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EVALUATION OF STABILITY IN NEW EARLY-MATURING SUNFLOWER HYBRIDS
OCENA STABILNOSTI NOVIH RANOSTASNIH HIBRIDA SUNCOKRETA

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ABSTRACT

Sunflower is one of the most important oil crops in Serbia and in the world. The breeding process involved the selection of the medium-early maturity hybrids which had the tendency to maximize yield potential and stability in different regions of sunflower production in Serbia.The objective of this study was to test the possibility of using early-maturing hybrids instead of the medium-maturing ones, given the balance between yield and stability parameters. Three new early-maturing sunflower hybrids NS1, NS2 and NS3, developed at the Institute of Field and Vegetable Crops, Novi Sad, were used in the study. There was no significant variation between early-maturing hybrids and standard hybrids for seed and oil yield. Results showed that early-maturing, high yielding hybrids were suitable for the cropping system in all tested locations. The early-maturing hybrids NS2 and NS3 are recommended for further inclusion in the breeding program due to their stability and high seed and oil yield. The entire sunflower breeding program contributed to the development of the local early-maturing hybrids and hybrids with better yield potential.

Key words: *sunflower, hybrid, early-maturing, seed yield, oil yield, stability.*

REZIME

Suncokret je najvažnija uljana kultura u Srbiji. Glavni ciljevi oplemenjivanja suncokreta su stvaranje srednje ranih hibrida sa visokim genetskim potencijalom za prinos semena i ulja, a stabilnim u regionima proizvodnje suncokreta u Srbiji. Cilj ovog istraživanja bio je da se ispita mogućnost korišćenja ranostasnih hibrida umesto hibrida srednje dužine vegetacije, koji su u pogledu prinosa semena i ulja i parametara stabilnosti na nivou standardnih hibrida suncoreta. U radu su ispitana tri nova ranostasna hibrida suncokreta NS1, NS2 i NS3, stvorena u Institutu za ratarstvo i povrtarstvo, Novi Sad. Na osnovu dobijenih rezultata utvrđeno je da nije bilo značajne razlike između ranih hibrida i standardnih hibrida suncokreta za prinos semena i ulja. Rani hibridi suncokreta pokazali su različit nivo stabilnosti gajenja u ispitivanim lokalitetima. Rani hibridi NS2 i NS3 su pokazali visok stepen stabilnosti na svim ispitivanim lokalitetima i visoke prinose semena i ulja. Dobijeni rezultati predstavljaju značajan doprinos u oplemenjivanju suncokreta i razvoju domaćih hibrida sa kraćom dužinom vegetacije, a boljim potencijalom prinosa semena i ulja.

Ključne reči: *suncokret, hibrid, ranostasnost, prinos semena, prinos ulja, stabilnost.*

INTRODUCTION

Sunflower is one of the most important oil crops in Serbia and in the world. In the period 2006-2012 the average seed yield in Serbia was 2.2 t/ha harvested on 170994 ha with an average production of 383961 t *(FAO 2013)*. The main objective of sunflower breeding is the development of productive F_1 hybrids with high and stable seed and oil yields. Oil yield depends on seed yield and oil content in the seed *(Cvejić et al., 2014)*. Ideal hybrid in terms of seed yield is capable to use its genetic potential to the maximum in different environments *(Jocković et al., 2012)*, therefore stability and adaptability investigation of such hybrids should be considered. Seed and oil yield as well as seed oil concentration in sunflower is sensitive to environmental conditions during the grain-filling period *(Leon et al., 2003)*.

Sunflower hybrids show wide variation in maturing. The modern high-yield hybrids are usually medium-late, medium-early or early, which in turn reflects the negative associations between seed and oil yield and maturity *(Kaya et al., 2004)*. Late maturity hybrids (full vegetation) have a high relative seed yield compared to medium-early to early maturity hybrids. The breeding process involved the selection of the medium early maturity hybrids which had the tendency to maximize yield potential and stability in different regions of sunflower production in Serbia *(Balalić et al., 2012)*.

Early-maturing hybrids are more favourable in areas with short growing seasons or for double-cropping. Additionally, early hybrids grow and dry faster than later hybrids. Maturity is especially important if planting is delayed or in case of possible unstable environmental conditions during the harvesting period. The cultivated sunflower normally requires about 50–80 days starting flowering, and 90–120 to reach physiological maturity. Early hybrids flower at about 55 days and mature in less than 100 days *(Taran et al., 2014)*.

Early-maturing sunflower hybrids generally exhibit lower genetic yield potential, but more favourable values of stability parameters in comparison with standard (medium-early or medium-late) hybrids. The objective of this study was to test the possibility of using early-maturing hybrids instead of the medium-maturing ones, given the balance between yield and stability parameters.

MATERIAL AND METHOD

Three new early-maturing sunflower hybrids were used in the study - NS1, NS2 and NS3, which were developed at the Institute of Field and Vegetable Crops, Novi Sad. Hybrids are still in the experimental phase and have not been commercialized yet. Hybrids feature less than 100 days maturity. Moreover, four standards (two local and two foreign hybrids), were planted together with early hybrids. Standard hybrid belonged to medium-early group. The experiment was carried out at six locations in Serbia during the growing season 2014. Locality details are shown in Table 1. The experiment was laid out in a randomize block design with four replications, on each location. Plots considered four 5 m rows with 25 cm between the rows. Seed yield data were recorded on plants from the middle rows to avoid the edge effect. Oil content was determined by nuclear magnetic resonance (NMR) analyser.

Table 1. Planting locations, soil type, rainfalls and temperature for growing season 2014

	Location	Rainfall	Soil type	Average daily temperature					
				IV	V	VI	VII	VIII	IX
E1	Novi Sad	595.2	Chernozem	13.2	16.3	20.5	21.9	20.9	17.2
E2	Subotica	545.8	Sendy soil	13.0	16.1	20.5	22.5	20.9	17.1
E3	Novo Miloševo	625.3	Humogley	13.1	16.4	20.3	22.2	21.1	17.2
E4	Pančevo	787.5	Chernozem	13.0	16.3	20.1	21.6	21.0	17.1
E5	Zrenjanin	805.5	Chernozem	13.2	16.5	19.9	22.3	21.4	17.0
E6	Kikinda	424.7	Humogley	13.1	16.3	20.4	22.2	21.1	17.5

Analyses of variance (ANOVA) were done for separate locations as well as combined across locations for seed yield, oil content and oil yield. The ANOVA was useful in identifying sources of variability and in determining the significance of GxE interaction, but did not provide a pattern of response of genotypes and environment. The AMMI method combines the traditional ANOVA and principle component analysis (PCA) into a single analysis with additive and multiplicative parameters (*Gauch, 1992*). In the AMMI biplot, the interaction principle component (IPCA) scores were plotted against genotype and environmental means. Therefore, genotype and environment main effects, genotype stability and adaptability to different environments are observed. The ANOVA and AMMI analysis were processed using the GenStat programme, version 9. Significant differences were calculated from the F-test.

RESULTS AND DISCUSSION

Highly significant variations were observed among genotypes, environments and their interactions for seed yield, as well as within analyses for oil content and oil yield (Table 2). Analysis of variance examined the main effects and their interaction in detail. Analysis of seed and oil yield showed that the total sum of squares attributed to the impact of environments in large percentage (71.09 % and 74.09 % respectively), the effect of genotypes was 7.06 % and 3.71 %, while GxE was represented with 6.67 % and 7.05 % respectively. For oil content, 44.61 % of the total sum of squares was mainly the result of environmental effect, while genotype and GxE effect contribute 38.58 % and 5.28 %.

The mean seed yield varied throughout different locations, with an average of 3293 kg/ha (Table 3). There were no significant variations between early-maturing hybrids and standards for seed yield. Average performance of early-maturing hybrid G3 resulted very high ranking (second place) due to high average seed yield (3428 kg/ha). Hybrids G1 and G2 performed solid seed yield ranking on the 6th and 5th place, respectively. There were significant differences across six locations. The highest seed yields were observed in Novi Sad-E1 (4028 kg/ha) and the lowest in Novo Miloševo-E3 (2222 kg/ha). Genotype stability is considered as a reaction to changing environmental conditions, which depend on unpredictable variation components (*Kang, 2002*). In this study, climatic conditions were the source of this variation component. The stability of tested hybrids was evaluated according to biplot for seed yield (Figure 1A). Early-maturing experimental hybrids interacted differently with climate conditions in the observed locations. Sunflower hybrids were grouped in three pools according to seed yield stability: hybrids G2, G6 and G7 generally showed very good stability, achieving strong interaction with E1 (Novi Sad) and E4 (Pančevo). The second pool are medium stable hybrids (G3, G4 and G5), and G1 is the minimum stable hybrid. Seed yield variation of hybrid G1 might be due to sensitivity to too much rain, especially in period of grain filling which was the case in location E5. This location (E5) and some others, for example Subotica (E2) showed low stability since uncommonly more rainfall in 2014. This effected on seed yield performance of some hybrids, such as G1 which were selected in the different meteorological conditions. Therefore, experiment should be repeated one more year to have a lower interaction of environment. However, hybrid G2 showed high stability throughout six locations although not so high seed yield. The mean oil content showed significant differences between locations, with the average performance 42.26 % (Table 4). The mean oil content was highest in Subotica-E2 (45.11 %) and lowest in Kikinda-E6 (40.07 %). Hybrids were differently distributed into groups according to stability performance and oil content (Figure 1B). The most stable hybrids were G3, G5 and G7, but oil content was below average. Medium stable hybrids were G1, G2 and G4, although hybrids G1 and G2 had high mean oil content. Hybrid G6 was considered less stable for oil content than other hybrids.

Table 2. Mean squares and percentage variations explained for seed yield, oil content and oil content of seven hybrids tested over six locations

Sources of variation	Seed yield		Oil content		Oil yield	
	Mean squares	Variation explained (%)	Mean squares	Variation explained (%)	Mean squares	Variation explained (%)
Environments (E)	14025288**	71.09	128.48**	44.61	3218600**	74.09
Genotypes (G)	1159930**	7.06	92.60**	38.58	134218**	3.71
GxE	219416**	6.67	2.53**	5.28	51022**	7.05
IPCA 1	383448**	(58.25)	5.32**	(70.00)	85601**	(55.92)
IPCA 2	200080	(24.32)	1.91	(20.13)	46458	(24.28)
Residual	95614	17.43	0.63	9.87	25249	19.79

GXE genotype-by-environment interaction, IPCA interactive principle component analysis, Figures between brackets indicate GXE percentage explained by IPCA
$* P \leq 0.05$; $** P \leq 0.01$

Table 3. Seed yield (kg/ha) of early-maturing and standard hybrids tested in six different locations and their average performance

	Genotype	Location						Average performance	
		E1	E2	E3	E4	E5	E6	Mean	Rank
	Early hybrids								
G1	NS 1	3817	4165	2197	3390	2206	2493	3045	6
G2	NS 2	3796	3837	1936	3375	2763	2599	3051	5
G3	NS 3	4105	4153	2061	3860	3334	3055	3428	2
	Mean	3906	4085	2054	3519	2786	2698	3175	
	Standards								
G4	Foreign 1	3792	3587	1814	3308	3120	2640	3044	7
G5	Foreign 2	4389	4016	2560	3649	3632	3086	3555	1
G6	Domest. 1	3999	3877	2353	3267	2787	2603	3148	4
G6	Domest. 2	4295	4056	2637	3490	3189	2884	3425	3
	Mean	4119	3859	2349	3446	3169	2817	3293	
	Average	4028	3956	2222	3477	3004	2766	-	-
	LSD 5%	670	582	752	395	671	539	-	-

Table 4. Oil content (%) of early-maturing and standard hybrids tested in six different locations and their average performance

	Genotype	Location						Average performance	
		E1	E2	E3	E4	E5	E6	Mean	Rank
	Early hybrids								
G1	NS 1	44.77	46.24	42.94	41.82	44.91	40.26	43.49	3
G2	NS 2	47.68	49.87	46.15	42.83	46.75	42.85	46.02	1
G3	NS 3	42.19	42.85	41.50	38.70	42.86	38.59	41.12	6
	Mean	44.93	46.30	43.56	41.00	44.83	40.53	43.54	
	Standards								
G4	Foreign 1	42.27	43.99	40.08	39.53	42.27	37.48	40.94	7
G5	Foreign 2	42.50	43.16	41.83	38.99	43.16	38.91	41.43	5
G6	Domest. 1	45.67	45.71	46.36	40.81	46.47	42.94	44.66	2
G7	Domest. 2	43.16	43.96	42.54	39.27	43.61	39.50	42.01	4
	Mean	43.37	44.23	42.69	39.65	43.89	39.73	42.26	
	Average	44.03	45.11	43.06	40.28	44.29	40.07	-	-
	LSD 5%	3.27	3.83	3.73	2.40	2.86	3.11	-	-

The mean oil yield of the early-maturing and standard hybrids showed significant differences across six locations, with an average of 1395 kg/ha (Table 4). The mean oil yield ranged between 1786 kg/ha (Subotica-E2) and 958 kg/ha (Novo Miloševo-E3). Hybrids showed similar patterns of stability and adaptability for oil yield and for seed yield (Figure 1C). Hybrids G2, G6, and G7, including hybrid G3, were the most stable with above average oil yield. Hybrids G4 and G5 showed medium stability and hybrid G1 was the least stable for oil yield.

Biplot graph showed average values of genotype, environment and interaction (Figure 1). According to *Gauch and Zobel (1997)* genotype effects (abscissa) control the wide sense adaptability while the interaction effects (ordinate) control the narrow sense adaptability. As presented in Figure 1. hybrids grouped around abscissa exhibited low effect of the interaction and those hybrids are characterized by good stability. However, our primary goal is high yield and special attention should be given to hybrids with low effect of the interaction and high values of seed and oil yield, such as domestic standards G6 and G7 and early-maturing hybrids G2 and G3. The worst performing hybrid was G1 which exhibited the lowest seed and oil yield, and the highest effect of interaction. As mentioned before, this hybrid considered to be sensitive to too humid conditions in grain filling period, as well as to too wetland soils. We assume that in years with a less rainfalls hybrid G1 would perform with an higher seed and oil yield.

Table 5. Oil yield (kg/ha) of early-maturing and standard hybrids tested in six different locations and their average performance

	Genotype	Location						Average performance	
		E1	E2	E3	E4	E5	E6	Mean	Rank
	Early hybrids								
G1	NS 1	1732	1933	963	1354	1008	996	1331	6
G2	NS 2	1786	1971	862	1487	1298	1102	1415	3
G3	NS 3	1767	1793	869	1451	1459	1139	1413	4
	Mean	1755	1891	895	1441	1247	1089	1386	
	Standards								
G4	Foreign 1	1615	1571	743	1271	1334	991	1254	7
G5	Foreign 2	1868	1705	1090	1439	1530	1223	1476	1
G6	Domest. 1	1818	1754	1091	1369	1285	1124	1407	5
G7	Domest. 2	1845	1777	1087	1416	1372	1166	1444	2
	Mean	1787	1708	1006	1366	1387	1119	1395	
	Average	1773	1786	958	1398	1327	1106	-	-
	σ^2	318	323	333	127	266	203	-	-

As for the environments in which hybrids were grown, we can see that locality Novi Sad (E1) and Pančevo (E4) had the lowest interaction and hybrids showed the best performance in those environments, while localities Subotica (E2) and Zrenjanin (E5) were unstable environments for hybrids because of high interaction. Both locations (E2 and E5) had more rainfalls in 2014 than average, indicating unstable conditions. Testing different wheat characteristics, *Mladenov et al. (2012)* observed changes under the influence of locality, which was reflected through significant GxE. Calculated values of GxE showed that there were differences in the stability of genotype across investigated traits.

The entire sunflower breeding program contributed to the development of local early-maturing hybrids and hybrids with better yield potential. Similar results were presented by *Taran et al. (2014),* who concluded that earliness and yield performance varied across genotypes, environments and G × E interactions, and that the selection of early maturing hybrids for specific locations could significantly increase sunflower yield. There were no significant variations between early-maturing hybrids and standard hybrids for seed and oil yield and oil content. Therefore, the stability for earliness and oil and seed yield were proved in all three examined early-maturing hybrids. Results showed that early-maturing, high yielding hybrids were suitable for the cropping system in all six tested locations.

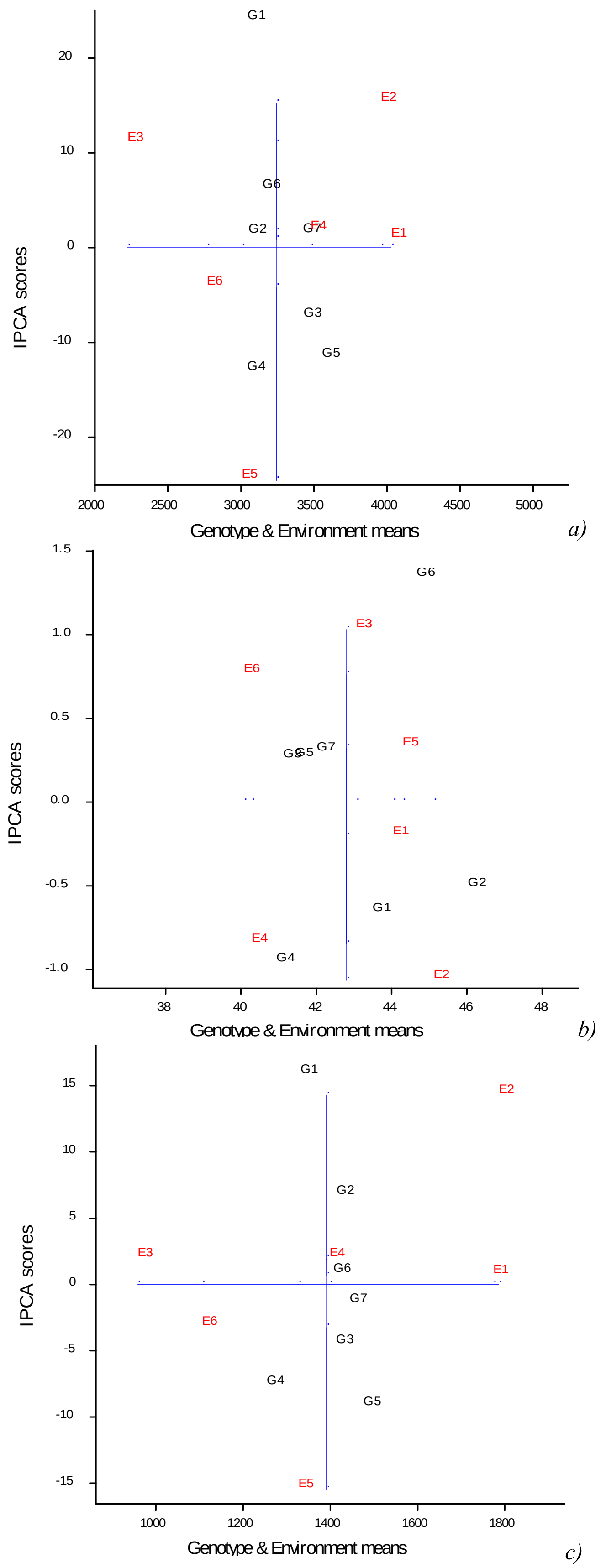

Fig. 1. AMMI biplot genotype and environment mean for seed yield (A), oil content (B) and oil yield (C) plotted against respective scores of the first interaction principle component (IPCA 1)

CONCLUSION

Early-maturing hybrids performed as standard hybrids regarding high seed and oil content. Environmental factors had the highest influence on the formation of seed and oil yield. The early-maturing hybrids NS2 and NS3 are recommended for further inclusion in the breeding program due to their stability and high seed and oil yield.

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