both years with 15.515 t/ha in 2018 and 14.332 t/ha in 2019 (Table 4). This indicates it showed very high yield and yield stability (no significant difference was observed between 2018 and 2019). Based on that, it will be proposed for commercialization.

Of all experimental hybrids, Exp.14 and Exp.15 performed best in 2018, with 14.999 t/ha and 15.301 t/ha, respectively, by taking forth (Exp.15) and fifth (Exp.14) place (Table 4). In 2019, which was a less favorable year for maize production, experimental hybrid Exp.15 had higher grain yield than ZP 666 and ZP 685 (14.420 t/ha vs. 13.887 t/ha and 14.332 t/ha, respectively) and found itself on the second position. ZP 606 only showed higher grain yield than Exp.15 in 2019, but not statistically significantly higher (0.350 is less than LSD at 0.05 probability level in 2019). Not ideal environmental conditions – such as the ones in 2019 – are common in Serbia. Hybrids like Exp.15, which could show high grain yield in a year like 2019, are needed for Serbians farmers. Beside good performances shown in 2019, this experimental hybrid (Exp.15) did not show significantly lower yield in 2019 compared to 2018 which indicates its high yield stability. Based on these results, hybrid Exp.15 will be signed up for testing by Serbian Variety Commission in the two-year trial starting from 2020. This will initiate a process of possible future approving and registration by the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. Also, based on the results shown, experimental hybrid Exp.14 (in both years it was rated fifth) is suggested for further evaluation. All six hybrids (Exp.1, Exp.2, Exp.3, ZP 606, ZP 666, Exp.4) with L1 female parent line (BSSS) were in the top ten in terms of grain yield in both years (Table 4). Further, Line L1 crossed as mother with line L5 as father give the most yielding and the best-selling hybrid of MRIZP ZP 606. This indicates that L1 is a maize inbred line with the best combining ability of the Maize Research Institute “Zemun Polje”. Hybrids ZP 685, Exp.15 (signed up for registration) and Exp.14 (chosen for further evaluation) have the same female parent line (L4) which belongs to unknown heterotic group (Independent). These two lines (L1 and L4) should be crossed for creating a new origin population (new source) for quickly deriving new inbred lines via double haploid method (Vančetović et al., 2004). Some of these recombinant inbred lines which are going to be originated from this source (L1 x L4) will possibly have better combining ability, adaptability and stability than their parents (L1 and L4). They are expected to produce better hybrids with Lancaster lines in future breeding programs. L1 and L4 are also suggested for crossing with all others Lancaster lines from MRIZP (which are not parental components of tested hybrids in this study) for deriving new hybrids.

As well, Lancaster lines L5, L6 and L7 are all male parents of the most yielding hybrids (ZP 606, ZP 666, ZP 685, Exp.15 and Exp.14). It is concluded that L5, L6 and L7 should be crossed between themselves for creating new origin populations (F2 sources) for deriving new recombinant Lancaster inbred lines.

As expected, the lowest grain yield was recorded in hybrids Sister 1, Sister 2 and Sister 3 (from 6.204 t/ha to 8.279 t/ha) (Table 4). These hybrids are female components of many three-way cross hybrids and they all derive from three Lancaster lines (L5, L6 and L7). Their low yield is a consequence of a small heterosis which occurs due to genetic similarity of the parents of these hybrids (Shull, 1908). However, these hybrids were high yielding and based on that very cost effective for seed production (as female parents-mothers). This is also confirmed by statement of Čamdžija (2014). He states that for profitable seed production female parents must be characterized by high yield (minimum 3 t/ha) and tolerance to both abiotic and biotic stresses. Sister 1 had the highest (8.279 t/ha and 8.046 t/ha, in 2018 and 2019, respectively) and the most stable grain yield (no significant difference was observed between 2018 and 2019) and as such it is the most cost effective for seed production.

Yield components of tested hybrids in 2018 and 2019

The analysis of variance showed a statistically significant influence of genotype factor on all yield components in both years (2018 and 2019) at 0.01 level of probability (Table 3). It is well-known that all yield components contribute to greater grain yield (Hallauer et al., 2010). The kernel-rows number of the tested hybrids varied from 12.85 to 17.85 in 2018, and from 12.7 to 17.8 in 2019 (Table 5). Experimental hybrids Exp.1 and Exp.3 showed the largest values of this trait in 2018 (17.85 and 17.35, respectively) and in 2019 (17.8 and 17.3, respectively). These two hybrids have the same female parent line, L1 (BSSS). It is noted that hybrids which had Lancaster as male parental components showed a smaller number of kernel-rows then hybrids with both non-Lancaster parental components. The smallest number of kernel rows in both years was showed by hybrids Sister 1, Sister 2 and Sister 3 whose parental components were both from Lancaster heterotic group. These results confirmed the claims of Hallauer et al. (2004) that Lancaster heterotic group had fewer kernel rows as opposed to genotypes originating from Reid Yellow Dent (from which some progenitors of BSSS population were originated). It is also noted that the most yielding hybrids (ZP 606, ZP 666, ZP 685, Exp.15) had the medium number of kernel rows. There is a general stance that this trait has high heritability and positive correlation with grain yield (Singhal et al., 2006). Hence, inbred lines which derive hybrids with high number of kernel-rows should be widely used in breeding programs.

Table 5. Average values of yield components of tested hybrids in both 2018 and 2019

Hybrid	KRN		KD (cm)		KW (kg)		NKPR		EL (cm)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Exp.1	17.85	17.8	1.244	1.089	0.396	0.373	42.91	41.79	23.32	21.59
Exp.2	16.5	16.55	1.183	1.151	0.391	0.379	44.45	41.2	23.24	22.08
Exp.3	17.35	17.3	1.286	1.265	0.385	0.375	43.54	41.58	22.20	21.41
ZP 606	14.55	14.55	1.274	1.249	0.433	0.431	47.64	45.88	23.87	21.91
ZP 666	15.15	14.85	1.306	1.217	0.432	0.438	49.40	49.41	24.02	23.37
Exp.4	16.15	16.25	1.279	1.254	0.383	0.387	49.06	48.46	23.24	22.17
Exp.5	16.15	17	1.097	1.000	0.364	0.342	41.35	40.9	21.75	21.77

Hybrid	KRN		KD (cm)		KW (kg)		NKPR		EL (cm)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
Exp.6	16.6	16.5	1.235	1.155	0.373	0.369	42.75	41.13	20.90	19.79
Exp.7	14.9	14.85	1.256	1.156	0.416	0.403	47.73	44.3	22.25	20.89
Exp.8	15.4	15.75	1.195	1.150	0.383	0.377	47.86	45.21	23.49	21.52
Exp.9	15.75	15.7	1.163	1.149	0.390	0.396	46.65	44.13	23.16	20.77
Exp.10	15.6	15.3	1.129	1.098	0.364	0.359	45.46	45.19	21.80	21.75
Exp.11	14.75	14.05	1.122	1.102	0.388	0.397	51.14	50.49	25.10	23.40
Exp.12	15.45	15.65	1.135	1.155	0.355	0.363	51.04	50.74	25.11	24.34
Exp.13	15.2	15.2	1.096	1.090	0.322	0.325	50.73	50.18	23.89	23.32
ZP 685	14.9	14.95	1.260	1.245	0.425	0.418	49.98	49.91	23.14	22.85
Exp.14	14.95	15.15	1.245	1.174	0.407	0.410	47.66	47.28	23.22	22.52
Exp.15	15.45	15.35	1.219	1.206	0.368	0.374	47.73	47.85	22.19	21.81
Sister 1	12.9	13.2	1.079	1.084	0.346	0.343	45.35	44.15	21.18	19.59
Sister 2	12.85	12.7	1.070	0.996	0.301	0.302	45.39	45.19	19.91	19.64
Sister 3	13.55	13.35	1.020	1.001	0.297	0.305	44.48	43.86	19.80	19.75
LSD 0.01	0.843	0.818	0.049	0.059	0.016	0.016	2.417	1.789	0.858	0.680
LSD 0.05	0.641	0.622	0.037	0.045	0.012	0.012	1.838	1.361	0.653	0.517

(KRN= kernel-rows number; KD= kernel depth; KW= 1000-kernel weight; NKPR= number of kernels per row; EL= ear length)

Hybrids Exp.3, Exp.4, ZP 606, ZP 666 and ZP 685, all with the same female parent (L1) except ZP 685 (L4 is female parent) showed the greatest value of kernel depth in both years (2018 and 2019) (Table 5). Between this trait and grain yield there is significant positive correlation (Rafiq et al., 2010) suggesting the importance of this trait in maize breeding. These results of kernel depth are confirmation of high performances of ZP 606, ZP 666 and ZP 685, and indicate that L1 and L4 might be potential donors of desirable alleles for improving kernel depth of breeding material.

Results showed that hybrids ZP 606, ZP 666 and ZP 685 had the highest 1000-kernel weight of all tested hybrids in 2018 (0.433 kg, 0.432 kg and 0.425 kg, respectively) and in 2019 (0.431 kg, 0.438 kg and 0.418 kg, respectively) (Table 5). All male parents of these hybrids belong to Lancaster heterotic group. Nonetheless, L1 (mother of ZP 606 and ZP 666) and L4 (mother of ZP 685) are carriers of desirable alleles for high values of kernel weight. This is important to know because grain yield is positively and significantly correlated with 1000-kernel weight (Reddy et al., 2012) which indicates that this trait is important trait for improving grain yield.

Experimental hybrids Exp.11 and Exp.12 showed the highest values of ear length and number of kernels per row in both 2018 and 2019 (Table 5). These results are in agreement with Begum et al. (2016) and many other researchers who found significant positive correlation between ear length and number of kernel per row. Both of these hybrids (Exp.11 and Exp.12) have the same female parent, line L3 belonging to BSSS heterotic group. It may be concluded that this line is a source of desirable alleles for these two traits.

There is a general agreement that yield components should be used as target traits to improve maize grain yield i.e. they should be breeding criteria within phenotypic selection during development of inbred lines (Rafiq et al., 2010). The results of the yield components confirmed the best performances of the hybrids designated as the most yielding in this study. As well, these results serve as an evidence that the lines previously selected for further use in breeding programs have good performance when it comes to yield components. This goes in favor of earlier made decision that parental components (inbred lines) of best performing hybrids tested in this study should be crossed with both related and unrelated inbred lines with an aim to create new origin populations (F2 sources) or new hybrids, respectively.

Correlation among investigated traits

In addition, simple correlation coefficients among all tested traits were calculated (Table 6). The highest positive and statistically significant (at p=0.01) correlations were found between grain yield and ear length (0.712), grain yield and 1000 kernel weight (0.817), grain yield and kernel depth (0.829), ear length and number of kernels per row (0.707) and kernel depth and 1000-kernel weight (0.818). Similar results were reported by many researchers (Begum et al., 2016; Čamdžija et al., 2011). Between kernel-rows number and grain yield a positive statistically significant (at p=0.05) correlation (0.512) was also found. Negative correlation (-0.357) showed only number of kernel per row and kernel-rows number, but it was not statistically significant, which was in accordance with result obtained by Čamdžija et al. (2011). All these results confirm many widely accepted claims that yield components could be important selection criteria in maize breeding.

Table 6. Pearson's correlation coefficients between investigated traits

	KRN	KD	KW	NKPR	EL	Grain Yield
KRN	1					
KD	0.345^{ns}	1				
KW	0.264^{ns}	0.818^{**}	1			
NKPR	-0.357^{ns}	0.098^{ns}	0.29^{ns}	1		
EL	0.259^{ns}	0.283^{ns}	0.43^{ns}	0.707^{**}	1	
Grain Yield	0.512^{*}	0.829^{**}	0.817^{**}	0.323^{ns}	0.712^{**}	1

(KRN= kernel-rows number; KD= kernel depth; KW= 1000-kernel weight; NKPR= number of kernels per row; EL= ear length; ns- no significant; *-significant at p=0.05; ** -significant at p=0.01)

Conclusion

This research was conducted to provide important information in the breeding process. Based on the results of this study, some steps are suggested and some important decisions are made:

- Experimental hybrid Exp.15 is submitted for testing to the Variety Commission of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia. This hybrid, as a high-yielding and a stable one, could enrich the assortment of registered medium-late maize hybrids in Serbia. First year of its testing for the purpose of being registered is going to be 2020.
- Registered hybrid ZP 685 is suggested for commercialization as one of the best performing in the present study. Results showed that this hybrid isn't only high yield, but stable as well.
- The goal of this study was also identification of superior inbred lines for use in future breeding programs. Based on the results, lines L1 (BSSS) and L4 (Independent heterotic group) are marked as carriers of the most desirable alleles for grain yield and its components examined in this study. These two lines are female parental components of the most yielding hybrids and they showed the best combining ability for grain yield and its components. Hence, L1 and L4 are chosen for crossing with an aim to create a new origin population (source) for deriving new recombinant inbred lines. Cross L1 x L4 will be a part of maize breeding program at Maize Research Institute "Zemun Polje" in 2020. Inbred lines which are going to be originated from this source are expected to produce better hybrids with Lancaster lines in future crosses.
- Inbred lines L1 and L4 are also suggested for crossing with all others Lancaster lines from MRIZP (which are not parental components of tested hybrids in this study) for deriving new experimental F1 hybrids.
- Lancaster lines L5, L6 and L7 as male parents of the most yielding hybrids (ZP 606, ZP 666, ZP 685, Exp.15 and Exp.14) should be crossed between themselves for creating new origin populations (sources) for deriving new recombinant Lancaster inbred lines.
- Hybrid Sister 1, single cross female parental component of many registered and commercial three-way cross hybrids of MRIZP, had very high and stable grain yield and as such it is the most cost effective for seed production.

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