CONTEMPORARY AGRICULTURE / *SAVREMENA POLJOPRIVREDA* 60 (3-4) 267-275, 2011.
UDC: 63(497.1)(051)-"540.2" ISSN 0350-1205

UDC: 330.131.5:631.52

ECONOMIC GAIN OBTAINED BY CHOICE OF SPECIFICALLY-ADAPTED SUNFLOWER HYBRIDS FOR CROPPING

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SUMMARY: The aim of the study was to determine specifically adapted sunflower hybrids based on 2007 testing network grain yield results, and also to show economic gain obtained by minimizing crossover interaction (COI) and utililising specific adaptation. Twenty commercial sunflower hybrids and 16 locations were included in testing. SREG (sites regression) analyses were done for the set of all tested locations, set of locations with above-average mean yield and set of locations with below-average mean yield, to obtain GGL biplot with "which-won-where" patterns. When giving recommendations for growing sunflower hybrids, their adaptability examined in past years via GGL biplot methodology must be taken into account. Based on the results of GGL biplot comparative analyses, the specifically adapted hybrids identified were: Duško for Rimski Šančevi, Kikinda, Bačko Gradište, Bačka Topola set of above-average mean yield („better") locations, and for Neuzina, Neštin, Vršac set of below-average mean yield („poorer") locations; Bačvanin for Kula Vitovnica, Đurđin, Zaječar, Zrenjanin set of „poorer" locations; Branko for Kula location. Significant economic gain was obtained when cropping these three specifically adapted hybrids, in comparison to cropping those not adapted to particular locations.

Key words: *sunflower hybrids, GGE biplot analysis, grain yield, economic gain.*

Original scientific paper / *Originalni naučni rad*
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INTRODUCTION

Sunflower represents the most important crop for edible oil production in Serbia with an average grain yield of 1.902-2.419 t ha-1, with areas harvested ranging from 154.793-187.822 ha and with total production of 294.502-454.282 tonnes for the 2006-2009 period (Food and Agriculture Organization of the United Nations, 2009).

For general cultivation of any crop plant, testing by multi-environment trial (MET) is very important to ensure that the selected hybrids/cultivars have acceptable performance in variable environments within the target region (Kang et al., 2005). Genotype × environment interaction (GEI), commonly known as the differential response of genotypes to diverse environmental conditions, indicates the importance of environments and their variable factors on genotype adaptability and stability, and is a favorable phenomenon only if it is correlated with above-average yield (Yan and Hunt 2003). As a component of phenotype variability it reduces correlation between phenotypic and genotypic values, causes heritability and genetic progress from selection to decrease (Kang, 2002) and hinders identification of superior genotypes in METs (Shaffi and Price, 1998). MET is organized as a part of breeding program efforts to (i) investigate performance and stability of genotypes of interest; (ii) identify groups of locations with low crossover GEI (COI) for single and multiple years; (iii) check mega-environment differentiation for the target tested region; (iv) examine representativeness and discriminating ability of the test locations; and (v) determine specifically and generally adapted cultivars.

Effective interpretation and utilization of the MET data in making selection decisions, however, remain a major challenge to researchers. Yan et al. (2000) referred to biplots based on singular value decomposition (SVD) of environment-centered or within-environment standardized GE data as "GGE biplot" and this term emphasizes that both genotype (G) and genotype × environment (GE) effects are relevant to genotype evaluation and must be considered simultaneously (Yan and Tinker, 2006). GGE biplot offers opportunity to portray the relationship between the genotypes and environments for each attribute graphically. GGE biplot represents the most appropriate multivariate technique for this purpose, because of all used multivariate models used like Additive main effect and multiplicative interaction effects (AMMI) (Gauch and Zobel, 1996), Shifted multiplicative model (SHMM)(Seyedsadr and Cornelius 1992), Completely multiplicative model (COMM) (Cornelius et al., 1992), it is the only to possess feature of „which-won-where" biplot view revealing specific adaptation.

Determination of specifically adapted genotypes for different crop cultivars is a valuable aim for national breeding programs, in which yield gain from GEI utilisation within the state, can help increase competitiveness of national seed companies in comparison to international ones. It is considered as a rule that cultivars that have wide or general adaptation show yield stability over a great range of environmental conditions and different environments, but lower mean performance, in comparison to specifically or narrowly adapted cultivars that possess genetic potential for high yield potential and accomplish high yield in favorable evironments and lower yields in less favorable environments (Annicchiarico, 2002). Sunflower prices creating may affect a number of factors some of which are general and some specific. General factors may be costs level, competition, and even the relationship of supply and demand (Woodworth, 1977). Particular factors may be durability in demand or fluctuations in supply under the influence of natural factors, because natural factors affect both the quantity and the quality of the goods offered.

The objective of this study was to determine specifically adapted sunflower hybrids based on multilocation trial in 2007, and also to show economic gain obtained by minimizing COI and utililising specific adaptation.

MATERIAL AND METHODS

Genetic material used in this research was represented by 20 commercial sunflower hybrids from the collection of Oil Crops Department of the Institute of Field and Vegetable Crops, Novi Sad, Serbia. Sunflower hybrids were tested in multi-location trial over 16 locations distributed in the sunflower growing region in Serbia. Variety trials were organized by Oil Crops Department of the Institute of Field and Vegetable Crops, in 2007 in Serbia. Names, codes, mean yield values for hybrids and locations used in 2007 sunflower testing network are presented in Table 1.

Table 1. Mean grain yield (t/ha) of sunflower hybrids across locations for 2007 testing network
Tabela 1. Prosečan prinos zrna (t/ha) hibrida suncokreta u višelokacijskom ogledu za 2007 godinu

Hybrid / Hibrid	Code/ Kod	*Regions* / Regioni															
		RS	KU	BG	BT	DU	SO	AS	KI	ZR	NZ	VS	NS	KV	KG	NE	ZA
Ns-h-45	1	3,63	2,88	3,48	3,78	2,54	2,71	2,24	3,49	2,71	2,85	2,09	3,65	2,14	2,34	1,37	2,24
Vranac	2	3,78	3,20	3,68	3,86	2,61	2,72	2,33	3,38	2,41	2,31	2,27	3,38	2,36	2,22	1,24	2,02
Rimi	3	3,76	2,51	3,34	3,76	2,21	3,27	2,28	3,39	2,47	2,38	2,17	2,97	2,36	1,75	1,10	2,00
Bačvanin	4	3,73	2,79	3,57	4,01	3,01	3,71	2,55	3,46	2,51	2,39	2,54	3,50	2,71	2,13	1,05	1,97
Ns-h-111	5	4,10	2,82	3,84	3,94	2,42	3,12	2,28	3,10	2,73	2,47	2,51	3,99	2,56	1,76	1,26	2,25
Velja	6	4,18	3,06	3,92	4,02	2,67	3,29	2,54	3,74	2,39	2,99	2,84	3,80	2,31	2,05	1,16	1,90
Krajišnik	7	3,66	2,54	3,49	3,71	2,52	3,24	2,13	3,10	2,66	2,20	2,50	3,84	2,59	1,88	0,97	1,87
Perun	8	3,72	2,93	3,65	3,58	2,67	2,55	2,04	3,12	2,29	2,92	2,67	3,55	2,28	1,89	1,26	2,14
Pobednik	9	3,75	2,62	3,51	3,94	2,58	3,40	2,49	3,15	2,24	2,49	2,56	3,99	2,30	2,06	0,99	2,03
Baća	10	3,97	3,13	3,24	4,35	2,84	3,48	2,19	3,54	2,38	2,35	2,29	4,09	2,40	1,88	0,71	1,57
Sremac	11	4,24	2,85	3,83	3,99	2,52	3,29	2,46	3,89	2,27	2,79	2,19	3,79	2,61	2,05	1,15	2,13
Somborac	12	3,83	2,87	3,91	3,91	1,75	3,17	2,51	3,22	2,23	2,66	2,42	3,90	2,12	2,11	1,04	1,94
Šumadinac	13	4,11	3,30	3,86	4,41	2,51	3,07	2,31	3,36	2,60	2,78	2,64	3,94	2,41	2,12	1,38	2,06
Kazanova	14	4,31	2,92	3,67	4,22	2,54	3,22	2,50	3,78	2,67	2,84	2,45	3,39	2,28	2,23	1,22	1,95
Olivko	15	3,17	3,12	3,63	3,54	2,24	2,71	2,04	2,56	2,28	2,29	2,23	3,01	1,94	2,41	1,00	1,71
Plamen	16	3,84	2,94	3,59	3,71	1,88	3,12	2,33	3,53	2,22	2,62	2,51	3,60	2,18	2,49	0,70	1,32
Duško	17	4,02	3,14	3,53	4,04	2,61	3,28	2,44	4,54	2,38	3,54	2,54	4,00	2,34	2,23	1,39	1,93
Branko	18	4,06	3,15	3,54	3,56	2,38	3,07	2,21	3,02	2,37	2,72	2,21	4,32	2,08	2,37	1,42	1,74
Novosađanin	19	3,67	3,45	3,45	3,81	2,70	2,73	2,13	3,26	2,44	2,76	2,26	4,20	2,44	2,04	1,37	1,72
Oliva	20	4,07	3,02	3,85	4,07	2,79	3,11	2,65	3,55	2,17	2,31	2,24	3,21	2,45	1,96	1,08	2,27

RS-Rimski Šančevi, KU-Kula, BG-Bačko Gradište, BT-Bačka Topola, DU-Đurđin, SO-Sombor, AS-Aleksa Šantić, KI-Kikinda, ZR-Zrenjanin, NZ-Neuzina, VS-Vršac, NS-Neštin, KV-Kula Vitovnica, KG-Kragujevac, NE-Negotin, ZA-Zaječar.

Experimental data were mean grain yields (t ha-1) of tested hybrids over tested locations. The experimental design was a randomized complete block design with four replications and plot size was 28 m2. Two middle rows of four were used for analysis and border plants were excluded. Elementary plot size was 13.3 m2 (0,7 x 0,25 x 76). Parcels on which sunflower had not been cultivated for four last consecutive years, soybean and oil seed rape for three years and maize as preceding crop were not treated with herbicides based on Atrazine, was choosen for experiment implementation. Winter ploughing was done on 30 cm soil depth. Fertilisation included application of mineral fertilisers with 50 kg ha-1 of nitrogen, 80-90 kg ha-1 of phosphorus oxide (P2O5) and 60 kg ha-1 of potassium oxide (K2O). The whole quantity of phosphorus and potassium, and half of nitrogen was added during primary tillage in autumn and other half of nitrogen quantity was added during secondary tillage. Sowing was done mechanically during April. Grain yield evaluation was performed by measurment of grain mass for each elementary plot, and grain yield (t ha-1) with 11% moisture ha-1 was calculated.

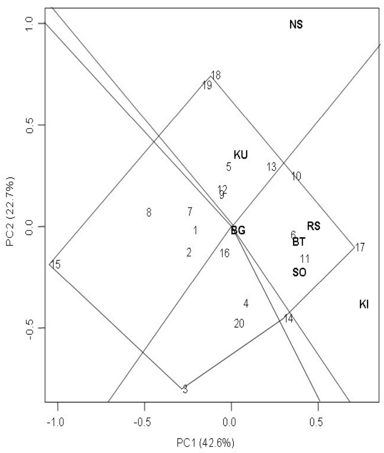
In order to evaluate hybrids specific adaptation both genotype (G) and genotype by location interaction (GL) effects must be considered simultaneously, and we used the sites regression (SREG) model (Crossa and Cornelius 1997) to obtain GGL biplot with "which-won-where" pattern. SREG analyses were done for the set of all tested locations, locations with above-average mean yield and locations with below-average mean yield, within R computing environment (R Development Core Team 2010). For plotting the biplot, Excel (macro), according to Lipkovich and Smith (2002), was used.

RESULTS AND DISCUSSION

Plant breeders and agronomists have found GGL biplot analysis to be useful for simultaneous evaluation of genotype performance and stability, mega-environment investigation and adaptability studies (Yan et al., 2001; Lee et al., 2003; Butron et al., 2004; Samonte et al., 2005; Malvar et al., 2005; Voltas et al., 2005; Kang et al., 2005; Dardanelli et al., 2006; Fan et al., 2007; Mohammadi et al., 2010; Goyal et al., 2011).

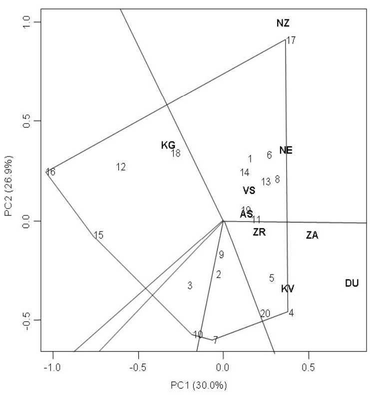
One of the most attractive features of a SREG biplot is its ability to show the "which-won-where" pattern of the dataset (Yan and Tinker, 2006). Many researchers find this use of a biplot intriguing, as it graphically addresses important concepts such as crossover GE, mega-environment differentiation, specific adaptation, etc (Yan and Hunt, 2003). A polygon is drawn on hybrids that are furthest from the biplot origin so that all other hybrids are contained within the polygon. Hybrids located on the vertices of the polygon performed either the best or the poorest in one or more locations. The perpendicular lines drawn to each side of the polygon or it extension, starting from the biplot origin represent equality lines which divide the biplot into sectors, and the winning hybrid for each sector is the one located on the respective vertex (Yan and Tinker, 2006).

By selecting a set of locations with above-average mean yield ("better" locations) and set of locations with below-average mean yield ("poorer" locations) from the whole set of tested locations, and by comparing all three "which-won-where" patterns (Graph. 1; Graph. 2) for all three sets of locations, we determined specifically adapted hybrids (graph for the set of all locations is not shown). Our procedure can be explained by the fact that varietal differences becomes more obvious when extracting a set of "better" or set of "poorer" locations from analysis because genetic backgrounds of varieties and their adaptability to various environmental conditions differ according to Lin's et al. (1986) definition of an adaptability as the consistence of genotype performance in space. Based on the results of biplot analysis for the 2007 testing network specifically adapted hybrids determined were: G17 (Duško) for RS, KI, BG, BT („better" locations), for NZ, NE, VS („poorer" locations); G4 (Bačvanin) for KV, DU, ZA, ZR („poorer" locations); G18 (Branko) for KU.



Graph. 1. GGL biplot („which-won-where" view) for hybrids grain yield across set of locations with above-average mean yield for 2007 sunflower testing network.

Grafikon 1. GGL biplot („which-won-where" prikaz) prinosa zrna hibrida za set lokaliteta sa iznad-prosečnim prinosom višelokacijskog ogleda suncokreta za 2007 godinu.



Graph. 2. GGL biplot („which-won-where" view) for hybrids grain yield across set of locations with below-average mean yield for 2007 sunflower testing network.

Grafikon 2. GGL biplot („which-won-where" prikaz) prinosa zrna hibrida za set lokaliteta sa ispod-prosečnim prinosom višelokacijskog ogleda suncokreta za 2007 godinu.

The average annual purchase price of sunflower in 2007. amounted to 25,64 din/kg or 25.640 din/t. (Statistical Office of the Republic of Serbia, 2007). Prices of agricultural products take into account both purchase and selling price. Purchase prices are the prices at which companies and organizations authorized purchase of agricultural products from private households and of course they do not include incentive premiums. On the other hand, selling prices are those prices at which agricultural enterprises and organizations in the domestic market sell products from their own production. Average purchase and selling prices are calculated based on the report of the entire purchase and sales from the owner's production (Koester and Zarić, 2009).

By correct use of specifically adapted sunflower hybrids for cropping in specific locations in Serbia significant economic gain can be obtained. The context of economic gain referred to in our paper meant the difference (increase) in total revenue obtained with the hybrid identified as compared with other not adapted hybrids. By cropping specifically adapted hybrid Duško in the Kikinda location significant economic gain of 1.692.240 dinars and of 1.346.100 per 50 hectares is obtained in comparison respectively to Olivko and Somborac (Table 2). Olivko and Somborac were poorly adapted hybrids to this location, as was shown by GGL biplot. Also economic gain obtained by cropping Bačvanin, specifically adapted hybrid to Đurđin location was 1.615.320 dinars and 641.000 dinars per 50 hectares in comparison to cropping not adapted hybrids Olivko and Vranac, according to GGL biplot, respectively (Table 2).

Table 2. Economic gain expressed in dinars achieved with correct and incorrect choice of sunflower hybrids for cropping based on biplot adaptability analyses
Tabela 2. Ekonomska dobit izražena u dinarima ostvarena pravilnim i nepravilnim izborom hibrida suncokreta za gajenje na osnovu biplot analiza adaptabilnosti

Location-Hybrid /*Lokalitet-Hibrid*	Economic gain expressed in dinars for / *Ekonomska dobit izražena u dinarima ostvarena na*				
	1 ha	5 ha	10 ha	20 ha	50 ha
RS-Duško	103.072,8	515.364	1.030.728	2.061.456	5.153.640
RS-Olivko	98.201,2	491.006	982.012	1.964.024	4.910.060
RS-Somborac	93.073,2	465.366	930.732	1.861.464	4.653.660
KI-Duško	116.405,6	582.028	1.164.056	2.328.112	5.820.280
KI-Somborac	89.483,6	447.418	894.836	1.789.672	4.474.180
KI-Olivko	82.560,8	412.804	825.608	1.615.216	4.128.040
BG-Duško	90.509,2	452.546	905.092	1.810.184	4.525.460
BG-Somborac	89.227,2	446.136	892.272	1.784.544	4.461.360
BG-Novosađanin	85.637,6	428.188	856.376	1.712.752	4.281.880
BT-Duško	103.585,6	517.928	1.035.856	2.071.712	5.179.280
BT-Novosađanin	96.406,4	482.032	964.064	1.928.128	4.820.320
BT-Branko	95.124,4	475.622	951.244	1.902.488	4.756.220
NZ-Duško	90.765,6	453.828	907.656	1.815.312	4.538.280
NZ-Olivko	68.202,4	341.012	682.024	1.364.048	3.410.120
NZ-Oliva	58.715,6	293.578	587.156	1.174.312	2.935.780
NE-Duško	35.639,6	178.198	356.396	712.792	1.781.980
NE-Olivko	26.665.6	133.328	266.656	533.312	1.333.280
NE-Baća	18.204,4	91.022	182.044	364.088	910.220
VS-Duško	65.125,6	325.628	651.256	1.302.512	3.256.280
VS-Pobednik	57.946,4	289.732	579.464	1.158.928	2.897.320
VS-Somborac	53.587,6	267.938	535.876	1.071.752	2.679.380
KV-Bačvanin	69.484,4	347.422	694.844	1.389.688	3.474.220
KV-Plamen	58.459,2	292.296	584.592	1.169.184	2.922.960
KV-Olivko	54.356,8	271.784	543.568	1.087.136	2.717.840
DU-Bačvanin	77.176,4	385.882	771.764	1.543.528	3.858.820

DU-Vranac	64.356,4	321.782	643.564	1.287.128	3.217.820
DU-Olivko	44.870,0	224.350	448.700	897.400	2.243.500
ZA-Bačvanin	50.510,8	252.554	505.108	1.010.213	2.525.540
ZA-Duško	47.946,8	239.734	479.468	958.936	2.397.340
ZA-Branko	33.844,8	169.224	338.448	676.896	1.692.240
ZR-Bačvanin	64.356,4	321.782	643.564	1.287.128	3.217.820
ZR-Olivko	57.177,2	285.886	571.772	1.143.544	2.858.860
ZR-Perun	55.638,8	278.194	556.388	1.112.776	2.781.940
KU-Branko	80.766,0	403.830	807.660	1.615.320	4.038.300
KU-Bačvanin	74.868,8	374.344	748.688	1.497.376	3.743.440
KU-Krajišnik	72.304,8	361.524	723.048	1.446.096	3.615.240
ZR-Bačvanin	64.356,4	321.782	643.564	1.287.128	3.217.820
ZR-Olivko	57.177,2	285.886	571.772	1.143.544	2.858.860
ZR-Perun	55.638,8	278.194	556.388	1.112.776	2.781.940
KU-Branko	80.766,0	403.830	807.660	1.615.320	4.038.300
KU-Bačvanin	74.868,8	374.344	748.688	1.497.376	3.743.440
KU-Krajišnik	72.304,8	361.524	723.048	1.446.096	3.615.240

RS-Rimski Šančevi, BG-Bačko Gradište, BT-Bačka Topola, DU-Đurđin, KI-Kikinda, ZR-Zrenjanin, NZ-Neuzina, VS-Vršac, KV-Kula Vitovnica, NE-Negotin, ZA-Zaječar.

Total economic gain calculated for Duško, Bačvanin and Branko, specifically adapted hybrids determined via GGL biplot comparative analyses, were in the range of 1.282-33.845 dinars per hectare and of 64.100-1.692.240 dinars per 50 hectares, in comparison to not adapted hybrids.

CONCLUSION

When giving recommendations for growing sunflower hybrids, their adaptability examined in past years via GGL biplot methodology must be taken into account. Based on the results of GGL biplot comparative analyses for 2007 sunflower testing network, specifically adapted hybrids determined were: Duško for RS, KI, BG, BT („better“ locations), and for NZ, NE, VS („poorer“ locations); Bačvanin for KV, DU, ZA, ZR („poorer“ locations); Branko for KU. Significant economic gain was obtained when cropping these three specifically adapted hybrids, in comparison to cropping those not adapted to particular locations.

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EKONOMSKA DOBIT OSTVARENA KORIŠĆENJEM SPECIFIČNO ADAPTIRANIH HIBRIDA SUNCOKRETA ZA SETVU

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Izvod

Cilj istraživanja je obuhvatao utvrđivanje specifično adaptiranih hibrida suncokreta na osnovu rezultata prinosa zrna hibrida u višelokacijskom ogledu organizovanom 2007 godine, kao i izračunavanje ekonomske dobiti ostvarene minimiziranjem interakcije sa izmenom ranga (COI) i iskorišćavanjem specifične adaptacije. U testiranje je bilo uključeno 20 komercijalnih hibrida suncokreta i 16 lokaliteta. SREG (sites regression) analiza je urađena za set svih testiranih lokaliteta, set iznad-prosečno prinosnih lokaliteta i za set ispod-prosečno prinosnih lokaliteta, da bi se dobio GGL biplot sa "which-won-where" obrascima. Radi davanja preporuke za gajenje hibrida suncokreta, njihova adaptabilnost utvrđena za prethodne godine GGL biplot metodologijom, mora biti uzeta u obzir. Na osnovu GGL biplot komparativne analize utvrđeni su specifučno adaptirani hibridi: Duško za Rimske Šančeve, Kikindu, Bačko Gradište, Bačku Topolu, set iznad-prosečno prinosnih ("boljih") lokaliteta, i za Neuzinu, Neštin, Vršac, set ispod-prosečno prinosnih ("lošijih") lokaliteta; Bačvanin za Kula Vitovnicu, Đurđin, Zaječar, Zrenjanin, set ispod-prosečno prinosnih ("lošijih") lokaliteta; Branko za Kulu. Značajna ekonomska dobit je ostvarena gajenjem navedena tri specifično adaptirana hibrida suncokreta u poređenju sa gajenjem neadaptiranih za određene lokalitete.

Ključne reči: suncokret, hibridi, GGE biplot analiza, prinos zrna, ekonomska dobit.

Received / *Primljen*: 21.06.2011.
Accepted / *Prihvaćen*: 26.08.2011.