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Original scientific paper

ENVIRONMENTAL MODELING OF INTERACTION VARIANCE FOR GRAIN YIELD OF MEDIUM EARLY MATURITY MAIZE HYBRIDS

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The phenomenon of genotype by environment interaction (GEI) represents permanent interest for breeders, geneticists and biometricians with its practical and theoretical aspects. We investigated GEI for grain yield of medium early maturity maize (*Zea mays* L.) hybrids from the official variety trial network by the Department of Protection and Recognition of Varieties of the Republic of Serbia that includes experimental maize hybrids on eight sites over two years. Environmental variables explained 77.6% and 60.7% of the GEI variation for two consecutive years, respectively. Factorial regression combined with stepwise procedure revealed the model which includes variables precipitation in July (pr7), minimum temperature in May (mnt5), maximum temperature in May (mxt5) and insolation hours in April (sh4), in 2004, and environmental index (EI) and average temperature in September (mt9) in 2005, to be the most explanatory models in the region of Vojvodina (Serbia) in two consecutive years. These results provide a base for further research in GEI and stability analysis, and are a useful tool in characterizing the sub-regions of maize growing area and extending the existing results to new sites.

Keywords: genotype by environment interaction, climatic variables, stability analysis, multi-environment trials.

INTRODUCTION

Maize represents one of the most important grain crops, with its global production exceeding 1×10^9 t (FAOSTAT, 2018). In Serbia alone, it was grown on more than 1 million ha in 2016 (www.rzs.gov.rs). It represents a staple in most parts of the world, and as it is economically

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one of the most important crops, successfully grown and well adapted for every environment in its wide growing area; the importance of it reflected in many of the state policies.

The ultimate goal of every individual farmer is to achieve the highest possible grain yield on their field from year to year. The efforts of breeding companies on the other hand are focused on the creating a maize hybrid that will be successfully commercialized - high yielding in most of the agro-ecological zones, and with the yield that will be consistent from year to year. The successful breeding of maize hybrids and their dissemination therefore requires multi-environment trials (METs) (YAN, 2014).

The phenomenon of genotype by environment interaction (GEI) is characteristic of multi-environment trials (MET) and represents permanent interest for breeders and biometricians with its practical and theoretical aspects (GAUCH, 2013; YAN, 2014). Genotype by environment interaction is said to exist when the phenotypic response caused by a change in environment is not the same for all genotypes (MALOSETTI *et al.*, 2013). For a long time this problem has been overcome by stratification of environment and allocation of different genotypes to different environments (MIROSAVLJEVIĆ *et al.,* 2014; ĆIRIĆ *et al.,* 2017; BRANKOVIĆ-RADOJČIĆ *et al.,* 2018).

However, in large breeding programs, intended for a global market, ”unpredictable” year-to-year fluctuations can cause large genotype by year and genotype by location by year interactions and may require other solutions. Appropriate strategy in such situations would be the identification of cultivars that are both high yielding and stable in performance across multiple environments (sites or years or sites-years combination), or that have specific adaptation, (BABIĆ *et al.*, 2011; STOJAKOVIĆ *et al.*, 2015; MITROVIĆ *et al.*, 2018). “Stable genotype” is the term used to describe a genotype that has constant performance over environments (LEIBMAN *et al.*, 2014). Desirable genotypes are therefore the ones that are both stable and high yielding: capable to produce high yields over wide range of different production environments (BANJAC *et al.*, 2015; BRANKOVIĆ-RADOJČIĆ *et al*., 2018).

The benefits of defining the variability of the interaction, as the function of the variation between the environments and genotypes had become obvious in the mid-20th century. This concept has been applied in the research in numerous plant species over the years (NZUVE *et al.,* 2013; MIROSAVLJEVIĆ *et al.,* 2014; BANJAC *et al.,* 2015; ĆIRIĆ *et al.,* 2017).

Information on individual environmental covariates is needed to understand the nature and causes of genotype × site interaction as well as to exploit it (KANG *et al.,* 2005). Collecting of additional information on climatic, soil, biotic or crop management factors of test sites in METs and morpho-physiological traits of genotypes can prove extremely valuable for: (i) providing reasons for the occurrence of GEI; (ii) providing a means for characterizing the sub-regions and extending the results to new sites; (iii) enlarging the set of possibly adopted models for analysis of adaptation; and (iv) identifying adaptive traits and assessing their potential as indirect selection criteria for breeding (ANNICCHIARICO, 2002).

Factorial regression models are commonly used linear models that explain GEI by differential cultivar sensitivity to explicit external environmental variables (environmental characterization) and are able to make hypothesis about the influence of external variables on GEI of grain yield that can be statistically tested (VARGAS *et al.*, 1999). An analytical assessment of GEI by factorial regression can be regarded as a predictive strategy for recommendation purposes and the information supplied by factorial regression analyses could be easily implemented into geographical databases in which yearly environmental data is applied over a representative temporal scale (VOLTAS *et al*., 2005). Application of factorial regression using genotypic and environmental variables in maize MET trials was reported by many authors (BUTRON *et al.,* 2004; MALVAR *et al.,* 2005; SANDOYA *et al.,* 2010; LEE *et al.,* 2016) and successfully used in maize breeding programs.

The objective of this study was: (i) to dissect GEI for grain yield in the maize multi-site trails using additional climatic variables and factorial regression modeling, therefore getting the better understanding of the factors that influence the results of the maize yield test trials and (ii) to identify adaptive traits and assess their potential as indirect selection criteria for future breeding programs, obtaining the superior, high yielding hybrid that is stable across the environments.

MATERIALS AND METHODS

Experimental data

Genetic material used in this research was represented by 21 experimental medium early maturity maize hybrids tested in official variety trials organized by the Department for Protection and Recognition of Varieties of Ministry of Agriculture, Water Management and Forestry of the Republic of Serbia during 2004 and 2005. Experimental data were mean grain yields (t ha^{-1}), at 14% moisture, of tested hybrids over eight sites. The names of the test sites are shown in Table 1 along with their codes, latitudes, longitudes and soil characteristics.

Table 1. Description of the sites in the multi-site trial in Serbia during 2004-2005 period

Site	Abbreviation	Longitude	Latitude	Altitude	pH KCl	pH H_2O	Org. matt. %	N %	P_2O_5 mg/100g	K_2O mg/100g
Bečej	BC	45°37'0"N	20°02'06"E	85	7.60	8.08	2.81	0.209	45.50	34.96
Kikinda	KI	45°50'0"N	20°27'33"E	85	7.08	7.95	3.72	0.255	6.52	50.00
Pančevo	PA	44°52'0"N	20°39'33"E	80	7.50	8.34	3.53	0.242	27.5	20.6
Rimski Šančevi	RS	45°20'0"N	19°50'59"E	84	7.03	7.99	3.16	0.217	25.67	32.07
Sremska Mitrovica	SM	44°59'0"N	19°37' E	81	7.42	8.25	2.20	0.163	15.35	23.51
Sombor	SO	45°47'0"N	19°06'44"E	90	7.25	8.12	2.72	0.202	16.5	20.99
Zemun Polje	ZP	44˚87'0"N	20°19'E	80	7.37	8.19	3.39	0.232	14.71	18.60
Zaječar	ZA	43˚55'0"N	22°17'05"E	132	3.97	5.49	1.95	0.168	8.41	29.10

The experimental design was randomized complete block design with four replications and elementary plot size of 10 m^2. Standard cultural and agronomic practices were applied at all sites. Nitrogen, phosphorus, and potassium fertilizers were applied according to fertilizer recommendations for each site. Plant density for each hybrid was 60.606 plants ha^{-1}.

Data on climatic variables during 15 April - 15 October vegetation period for both years were provided by the Republic Hydro-meteorological Service of Serbia. Maximum temperature (mxt), minimum temperature (mnt), mean temperature (mt), precipitation (pr), relative humidity (rh) and insolation hours (sh) average values for test sites were used for analysis and labeled with the numbers accordingly: 4 for April, 5 for May, 6 for June, 7 for July, 8 for August, 9 for September and 10 for October, for every variable type (Supplementary table 1 and 2).

Statistical analyses

Two-way fixed effects ANOVA was used based on randomized complete block design (RCBD) for the analysis of data sets. The empirical mean response ($\bar{y}_{ij}$) of the *i*-th hybrid (*i* = 1, 2, . . ., *I*) in the *j*-th site (*j* = 1, 2, . . ., *J*) with n replications in each of the $I \times J$ cells is expressed as:

$$\bar{y}_{ij} = \mu + g_i + e_j + (ge)_{ij} + \bar{\varepsilon}_{ij} \quad (1)$$

where μ is the grand mean, g_i the effect of the *i*-th hybrid, e_j the effect of the *j*-th site, $(ge)_{ij}$ the interaction of the *i*-th hybrid in the *j*-th site and $\bar{\varepsilon}_{ij}$ is the average error.

In factorial regression (DENIS, 1988; VAN EEUWIJK *et al*., 2005), explicit environmental information is included to describe the interaction term:

$$E(Y_{ij}) = \mu + \alpha_i + \beta_j + \sum_{k=1}^{K} \xi_{ik} Z_{jk} \quad (2)$$

where $E(Y_{ij})$ is the expectation of genotype *i* in environment *j*, μ is the grand mean, α_i represents the genotype main effect, β_j is environment main effect, Z_{jk} refers to the value of any environmental variable *k* for environment *j*, and ξ_{ik} represents the sensitivity of genotype *i* to the explicit environmental variable *k* (VOLTAS *et al*., 2005).

The R program also provided a partition of the total hybrid × site (HS) interaction into heterogeneity (non-additivity or the linear effect of environmental index (*EI*); EI $= \bar{X}_{\bullet j} - \bar{X}_{\bullet\bullet}$, where $\bar{X}_{\bullet j}$ is mean of all hybrids in the site *j* and $\bar{X}_{\bullet\bullet}$ is mean of all hybrids across all sites) and residual HS interaction.

RESULTS AND DISCUSSION

The ANOVA analysis shows that there are highly significant effects ($P < 0.01$) for all observed sources of variation (Table 2) for the tested maize hybrids in 2004 as well as in 2005. Site effect in 2004 accounted for as much as 82.9% of the total sum of squares and was 9.31 times higher than the hybrid effect (Table 2). This could be explained by high variability of weather conditions between the sites in 2004, (Supplementary table 1) of which precipitation was likely to affect the site effect.

Less obvious differences among observed effects were shown for testing network in 2005, when hybrid and hybrid × site (interaction) effects captured 32.3% and 38.2% of the total sum of squares (Table 2), respectively, while site accounted for only 29.5% of the total sum of squares. Variance due to site effect was as much as 2.81 times smaller in the testing network of maize hybrids in 2005 than the same effect observed in 2004. This could be explained by much more favorable conditions in 2005 (Supplementary table 2) that did not magnify the differences between the sites as they did in 2004.

Table 2. Two-way fixed effect ANOVA for grain yield of tested experimental hybrids

Source of	2004			2005		
variations	df	SS (%)	MS	df	SS (%)	MS
Hybrid	20	8.9	28.8**	23	32.3	16.8**
Site	7	82.9	758.7**	6	29.5	58.7**
Interaction	140	8.2	3.7**	138	38.2	3.3**
Error	480	–	0.77	483	–	1.79

. ** Significant at the probability level of P=0.01

Maize hybrids in field trials conducted in 2004 and 2005 showed 4.66 times greater hybrid × site interaction in 2005 than in 2004. Although the usual proportion of the genotype × site interaction counts around 10% of total sum of treatments in standard MET's (GAUCH, 2013), in some cases it can be much larger. STANISAVLJEVIĆ *et al.* (2013) reported the proportion of the genotype × site interaction in total variation from 6.7% to 36.3% in five consecutive years (2007-2011). The genotype effect also contributed more to the grain yield variance in 2005 and it was 3.62 times larger than the genotype effect recorded in 2004.

In order to test the individual influence of climatic variables, we conducted individual factorial regression on all measured climatic variables in the hybrid × site sum of squares. By using 20 degrees of freedom (or more than 14.3% total) all variables showed significant ($P < 0.01$) contribution to the interaction observed for the maize hybrids in 2004 (Table 3). Precipitation in the month of July (Pr7) showed the greatest contribution to the interaction sum of squares (29.9%) while the Relative humidity in the month of April (rh4) showed the least contribution (6.6%) (Table 3).

Among climatic variables tested by the individual factorial regression model for their influence on maize hybrids in 2005, 24 variables proved to be highly significant ($P < 0.01$) and eight variables were significant ($P < 0.05$) (Table 3). In 2005, the most important variable for expressing differential hybrids response to the locations was EI (43.9%) and the least significant was rh10 (14.6%) (Table 3). This was to be expected, since 2005 was the year with no exceptional weather extremes (Supplementary table 2), therefore EI variable explains the variation most successfully, since it captures not only climatic variables but also reflects specific site characteristics such as the soil type and condition. This is in accordance with the results of KANG and GORMAN (1989) who found heterogeneity caused by environmental index to be significant for the maize MET in a Louisiana contributing with 9.16% to the interaction variance. MAGARI and KANG (1993) estimated contribution of environmental index, minimum temperature, maximum temperature, preseason rainfall, rainfall during the growing season, and relative humidity to GEI by determining heterogeneity attributable to each of these covariates. In five of eight trials, heterogeneity due to environmental index was found to be significant. FAN *et al.* (2007), however, who conducted maize MET trials in People's Republic of China, observed no significant heterogeneity caused by environmental index.

Table 3. Analysis of variance of individual factorial regression model for maize hybrids in 2004 and 2005.

Source of variation	FAO400 (2004) SS (%)	*P*	Source of variation	FAO400 (2005) SS (%)	*P*
pr7	29.9	0.000	EI	43.9	0.000
pr5	28.3	0.000	pr4	36.4	0.000
pr9	27.4	0.000	mnt9	35.1	0.000
mt9	27.1	0.000	mt9	34.7	0.000
mnt5	26.3	0.000	mxt8	34.0	0.000
mnt9	25.5	0.000	pr6	31.7	0.000
mnt4	24.3	0.000	mt10	31.5	0.000
mt5	23.3	0.000	mxt7	30.8	0.000
mnt8	23.3	0.000	mt5	29.9	0.000
mt4	23.3	0.000	mnt10	28.9	0.000
mt8	23.1	0.000	mnt8	28.7	0.000
mxt7	22.2	0.000	mnt7	27.1	0.000
mxt9	21.9	0.000	mt8	26.6	0.000
mnt7	21.5	0.000	mnt4	26.2	0.000
mt7	21.0	0.000	mnt5	24.1	0.000
mxt10	20.5	0.000	mt7	24.0	0.000
EI	20.5	0.000	mt4	23.6	0.000
mnt10	20.4	0.000	sh9	22.8	0.000
sh8	19.9	0.000	sh7	20.7	0.001
mxt4	19.7	0.000	mxt9	19.1	0.002
mxt8	19.4	0.000	mt6	19.0	0.002
sh5	19.4	0.000	mnt6	18.9	0.002
rh10	18.8	0.000	mxt6	18.6	0.003
mt10	18.1	0.000	rh5	17.3	0.007
mxt5	18.0	0.000	rh6	16.4	0.012
mnt6	15.8	0.000	pr10	16.3	0.013
mt6	15.8	0.000	rh8	16.1	0.014
pr6	14.7	0.000	pr5	16.0	0.015
pr4	13.9	0.000	pr7	16.0	0.016
sh4	13.9	0.000	sh10	14.7	0.033
rh5	13.3	0.000	rh7	14.7	0.033
mxt6	13.3	0.000	rh10	14.6	0.035
sh6	13.1	0.000			
sh7	13.0	0.000			
pr10	11.7	0.000			
rh6	10.4	0.000			
sh9	10.0	0.000			
sh10	9.8	0.000			
rh8	9.2	0.000			
pr8	8.0	0.000			

rh9	7.3	0.000
rh7	6.8	0.001
rh4	6.6	0.002

mxt-maximum temperature; mnt-minimum temperature; mt-average temperature; pr-precipitation; rh-relative humidity; sh-insolation hours; 4-April; 5-May; 6-June; 7-July; 8-August; 9-September; 10-October.

Table 4. Multiple factorial regression models for grain yield of tested maize hybrids

Model	Environmental variables included in the final model	Residual
	2004	
All	pr7 (29.9), mnt5 (24.7), mxt5 (13.2), sh4 (9.8)	22.4
mxt	mxt8 (23.4), mxt7 (22.2), mxt6 (11.4), mxt10 (11.1)	31.9
mnt	mnt9 (27.3), mnt5 (26.3), mnt6 (11.6), mnt7 (8.1)	26.8
mt	mt9 (27.1), mt4 (24.3), mt6 (9.0), mt10 (7.4)	32.2
pr	pr7 (29.9), pr4 (14.1), pr10 (12.7), pr6 (11.1)	32.2
rh	rh8 (20.7), rh7 (19.9), rh10 (18.7), rh6 (9.9)	30.8
sh	sh8 (19.9), sh7 (19.4), sh9 (13.0), sh4 (11.3)	36.4
April	mnt4 (24.3), mxt4 (19.9), mt4 (13.7), sh4 (12.9)	29.2
May	pr5 (28.3), mt5 (24.7), mxt5 (13.4), rh5 (8.3)	25.3
June	sh6 (19.9), mnt6 (15.8), mxt6 (15.5), mt6 (13.9)	34.9
July	pr7 (29.9), mnt7 (22.3), mxt7 (11.6), mt7 (10.2)	26.0
August	mnt8 (23.3), mt8 (17.3), sh8 (15.8), rh8 (11.5)	32.1
September	pr9 (27.4), mnt9 (25.7), mt9 (13.5), mxt9 (11.1)	22.3
October	mnt10 (21.1), mxt10 (20.5), rh10 (19.5), mt10 (16.3)	22.6
	2005	
All	EI (43.9), mt9 (16.8)	39.3
mxt	mxt8 (34.0), mxt9 (20.3)	45.7
mnt	mnt9 (35.0)	65.0
mt	mt9 (34.7), mt10 (18.1)	47.2
pr	pr4 (36.4), pr5 (21.1)	42.5
rh	rh10 (18.2), rh5 (17.3)	64.5
sh	sh9 (22.8), sh7 (17.4)	59.8
April	pr4 (36.4)	63.6
May	mt5 (29.8)	70.2
June	pr6 (31.7)	68.3
July	mxt7 (30.7), pr7 (19.0)	50.3
August	mxt8 (34.0)	66.0
September	mnt9 (35.0), sh9 (22.2)	42.8
October	mt10 (31.5), sh10 (18.3)	50.2

mxt-maximum temperature; mnt-minimum temperature; mt-average temperature; pr-precipitation; rh-relative humidity; sh-insolation hours; 4-April; 5-May; 6-June; 7-July; 8-August; 9-September; 10-October. All reported values are given as percentage of the explained variance of interaction by the term

Multiple factorial regression, coupled with a stepwise procedure for variable selection was used to search for the most informative sets of environmental covariables. Multiple factorial regression models that showed as most successful in explaining interaction variance in the 2004 was the one that included pr7, mnt5, mxt5 and sh4 variables (77.6%) (Table 4).

Rainfall in July had such a significant impact on explaining the variance in 2004 due to high daily average temperatures combined with severe drought in 2004 (Supplementary Table 1). Water stress is one of the most detrimental stress factors although high temperatures, defoliation - from hail, insects, etc. and extremely high plant populations, among others, also reduce yield during this critical time, especially when coupled with drought stress. During flowering, plants use more water (0.89 to 1.1 cm per day) than at any other time. This is in part because silks have the highest water content among all parts of the corn plant. Early medium maize hybrids flower in June and July, and stress during the pollination and silking period often reduces yield potential (HAYASHI, 2016). Rainfall in July (pr7) is, therefore, logically the variable that explains the variation in yield in the moderate to high-drought 2004 season.

The importance of the variables concerning minimum and maximum daily temperatures in May (mnt5, mxt5) just underlines the importance of the favorable conditions in, and right after the sowing. Favorable conditions at the time of planting, and in the period after planting is crucial for good rooting and root system development. In basic plant physiology experiments, KUCHENBUCH and BARBER, (1988) found that root length density below 30 cm, essential for the water and nutrient uptake in the later stages, was correlated with GDD for two weeks following planting.

Analysis of variables belonging to the same type resulted in models with less efficacy compared to the model of all variables considered. The biggest portion of explained variance of interaction for the maize testing network in 2004 by the type of the variable was in the model with minimum temperatures (73.3%) and the smallest in the model with insolation hours (63.6%) (Table 4).

Very successful in explaining the variance of interactions in 2004 were also the models using relative humidity and maximum temperature, explaining 69.2% and 68.1% variance of interactions, respectively. Among the relative humidity, the most significant was rh8 (20.7%) while among the maximum temperature the most significant was mxt8 (23.4%). This is consistent with the CHUNG *et al.* (2014) who have showed that the effects of weather extremes such as high temperatures from June to August, when ears are developing, a crucial period for maize growth, can be used to predict grain yield losses from a heat wave.

The most important variables in explaining interaction sum of squares within their type of variable for multi-site trial in 2004 were: pr7 (29.9%), mnt9 (27.3%), mt9 (27.1%), mxt8 (23.4), rh8 (20.7%) and sh8 (19.9%) (Table 4). Most of them are concentrated in the above mentioned critical three months, in the accordance with CHUNG *et al.* (2014). Variables mnt9 and mt9 were more likely related to the Stay Green effect of certain hybrids, allowing them the functional photosynthesis in the final stage of vegetative cycle which can be a comparative advantage in terms of the final yield.

Models which considered climatic variables by months for 2004 showed the greatest explanation of interaction variance in September (77.7%) and the least in June (65.1%). During the vegetative cycle for 2004, minimum temperature was most important in April (24.3%), August (23.3%) and October (21.1%); precipitation in May (28.3%), July (29.9%) and September (27.4%) and insolation hours in June (19.9%) (Table 4).

The effect of the temperatures in April (mnt4) on the final yield was not surprising; growers tend to sow as early as they can, and the years with favorable conditions in the first decade of April provide them with a head-start that can affect their yields at the time of harvest by providing the crop with the more time to photosynthesize and avoiding the drought in the critical period of flowering (MARESMA *et al.,* 2019). Precipitation in May and July are crucial in alleviating the harsh temperature conditions and providing the better conditions in the most critical moment in the vegetative cycle - flowering, therefore affecting the pollination, kernel number and seed set as the components of the yield. Insolation hours in June, are crucial in using the most of the developed photosynthetic surface and photosynthetic apparatus for carbon fixation.

The best model according to multiple factorial regressions for 2005 was the one obtained by considering all available variables EI and mt9 (60.7%) (Table 4) which is not surprising – the EI represents a majority of differences including soil fertility, cultural practices, humidity, insolation and insect or disease occurrences (YAN, 2014).

Models obtained by the analysis by type of variable, proved to be less efficient in comparison to one which treated all available climatic variables. Among them, the most successful in explaining the variance was the one which considered precipitation (57.5%) and the least successful the one which had taken into account minimum temperatures (35.0%) (Table 4).

Models obtained by taking into account climatic variables by months of maize hybrids vegetative cycle for 2005 show that the maximum temperature is most explanatory in July (30.7%) and August (34.0%) minimum temperature in September (35.0%); average temperature in May (29.8%) and precipitation in April (36.4%) and June (31.7%) (Table 4).

By comparing the most influential climatic variables in models by type of variable in 2004 and 2005, mxt8, mnt9 and mt9 were the most relevant for the genotype × site interaction in both years for tested maize hybrids. This is in accordance with MALVAR *et al*. (2005), who studied the performance of crosses among French and Spanish maize populations across eight environments and concluded that effects of G, E and GE for grain yield were mainly because of earliness, vigor effects and/or environmental factors related to cold stress-the means of minimum and maximum temperatures. They had identified maximum temperature as the most important environmental variable for GEI for biomass of 161 lines from a $F_{3:4}$ maize segregating populations originally created with the purpose of mapping QTLs loci and investigating adaptation differences between highland and lowland tropical maize.

CONCLUSION

The research conducted in maize field trials identified important sources of genotype × environment interaction, and demonstrated the magnitude of their impact on yield variation in two very different vegetative seasons: 2004 that proved itself to be harsher in weather extremes, and 2005 vegetative season that was more moderate in precipitation and temperature maximums in critical phases of corn development.

The results of this research have both theoretical and practical implications in maize breeding as well as in commercial maize production. They provide a base for further research in

GEI analysis and analysis of hybrid combination stability and their identification. Furthermore, they represents a useful tool in characterizing the sub-regions of maize growing area and extending the existing the results to new sites.

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MODELIRANJE INTERAKCIJSKE VARIJANSE ZA PRINOS ZRNA SREDNJE RANIH HIBRIDA KUKURUZA

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Izvod

Interakcija genotip – spoljašnja sredina (GEI), sa svim praktičnim i teorijskim aspektima koje obuhvata, je fenomen od izuzetne važnosti u oblasti genetike i oplemenjivanja. U ovom radu, ispitivali smo uticaj interakcije na prinos zrna srednje-ranih hibrida kukuruza iz mreže ogleda koje sprovodi Odsek za priznavanje sorti Ministarstva poljoprivrede, šumarstva i vodoprivrede Republike Srbije, na osam lokaliteta u toku dve godine. Ispitivane varijable objasnile su 77.6% u prvoj, odnosno 60.7% varijacije u drugoj posmatranoj godini. Faktorijalna regresija sa izborom promenljivih je pokazala da je model koji uzima u obzir padavine u mesecu julu (pr7), minimalnu (mnt5) i maksimalnu temperaturu u maju (mxt5), i količinu sunčanih sati u aprilu (sh4) u 2004. godini, i indeks spoljašnje sredine (EI) i prosečnu temperaturu u septembru (mt9) u 2005, godini, najuspešnije objašnjava prisustvo interakcije na teritoriji Vojvodine u toku dve posmatrane godine. Ovi rezultati pružaju osnovu za dalja istraživanja vezana za fenomen interakcije genotip-spoljašnja sredina i stabilnost prinosa, a takođe predstavljaju koristan alat u karakterizaciji sub-regiona u oblasti gajenja kukuruza.

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