UDC 575.633
https://doi.org/10.2298/GENSR1901081C
Original scientific paper

SELECTION OF SUNFLOWER HYBRIDS BASED ON STABILITY ACROSS ENVIRONMENTS

Sandra CVEJIĆ[1*], Siniša JOCIĆ[1], Velimir MLADENOV[2], Borislav BANJAC[2], Ilija RADEKA[1], Milan JOCKOVIĆ[1], Ana JEROMELA MARJANOVIĆ[1], Dragana MILADINOVIĆ[1], Vladimir MIKLIČ[1]

[1]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[2]Faculty of Agriculture, University of Novi Sad, Novi Sad, Serbia

Cvejić S., S. Jocić, V. Mladenov, B. Banjac, I. Radeka, M. Jocković, A. Jeromela Marjanović, D. Miladinović, V. Miklič (2019): *Selection of sunflower hybrids based on stability across environments.*- Genetika, Vol 51, No.1, 81-92.
Bearing in mind that the sunflower production in Serbia is extensive, it is very important to select a hybrid that will achieve stable and high seed and oil yields in different enviromental conditions. The objective of the study was to identify the most stable sunflower hybrids for seed and oil yield using AMMI model analysis. Nine newly developed early, medium early and medium late hybrids were tested. Hybrids were grown in different locations across Northern Serbia during two growing seasons (2013-2014). Selected locations are geographically close, but environmentally different in terms of soil, rainfalls and temperature, thus creating a specific microclimate conditions for sunflower growing. Pooled analysis of variance for seed and oil yield showed that the main effects of hybrids, environments and their interaction were highly significant. The agro-ecological environment E3 is most favourable for achieving high seed and oil yields, but E9 was the most stable. According to results of AMMI model, the most stable hybrids for the seed and oil yield, i.e. the lowest interaction with the enviroment, were NS2, NS8 and NS9. The obtained results indicate that hybrids can be recommended for production in different environments in Serbia; NS2 hybrid as early-growing, stable for oil yield; NS8

Corresponding author: Sandra Cvejić, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia. Phone: +381214898403; cell phone: +381648706028, e-mail: sandra.cvejic@ifvcns.ns.ac.rs

and NS9, medium-late hybrids, high productivity potential and suitable for all production systems.

Keywords: sunflower, hybrid, seed yield, oil yield, stability

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the world's four most important oilseed crops, after soybean, rapeseed and palm seed. Sunflower seed is mostly produced for oil extraction due to high quality. It is the main oilseed crop in Serbia, accounting for over 80% of the total amount of edible oil derived from plant sources. In the period 2006-2016 the average seed yield in Serbia was 2.43 t/ha, harvested on 176 909 ha, with an average production of 433 457 t (FAO, 2018). Locally developed sunflower hybrids are used in the commercial production and the main directions of its breeding are increased productivity (seed and oil yield per unit area) and resistance to diseases and stressful conditions (CVEJIĆ, 2011). An ideal hybrid in terms of seed yield is capable to use its genetic potential to the fullest in different environments (JOCKOVIĆ *et al*., 2012), therefore investigation of stability and adaptability 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).

Serbian arable land is rich in chernozem, but it also contains other types of soil. Richer soils are used for growing staple crops, while sunflower is mainly grown on marginal soils. Yield potential is therefore insufficiently used, and average yields could be closer to the genetic yield potential (ŠKORIĆ, 2009). Full season usually means planting in April and harvesting in September, but this period can be almost a month longer or shorter, depending on the environmental conditions. Temperatures and rainfalls also largely affect yield formation. Weather conditions in the sowing (April) and harvesting period (September and October) are often characterized by low temperatures, which affect the condition of crops. Therefore, genotype × environment interaction proved to be a challenging issue among plant breeders, geneticists and production agronomists within their studies of crop performance across diverse environments (TARAN *et al.*, 2013). Adaptability and genetic make-up information of sunflower hybrid development is an important consideration.

Sunflower hybrids show wide variation in maturing. The modern high-yielding hybrids are usually medium-late, medium-early or early, which in turn causes 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 and early maturity hybrids. However, late hybrids go through the critical stages of seed formation and filling during the most unfavourable part of the season (second half of July and first half of August), when air temperature is highest and the possibility of drought is the greatest, which negatively affects yield. Drought is the main cause not only of differences between mean yield and potential yield, but also of multi-annual yield variation and therefore yields instability (MONTE, 1986). Hybrids with a shorter growing season go through this critical phase earlier and faster, so their yields are less affected by drought conditions. Early sunflower hybrids generally have lower leaf area index, lower total evapotranspiration and lower yield potential than later hybrids. According to ŠKORIĆ (2009), early sunflower hybrids are most often susceptible to charcoal rot (*Macrophomina phaseolina*), so in case of an early occurrence of drought such hybrids may become affected, thus nullifying any positive effect of early maturity. The breeding process involved the selection of medium-early maturity hybrids which showed a tendency to maximize yield potential and stability in different regions of sunflower production in Serbia (BALALIĆ *et al.*, 2012).

The objective of the study was to identify the most stable sunflower hybrids for seed and oil yield in locations characterised by its heterogeneous soils and irregular rainfall during the growing seasons in nine newly developed early, medium early and medium late hybrids. The aims were to: (1) determine the seed and oil yield of the newly developed sunflower hybrids (2) determine the influence of hybrids, environmental conditions and their interactions on seed and oil yield (3) examine the stability of hybrids through different locations using the AMMI model. Selected locations are geographically close, but environmentally different in terms of soil, rainfalls and temperature, thus creating a microclimate conditions for sunflower growing and (4) detect whether there is a link between maturity and stability of new hybrids.

MATERIAL AND METHODS

The research involved nine new sunflower hybrids, developed at the Institute of Field and Vegetable Crops, Novi Sad, Serbia. Since these hybrids are still experimental we used only breeder's reference. Also, four standards were used in the trials. These standards are also standards in Official trials of the Department for varity recognition in Serbian Ministry of Agriculture, Forestry and Hydrology (Table 1).

Table 1. List of sunflower hybrids and their maturity groups

Hybrid	Breeders reference	Maturity group
NS 1	NS-H-5841	Early
NS 2	NS-H-4362	Early
NS 3	NS-H-6215	Early
NS 4	NS-H-6955	Medium-early
NS 5	NS-H-4988	Medium-early
NS 6	NS-H-5201	Medium-early
NS 7	NS-H-6503	Medium-late
NS 8	NS-H-5214	Medium-late
NS 9	NS-H-6547	Medium-late
ST 1	Standard 1	Medium-late
ST 2	Standard 2	Medium-early
ST 3	Standard 3	Medium-late
ST 4	Standard 4	Medium-early

The experiment was carried out at three locations during the growing season 2013, and six locations during the growing season 2014 in Serbia. Locality details are shown in Table 2. The experiment was organized in a randomized complete block design with three replications. Basic plots were split in 4 rows with row length of 10 m. Inter-row spacing was 70 cm and intra-row spacing was 25 cm, and standard cultivation practices were applied. Seed yield data were recorded on plants from middle rows to avoid edge effect. Seed yield was measured in t per ha on an 11% moisture basis. Oil content was determined using the nuclear magnetic resonance (NMR) analyser.

Table 2. Planting locations, soil type, rainfalls and temperature for growing season 2013 and 2014

						Average daily temperature						
	Location	Coordinates	Growing season	Rainfall	Soil type	IV	V	VI	VII	VIII	IX	Ave
E1	Novo Miloševo	45°43′11″N; 20°18′07″E	2013	292	Humogley + Salty soil	14	20	22	24	25	17	20.3
E2	Subotica	46°05′53″N; 19°40′16″E	2013	296	Sandy soil	12,8	19	21	22	24	15	19
E3	Novi Sad	45°19´51˝N; 19°50´59	2013	445	Chernozem	13,5	20	22	24	25	17	20.2
E4	Kikinda	45°49′28″N; 20°27′33″E	2014	425	Humogley	13.1	16.3	20.4	22.2	21.1	17.5	18.4
E5	Zrenjanin	45°22′00″N; 20°23′00″E	2014	806	Chernozem	13.2	16.5	19.9	22.3	21.4	17.0	18.4
E6	Pančevo	44°51′49″N; 20°39′33″E	2014	788	Chernozem	13.0	16.3	20.1	21.6	21.0	17.1	18.2
E7	Novo Miloševo	45°43′11″N; 20°18′07″E	2014	625	Humogley + Salty soil	13.1	16.4	20.3	22.2	21.1	17.2	18.4
E8	Subotica	46°05′53″N; 19°40′16″E	2014	563	Sandy soil	13.0	16.1	20.5	22.5	20.9	17.1	18.4
E9	Novi Sad	45°19´51˝N;19° 50´59˝E	2014	645	Chernozem	13.2	16.3	20.5	21.9	20.9	17.2	18.3

The mean values and coefficient of variations were calculated as indicators of trait variability. These statistical calculations were done using StatSoft, Inc. (2011), STATISTICA, version 10 (www.statsoft.com). Genotype by environment interaction (GEI) was tested using AMMI (Additive Main Effects and Multiplicative Interaction) analysis by ZOBEL *et al.* (1998). Data processing was performed in GenStat 9th Edition VSN International Ltd (www. vsn-intl.com). Significant differences were calculated from the F-test.

RESULTS AND DISCUSSION

The weather conditions in the two examined years (2013 and 2014) varied during the vegetation season in observed locations (Table 2). The main feature of the climatic characteristics in the observed locations are unusual rainfall distribution and specific soil type (Table 2). The less amount of rainfall was in enviroments E1 (292 mm) and E2 (296 mm), which is less than average values for Northern Serbia for growing season period, 328 mm for rainfalls (PEJIĆ *et al.*, 2010; STOJAKOVIĆ *et al.*, 2015). Environments E5 and E6 had extremely high level of rainfall during growing season. For the sunflower production, the season 2013 was favourable due to little but well distributed rainfalls rate and higher temperatures. The 2014 was extremely unfavourable for the sunflower production, because of much more rainfall than the average.

The paper presents an adaptive value of 13 sunflower hybrids according to different cultivation conditions in areas where sunflower is traditionally grown. Of the 13 hybrids, 9 are brand new hybrids, different maturity groups, whose commercialization depends on their productivity but also on stability through different agroecological environments. Therefore, the interaction of the genotype and enviroment is crucial for the explanation of their adaptive nature.

Variability of seed and oil yield in sunflower hybrids

Avarage seed yield was determined for 13 sunflower hybrids (9 new and 4 standards) in 9 agroecological environments (Table 3). All hybrids showed a high genetic potential of seed yield, evident from the average value of seed yield which was not below 3000 kg ha^{-1}, far above the average value of seed yield in Serbia. The average yield of all hybrids and all environments was 3487 kg ha^{-1}, varied from 3142 to 3844 kg ha^{-1}. Hybrids ST2, NS3 and NS8 had the highest average seed yield. Concerning environments, there was high variability of seed yield among agroecological environments. Hybrids achieved the highest average seed yield in E3 (5154 kg ha^{-1}) while the lowest was in E7 (2171 kg ha^{-1}).

Table 3. Seed yield (kg ha^{-1}) of nine sunflower hybrids and four standards in nine environments

Hybrids	E1	E2	E3	E4	E5	E6	E7	E8	E9	Mean	Cv	Rank
NS1	4422	3496	4626	2645	2121	3392	2197	4068	3845	3423	27.03	10
NS2	3346	4286	4993	2440	2908	3227	1881	4084	3766	3437	28.02	9
NS3	3442	3552	5645	3009	3328	3937	2085	4103	4107	3690	26.21	2
NS4	3305	4028	5255	2609	2452	2589	1855	3417	3296	3201	31.38	12
NS5	3327	3527	5367	2186	2102	2655	2099	3657	3357	3142	33.31	13
NS6	4006	2916	4939	2473	2426	3065	1712	3877	3838	3250	30.68	11
NS7	4821	4973	5433	2291	2176	2625	1963	3583	4310	3575	37.80	5
NS8	3748	4203	5186	2588	3140	3126	2512	4140	3949	3621	23.82	3
NS9	3961	3693	4995	2902	2976	3301	2526	3938	3618	3546	20.66	6
ST1	4237	3977	4679	2719	3070	3345	1839	3507	3781	3462	24.61	8
ST2	4208	3548	5507	3260	3551	3587	2523	3963	4447	3844	21.77	1
ST3	3668	3813	5520	2515	2802	3343	2375	3853	3999	3543	26.98	7
ST4	3336	3654	4858	2774	3251	3509	2657	4112	4249	3600	19.74	4
Mean	3833	3820	5154	2647	2793	3208	2171	3870	3889	3487		
Cv	12.78	13.00	6.45	11.06	17.53	12.41	14.60	6.46	8.85	5.72		

The oil yield is a key indicator of the productivity of each hybrid and depends on the seed yield and oil content of the seed. Bearing in mind that sunflower is mostly grown for edible oil, improving oil content is one of the main goal of sunflower breeding (JOCKOVIĆ *et al.* 2018). The highest average oil yield was achieved in hybrid NS8 (1725 kg ha^{-1}) and the lowest was in hybrid NS4 (1410 kg ha^{-1}). High oil yields were also recorded in hybrids ST2, NS7 and NS2 (Table 4). Concerning the environments, sunflower hybrids achieved the best average oil yields in E3, as much as 2533 kg ha^{-1}, while the lowest average oil yields were in E7, 941 kg ha^{-1}. The average oil yield in all environments and in all hybrids was 1573 kg ha^{-1}.

Table 4. Oil yield (kg ha^{-1}) of nine sunflower hybrids and four standards in nine environments

Hybrids	E1	E2	E3	E4	E5	E6	E7	E8	E9	Mean	Cv	Rank
NS1	1921	1516	2229	1068	952	1419	942	1882	1723	1517	30.45	9
NS2	1717	2060	2563	1046	1356	1383	868	2033	1801	1648	32.61	4
NS3	1678	1616	2825	1153	1431	1521	874	1757	1741	1622	33.11	6
NS4	1552	1795	2527	1037	1067	953	769	1549	1438	1410	38.15	13
NS5	1638	1563	2728	874	934	1064	878	1717	1475	1430	41.55	12
NS6	1967	1263	2349	1058	1118	1289	767	1861	1853	1503	34.69	10
NS7	2328	2367	2721	979	995	1076	840	1665	1963	1659	43.05	3
NS8	1818	2048	2602	1162	1504	1386	1213	1918	1875	1725	26.60	1
NS9	1951	1726	2539	1102	1272	1277	1059	1702	1523	1572	30.04	7
ST1	2015	1616	2226	1017	1308	1318	741	1542	1600	1487	30.96	11
ST2	2059	1583	2688	1283	1505	1407	1053	1699	1908	1687	28.71	2
ST3	1814	1688	2679	1076	1307	1362	1102	1766	1829	1625	30.44	5
ST4	1606	1596	2252	1098	1427	1376	1127	1823	1811	1569	23.28	8
Mean	1851	1726	2533	1073	1244	1295	941	1763	1734	1573		
Cv	11.78	16.55	8.13	9.09	16.67	12.72	16.36	8.00	9.90	6.27		

AMMI model

The AMMI analysis of seed yield variance showed the statistical significance of the main sources of variation (hybrids and environment) and the multivariate part (interaction hybrid x environment). Based on entire trail for the seed yield, it was calculated that agro-ecological environments carry 83.40% of the sum of the squares of the experiment. The genotype x environmental interaction participated with 12.23 % in the sum of the squares of the experiment. The influence of hybrids on seed yield variability was the lowest and amounted to 4.37%. The largest share in the interaction of the genotype x environment had the first interaction IPCA axis, which explained 44.66% (Table 5). The small share of hybrids in seed yield variation may be due to the pronounced and complex quantitative nature of the yield, which is conditioned by a large number of components. Another reason may be the divergence of selected genotypes.

AMMI analysis of oil yield variance showed a similar result obtained in seed yield. In addition to the highly significant mean of the square of the environment (86.50%), high statistical significance of the middle of the square of the genotype x environment interaction (9.85%) and hybrids (3.65%) were also recorded. The largest share in the interaction of the hybrid x environment had the first interaction IPCA axis, which explained 40.35% (Table 6).

Table 5. AMMI analysis for seed yield of examined sunflower hybrids

Source	df	Sum of squares	Mean of squares	F value	F table 0.05	0.01	Share of total variation %
Treatments	116	393778654	3394644	**21.04	1.00	1.00	100
Hybrids	12	17203001	1433583	**8.88	1.75	2.18	4.37
Environments	8	328399460	41049932	**86.71	1.94	2.51	83.40
Interactions	96	48176193	501835	**3.11	1.00	1.00	12.23
$IPCA_1$	19	21516966	1132472	**7.02	1.57	1.87	44.66
$IPCA_2$	17	11012412	647789	**4.01	1.57	1.87	22.86
$IPCA_3$	15	5509313	367288	**2.28	1.75	2.18	11.44
$IPCA_4$	13	4084018	314155	*1.95	1.75	2.18	8.48
Residuals	32	6053483	189171	1.17	1.46	1.69	-

Table 6. AMMI analysis for oil yield of examined sunflower hybrids

Source	df	Sum of squares	Mean of squares	F value	F table 0.05	0.01	Share of total variation %
Treatments	116	115327079	994199	**27.50	1.00	1.00	100
Hybrids	12	4206673	350556	**9.70	1.75	2.18	3.65
Environments	8	99765472	12470684	**116.07	1.94	2.51	86.50
Interactions	96	11354935	118281	**3.27	1.00	1.00	9.85
$IPCA_1$	19	4582053	241161	**6.67	1.57	1.87	40.35
$IPCA_2$	17	2621349	154197	**4.26	1.57	1.87	23.09
$IPCA_3$	15	1553945	103596	**2.87	1.75	2.18	13.69
$IPCA_4$	13	1159338	89180	**2.47	1.75	2.18	10.21
Residuals	32	1438250	44945	1.24	1.46	1.69	-

For a clearer explanation of main effects and their interaction biplots were constructed for the seed yield. Average values of the main effects (hybrids and environments) were entered on the abscissa, while IPCA1 values were plotted on the ordinate (Figure 1). Values plotted on abscissa control the wide sense adaptability, while IPCA values (ordinate) control the stability. AMMI bioplot analysis for the seed yield of the tested sunflower hybrids was concentrated close to main effects and interaction showing good adaptive values and stability. Based on stability level hybrids were grouped in three pools: A, B and C. *Pool A* were the most stable hybrids; NS8, NS2 and ST3. In the *Pool B* were medium stable hybrids (NS1, NS4, NS5, NS6, NS9, and ST1) and *Pool C* were minimum stable hybrids (NS3, NS7, ST2, and ST4). The hybrid NS8 was singled out due to a small interaction value, i.e. a good stability with simultaneously higher yield than other hybrids. Also very stable hybrid was NS2, having minimum values of main effects and interaction. Hybrid ST2 was also distinguished as the hybrid that achieved the highest seed yield but had a high interaction of the hybrid x environment, which indicates a minimum stability in the observed agro-ecological conditions.

The environments differed both in the main effect and in the multivariate part of the total variation. This is indicated by the distribution of points of agro-ecological environments on AMMI biplot (Figure 1). In the agro-ecological environment, E3 hybrids achieved the highest average seed yield values, with satisfactory, low interaction values. However, the lower interaction value and yield greater than the average was achieved on E9, which makes it more favourable than other agro-ecological environments. The environments E4, E5 and E6 were not favourable for tested hybrids in terms of achieving high yields.

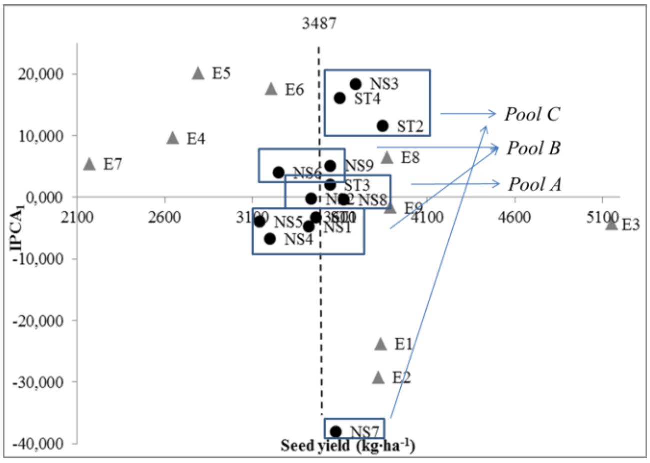

Figure 1. Biplot of the AMMI model for seed yield for nine examined sunflower hybrids and four standards grown across nine environments

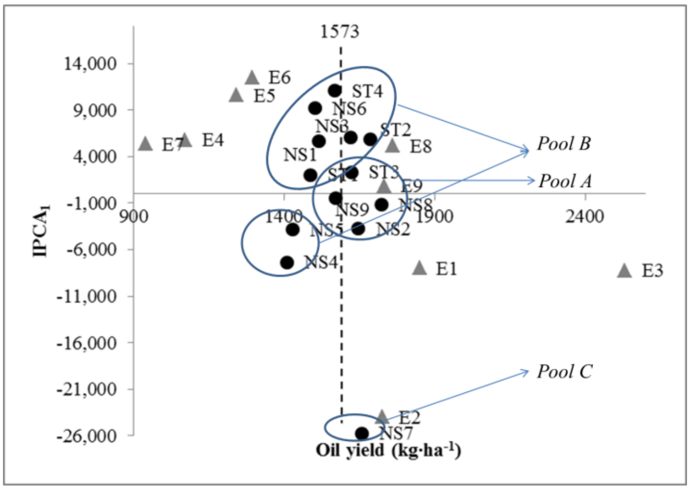

Figure 2. Biplot of the AMMI model for oil yield for nine examined sunflower hybrids and four standards grown across nine environments

The AMMI biplot for the oil yield had the similar arrangement as the seed yield. However, distribution of hybrid values on biplot and grouping slightly changed. The *Pool A* were same stable hybrids as for seed yield (NS2, NS8 and ST3), including hybrid NS9. The hybrid NS8 was favourable in the case of oil yield, because it has the smallest interaction value, i.e. the highest stability, and at the same time the highest yield in this case. The hybrid NS9, whose average oil yield is at the level of yield of the entire experiment, has a slightly higher stability. Early maturing hybrid NS2 was close to main effects and interaction showing good adaptive values. Moderate stabile hybrids were grouped in *Pool B* and consisted of most of tested hybrids (Figure 2). The minimum stable hybrid was NS7 (*Pool C*) had the highest interaction of the hybrid and environment.

The agro-ecological environment E3 is most favourable for achieving high oil yields, but E9 was the most stable. Similar to the seed yield, the environment E4, E5 and E6 were the most unfavourable for the yield of oil.

Environmental influence on hybrid stability

The AMMI analysis of 13 hybrids in nine agroecological environments in two years showed that the influence of enviroment was the largest in total variation for both seed and oil yield. MARINKOVIĆ *et al.* (2011) pointed out that complexity of quantitative traits, such as seed yield of sunflower hybrids showed significant variation in productivity depending on environmental conditions. MARJANOVIĆ-JEROMELA *et al.* (2011) found out that environmental factors, especially temperature and precipitation, had the most significant influence on the seed yield, which is in agreement with our research. Hybrids were tested environmentally different locations in terms of soil, rainfalls and temperature and the yields and stability of tested hybrids drastically varied among environments. The highest seed and oil yields, also the most stable enviroments were E3 and E9 belonging to same location (Novi Sad). Concerning seed and oil yield the best environment was E3 (less rainfall and higher temperature) but concerning stability of tested hybrids, the best was E9 (more rainfall and lower temperatures). This implicates that not only sum of rainfalls and temperature were influence adaptability and stability of hybrids but distribution of rainfalls, as well as other climate factors that can be predicted before planting; e.g., photoperiod, soil type, nitrogen, plant density etc. (DE LA VEGA and CHAPMAN, 2006).

The environments E4, E5 and E6 were not favourable for tested hybrids in terms of stability for seed and oil yields. These environments were characterized by rainfalls during the vegetation season, untypical for these locations which influenced the reduction in seed and oil yields and stability of all hybrids. VAN DER MERWE *et al*. (2013) explained that excessive precipitation may result in a decrease in oil content, since higher than normal rainfall during the maturation stage results in restriction in growth and development of sunflower seed (GRASSINI *et al.*, 2007) as well as poor pollination, resulting in poor seed set. Enviroment E7 had the lowest seed and oil yields of all enviroments but relatively good reactions to changing environmental conditions, showing that some hybrids have high adaptation in specific climates.

Selecting hybrids based on stability

Genotype stability is considered a reaction to changing environmental conditions, which depend on unpredictable variation components (KANG, 2002). The present study aimed to identify environmental stability of sunflower hybrids with respect to seed and oil yield. In terms of average seed and oil productivity of hybrids within years, vegetation 2013 was more favourable for seed yields in comparison to vegetation 2014, which had more rainfalls in all locations which that evidently had influence on disease pressure and present of pollinations during flowering time. This reflected on stability of hybrids, so only several hybrids reacted positively to these changes in environmental conditions. According to the presented results, the most stable hybrids for the seed and oil yield were NS8, NS2 and NS9. Hybrids NS8 and NS9 belong to medium-late maturity group, while NS2 is an early maturing hybrid. In corn, the late maturity hybrids (FAO 600 and 700) as compared to the early maturity ones generally exhibited unfavourable values of stability parameters, i.e. a specific response and better adaptation to more favourable environmental conditions, and produced higher average yields. The yield of these hybrids could not have been jeopardized by the yield of the early maturity hybrids (MADIĆ *et al.*, 2010). In our research, medium-late hybrids also showed better productivity but also improved stability, compared to mid-early and early hybrids. However, some early hybrids also showed good productivity and stability, so that statement could not be generalized. The NS2 hybrid, although it showed a solid seed and oil yield (ranking 9 and 4), had low response to the environment, thus showed good stability. Examining the stability of early hybrids, TARAN *et al.* (2014) stated that total hybrid stability for earliness and yield was not proved, however, further breeding could contribute to the development of local hybrids with early maturity and better yield potential.

CONCLUSION

The biggest challange to sunflower breeders is the introduction of new hybrids allowing higher seed and oil yield under a wide range of environmental conditions. Evaluations of hybrids in different environments must be employed to satisfactorily quantify their performance. Based on the mentioned, we can conclude that the selection of sunflower hybrids requires a complex analysis of their productivity and stability. The most stable hybrids for the seed and oil yield were NS8, NS2 and NS9. The obtained results indicate that hybrids can be recommended for production in different environments in Serbia; NS2 hybrid as early-growing, stable for oil yield; NS8 and NS9, medium-late hybrids, high productivity potential and suitable for all production systems. Hybrid NS3 seemed to be valuable hybrid due to earlyness and relativly stable oil yield. Our results also indicated that hybrid maturity does not affect either productivity or stability, and that all hybrids must be equally examined.

ACKNOWLEDGEMENTS

This study was supported by Ministry of Education, Science and Technological Development of Republic of Serbia, project TR31025, Provincial Secretariat for Higher Education and Science of Vojvodina, project 114-451-2126/2016-03, COST Action CA 16212 and Serbian-German bilateral cooperation project - No. 451-03-01732/2017-09/3.

Received, May 21th, 2018
Accepted February 18th, 2019

REFERENCES

BALALIĆ, I., M., ZORIĆ, G., BRANKOVIĆ, S., TERZIĆ, J., CRNOBARAC (2012): Interpretation of hybrid×sowing date interaction for oil content and oil yield in sunflower. Field Crops Res., *13*:770–77.

CVEJIĆ, S. (2011): Korišćenje heterozisa kod suncokreta. Monografija, Biblioteka Academia, Zadužbina Andrejević, Beograd. ISBN 978-86-7244-940-2. 1-104.

DE LA VEGA, A.J., S.C. CHAPMAN (2006): Defining sunflower selection strategies for a highly heterogeneous target population of environments. Crop Science *46(1):* 136-144.

FAOSTAT (2018): www.fao-stat.org

GRASSINI, P., G.V., INDACO, M.L., PEREIRA, A., HALL, N., TRAPANI (2007): Responses to short-term water logging during grain filling in sunflower. Field Crop Res., *101*:352–363.

JOCKOVIĆ, M., M., ĆIRIĆ, S., JOCIĆ, S., CVEJIĆ, R., MARINKOVIĆ, V. MIKLIČ (2012): Performance NS hibrida suncokreta u Rumuniji. Selekcija i semenarstvo, *18 (1):* 9-16. (In Serbian)

JOCKOVIĆ, M., S., JOCIĆ, S., PRODANOVIĆ, S., CVEJIĆ, M., ĆIRIĆ, P., ČANAK A., MARJANOVIĆ JEROMELA (2018): Evaluation of combining ability and genetic components in sunflower. Genetika, *50 (1)*: 187-198.

KANG, M.S. (2002): 15 Genotype–Environment Interaction: Progress and Prospects. Quantitative genetics, genomics, and plant breeding, 219.

KAYA, Y., D., BALTENSPERGER, L., NELSON, J., MILLER (2004): Maturity grouping in sunflower (*Helianthus annuus* L.) Helia, *27 (40)*: 257-270.

LEON, A.J., F.H., ANDRADE, M., LEE (2003): Genetic analysis of seed-oil concentration across generations and environments in sunflower. Crop Sci., *43*:135–140.

MADIĆ, M., D., ĐUROVIĆ, V., STEVOVIĆ, N., BOKAN (2010): Stability parameters for grain yield of maize hybrids (*Zea mays* L.). Genetika, *42* (1): 137-144.

MARINKOVIĆ, R., M., JOCKOVIĆ, A., MARJANOVIĆ-JEROMELA, S., JOCIĆ, M., ĆIRIĆ, I., BALALIĆ, Z., SAKAČ (2011): Genotype by environment interactions for seed yield and oil content in sunflower (*H. annuus* L.) using AMMI model. Helia, *34* (54): 79-88

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. (PAB), *46(2):* 174-181.

MLADENOV, V., B., BANJAC, M., MILOŠEVIĆ (2012): Evaluation of yield and seed requirements stability of bread wheat (*Triticum aestivum* L.) via AMMI model. Turk. J. Field Crops, *17*(2):203-207.

MONTE, L.M. (1986): Breeding plants for drought resistance- the problem and its relevance. Drought resistance in plants-Physiological and genetic aspects. Amalfi, October 19th to 23rd. 1-11.

PEJIĆ, B., L., MAKSIMOVIĆ, S., MILIĆ, D., SIMIĆ, B., MILETAŠKI (2010): Effect of redily available water deficit in soil on maize yield and evapotranspiration. Ratarstvo i Povrtarstvo, *47*(1):115–121.

ŠKORIĆ, D. (2009): Sunflower breeding for resistance to abiotic stress. Helia, *32*(50):1-16.

STOJAKOVIĆ, M., B., MITROVIĆ, M., ZORIĆ, M., IVANOVIĆ, D., STANISAVLJEVIĆ, A., NASTASIĆ, D., DODIG (2015): Grouping pattern of maize test locations and its impact on hybrid zoning. Euphytica *204*:419–431.

TARAN, S.A., N.U., KHAN, M.A., KAKAR, M.M., KHAN, M., SAEED, M., IQBAL, S., AGHA, F., AHMED (2014): Stability of sunflower hybrids for earliness and achene yield over environments. J. Food, Agric. Environ., *12* (1):317-322.

TARAN, S.A., D.M., BALOCH, N.U., KHAN, J.E.H.A.N., BAKHT, S.H., GHALOO, N., SHAHWANI, M.S., KAKAR (2013): Earliness and yield performance of sunflower hybrids in uplands of Balochistan, Pakistan. Pak. J. Bot., *45*(4):1397-1402.

VAN DER MERWE, R., M.T., LABUSCHAGNE, L., HERSELMAN, A., HUGO (2013): Stability of seed oil quality traits in high and mid-oleic acid sunflower hybrids. Euphytica, *193*(2): 157-168.

ZOBEL, R.W., M.J., WRIGHT, H.G., GAUCH (1998): Statistical analysis of yield trial. Agr. J., *80*:388 393.

IZBOR HIBRIDA SUNCOKRETA NA OSNOVU STABILNOSTI U RAZLIČITIM AGRO-EKOLOŠKIM USLOVIMA

Sandra CVEJIĆ[1], Siniša JOCIĆ[1], Velimir MLADENOV[2], Borislav BANJAC[2], Ilija RADEKA[1], Milan JOCKOVIĆ[1], Ana MARJANOVIĆ JEROMELA[1], Dragana MILADINOVIĆ[1], Vladimir MIKLIČ[1]

[1]Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija
[2]Poljoprivredni fakultert, Univerzitet u Novom Sadu, Srbija

Izvod

Imajući u vidu da je proizvodnja suncokreta u Srbiji ekstenzivna od velike je važnosti odabrati hibride koji će ostvariti stabilan i visok prinos semena i ulja u različitim uslovima spoljašnje sredine. Cilj rada bio je identifikacija najstabilnijih hibrida suncokreta za prinos semena i ulja korišćenjem AMMI modela. Ispitivano je devet novostvorenih hibrida koji pripadaju kategorijama rani, srednje rani i srednje kasni. Hibridi su gajeni na različitim lokacijama u severnom delu Srbije tokom dve vegetacione sezone (2013-2014). Odabrane lokacije jesu geografski bliske, ali različite su u pogledu agro-ekoloških uslova (zemljišta, padavina i temperature), čime su stvoreni specifični mikro-klimatski uslovi za gajenje suncokreta. Grupna analiza varijanse prinosa semena i ulja pokazala je da su glavni efekti, hibridi i spoljašnja sredina, kao i njihova interakcija bili statistički visoko značajni. Biplot analiza je utvrdila da je sredina E3 najstabilnija za proizvodnju suncokreta. Na osnovu rezultata AMMI modela, najmanju interakciju sa spoljašnjom sredinom, odnosno najstabilniji hibridi za prinos semena i ulja bili su NS2, NS8 i NS9. Dobijeni rezultati ukazuju da se ovi hibridi mogu preporučiti za proizvodnju u različitim sredinama u Srbiji; NS2 hibrid kao ranostasan, stabilan za prinos semena, a NS8 i NS9 srednje kasni hibridi, visokog potencijala za prinos i pogodni za sve proizvodne sisteme.

Primljeno 21.V.2018.
Odobreno 18. II. 2019.