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Variation of physiological traits and yield components of some maize hybrid (*Zea mays* L.) in agroecological conditions of Kosovo

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ABSTRACT

The aim of this study was to investigate some physiological traits and yield of different maize hybrids in growth conditions of Kosovo. The field experiment was conducted in 2006 and 2007 in Kosovo, near Prishtina. The experiment was based on a randomized complete block design with 3 replications. For calculating and statistical analysis 10 plants per each plot were randomly chosen. In the study, seven commercial maize hybrids belonging to different FAO groups (FAO 300, 400 and 600), originating from two breeding institutions: Maize Dept. of Bc Institute Rugvica – Croatia (Jumbo 48 [H-1], BC418 [H-2], BC408 [H-3], BC288 [H-4], BC394 [H-5]) and from Pioneer Hi-Bred Int. (Austria) (Pregia [H-6] and Colombo [H-7]), were included. For traits ear leaf area (LA), absolute growth rate (AGR), crop growth rate (CGR) and biological dry matter (BDM) higher values were obtained in the 2nd year in comparison to the 1st year, however the harvest index (HI) of the 1st year was of a higher value than the 2nd year. Also, for all investigated traits, except for HI, statistically significant differences were obtained among the studied maize hybrids. The highest values for all traits, except for HI, expressed the H-6 and these values were statistically significant higher than those of all other hybrids, but not for BDM. Our results indicated that the H-6 was the most appropriate for cultivation in agroecological conditions in Kosovo, while the H-4 and H-5 were less appropriate in the given conditions.

Keywords: maize, *Zea mays*, leaf area, absolute growth rate, crop growth rate, harvest index, yield.

Abbreviations: LA, ear leaf area; AGR, absolute growth rate; CGR, crop growth rate; BDM, biological dry matter; HI, harvesting index.

IZVLEČEK

VARIABILNOST FIZIOLOŠKIH LASTNOSTI IN KOMPONENT PRIDELKA NEKATERIH HIBRIDOV KORUZE (*Zea mays* L.) V AGROEKOLOŠKIH RAZMERAH KOSOVA

Namen raziskave je proučiti nekatere fiziološke lastnosti in pridelek različnih koruznih hibridov za pridelovanje v agroekoloških razmerah Kosova. Poljski poskus je bil izveden v letih 2006 in 2007 v Prištini na Kosovu po metodi naključnih blokov v 3 ponovitvah. Za obračunavanje in stastistične analize je bilo iz vsake parcelice naključno odbranih 10 rastlin. V proučevanje je bilo vključenih 7 hibridov različnih zrelostnih razredov (FAO 300, 400 in 600), iz dveh žlahtniteljskih institucij in sicer iz Zavoda za kukuruz Bc Inštituta iz Rugvice – Hrvaška (Jumbo 48 [H-1], BC418 [H-2], BC408 [H-3], BC288 [H-4], BC394 [H-5]) in iz Pioneer Hi-Bred Int. (Austria) (Pregia [H-6] in Colombo [H-7]). Za lastnosti listna površina lista ob storžu (LA), rastna stopnja na rastlino (AGR), rastna stopnja na enoto površine (CGR) in skupno suho snov (BDM) smo v drugem letu dobili višje vrednosti kot v prvem letu; medtem ko so za žetveni indeks (HI) bile višje vrednosti v prvem letu. Za vse proučevane lastnosti, razen za HI, smo ugotovili statistično značilne razlike med hibridi. Za vse lastnosti, razen za HI, je imel najvišje vrednosti H-6, ki so bile statistično značilno višje od vseh drugih hibridov; samo za BDM je H-6 bil statistično značilno enak H-2 in H-3. Rezultati nakazujejo, da je za pridelovanje v rastnih razmerah Kosova najbolj primeren hibrid H-6, medtem ko sta hibrida H-4 in H-5 manj primerna.

Ključne besede: koruza, *Zea mays*, listna površina, rastna stopnja na rastlino, rastna stopnja na enoto površine, žetveni indeks, pridelek.

Okrajšave: LA, listna površina; AGR, rastna stopnja na rastlino; CGR, rastna stopnja na enoto površine; BDM, skupna suha snov; HI žetveni indeks.

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1 INTRODUCTION

Maize (*Zea mays* L.) is an important field crop and a major component of numerous animal feeds. Based on the area and the production it ranks on the second place among field crops in Kosovo. During 2005-2006, maize was grown on a total area of 60,000-70,000 ha with an average yield of 4.5 t ha^{-1} (MAFRD, 2008). In Kosovo, there are two major agriculture regions and both have good soil and climatic conditions for maize production. However, yield per hectare is lower when compared to other maize growing countries of the region. Among the main reasons are inappropriate seed material and inappropriate hybrids, limited use of fertilizers and lack of adoption of modern technologies. Maize growth and productivity depends on many factors such as genetic structure, environmental characteristics and production technology. If environment is not optimal (i.e., in areas with marginal rainfall such as <600 mm per year) the production of maize is considered less reliable (Robertson et al., 2003).

The success of genetic improvement of maize yield depends on several factors such as initial sources of genes (initial parental material), improvement method, types of the gene actions involved in yield control, inheritance and genetic control of related traits such as capacity of production (Rezaei et al., 2004). Biomass accumulation in kernels begins shortly after fertilisation and can be represented by a sigmoidal pattern in which a lag and a linear growth phase can be distinguished (Duncan et al., 1965). Growth analysis is one approach to the analysis of yield-influencing factors and plant development (Berzsenyi and Lap, 2004).

In Kosovo, about 95 % of arable land (cca 66,000 ha) is planted by different types of hybrids. The activities aimed at the development of hybrids in territory of Kosovo started during 1970s, and more intensive work took place during 1980-1987. This work was not very successful and for this reason the research was re-established after 1999 (Aliu, 2006). The new program considered physiological parameters as crucial in the development of productive lines and hybrids. Physiological parameters, especially the leaf area and related components such as LA, AGR and CGR are crucial factors in photosynthesis. The environmental factors and their interactions with plant characteristics and with cultural practice are also very important (Aliu et al., 2008).

The main objective of this study was to determine the most appropriate genotypes regarding to physiological parameters associated with leaf area and yield suitable for agro-ecological conditions of Kosovo.

2 MATERIALS AND METHODS

Experimental site

The experiment was conducted during 2006-2007, 5 km southwest of the capital Prishtina (570 m a.s.l., 42°38’97’’ N latitude, 21°08’45’’ E longitude), with an average rainfall of 613.3 mm per year and the mean annual temperature is 10.27 °C (HMIK, 2008). Summer temperatures in this region are sometimes exceeding 35°C resulting in high evapotranspiration.

Plant material and experimental design

The experimental design was based on a randomized complete block design (RCBD) with three replications. The size of individual plots was 28 m^2. The distance between rows was 70 cm, whereas the distance between plants within rows was 30 cm (47,000 plants ha^{-1}). Seven commercial maize hybrids originating from two different institutions and belonging to FAO groups 300, 400 and 600 were included. Five hybrids originated from the Maize Dept. of Bc Institute Rugvica – Croatia (Jumbo 48 [H-1], BC418 [H-2], BC408 [H-3], BC288 [H-4], BC394 [H-5]) and two from the Pioneer Hi-Bred Int. (Austria) (Pregia [H-6] and Colombo [H-7]).

Measurements

The measurements took place in field conditions and laboratory. They included leaf area (LA), absolute growth rate (AGR), crop growth rate (CGR), biological dry matter (BDM), yield and harvest index (HI). The basic data were obtained from samples of 10 plants, randomly chosen in the middle rows of each plot.

Regarding to CGR and AGR up to silking time the maize plants were randomly chosen from middle rows of experimental plots, harvested manually, and cut in small partitions. Plants’ weight was measured in grams per plant and determined in laboratory for Plant production in Agriculture Faculty in Prishtina at temperature 60°C for 24 hours.

LA was determined according to the formula by Montgomery (1911), A = L×W×0.75, where *L* is the leaf length, *W* is the leaf width, *0.75* is the factor of recalculation for maize. The same formula was used by several researchers, e.g., Whigham et al., 1974; Pearce et al., 1975; Aliu et al., 2008.

Other parameters were calculated using the formulas by Radford (1967):

$$AGR = \frac{Wp}{Ds} \text{ (g plant}^{-1}\text{ day}^{-1}\text{)},$$

AGR – absolute growth rate,
Wp – weight per plant (biomass),
Ds – number of days to silking,

and

$$CGR = \frac{Wp}{Ds} \times \textit{No. of plants } m^{-2} \ (g\ m^{-2}\ day^{-1})$$

CGR – Crop Growth Rate.

AGR and CGR were also measured at physiological maturity using formulas:

$$AGR = \frac{Wp}{Dm} \ (g\ plant^{-1}\ day^{-1}),$$

Dm – number of days to maturity

and

$$CGR = \frac{Wp}{Dm} \times \text{No of plants } m^{-2} \ (g\ m^{-2}\ day^{-1}).$$

Yield and yield components

For the analysis of yield, data were collected at biological maturity from 10 plants and their corresponding ears from each replication. Data associated with biological yield or biomass were obtained by adding the weight of ears and stalk. Harvest Index (HI), was calculated as a percentage for each plot using the following formula:

$$HI = \frac{Gy}{By} \ (\%),$$

Gy – grain yield,
By – biological yield.

Statistical analysis

The collected data were analysed by ANOVA considering LSD at p=0.05 and p=0.01 using MINITAB-14 and Microsoft Excel programs.

3 RESULTS

Ear leaf area

The green ear leaf area (LA) and its duration are important factors associated with photosynthesis, especially for maize. Highly significant differences (p=0.01) were found among the seven maize genotypes (Table 1). The analysis of LA in our study showed that maize genotypes produced larger ear leafs (larger area of ear leaf) in the second year (Y2), than in the first year (Y1). An average minimal value for the two experimental years was obtained in H-4 (540.5 cm^2 $plant^{-1}$), while the highest LA was recorded in H-6 (752.4 cm^2 $plant^{-1}$). Individual comparison of H-4 and H-6 showed that differences were + 211.90 cm^2 $plant^{-1}$. Many researchers have reported different results for LA. According to observation data by Aliu et al. (2008), the total average value for LA was 677.8 cm^2 $plants^{-1}$. Comparing to our study the results differ for –55.2 cm^2 $plant^{-1}$. The coefficient of variation for LA in maize genotypes was 12.9 % respectively.

Table 1: Values of ear leaf area (LA) of different maize genotypes included in the study.

Hybrid	FAO group	LA (cm^2 $plant^{-1}$)			Homog. groups*
		Y1	Y2	$\overline{X}$	
H-1	400	475.5	636.0	555.8	ab x
H-2	400	578.0	677.3	627.6	b xy
H-3	400	567.9	685.1	626.5	b xy
H-4	300	477.5	603.5	540.5	a x
H-5	400	562.3	581.0	571.7	abc xy
H-6	600	797.0	707.9	752.4	d z
H-7	400	642.5	727.9	685.2	cd yz
Mean		585.8	659.8	622.8	
LSD p=0.05				77.8	
LSD p=0.01				117.9	

* - the same letters indicate the same homogenous groups:
- a–d – homogenous groups at p=0.05.
- x–z – homogenous groups at p=0.01.

Absolute growth rate (AGR) and crop growth rate (CGR)

The AGR and CGR are the instruments to measure dry matter accumulation for plant per unit time. Our results indicated the significant differences among the studied maize genotypes also for AGR and CGR (Table 2). The experimental average value of AGR up to silking was 6.62 g $plant^{-1}$ day^{-1}, while for CGR was 31.04 g m^{-2} day^{-1}. This is a relatively high value for AGR and CGR. The maize genotypes H-6 produced highest value of AGR

(8.58 g plant^{-1} day^{-1}), and CGR (40.33 g m^{-2} day^{-1}); both of them were statistically significant higher (at p=0, 05 and at p=0, 01) than other genotypes. Other genotypes had statistically same value for AGR (all genotypes, except H-6, form one homogeneous group), while for CGR all genotypes, except H-6 again, form two homogeneous groups. Tollenaar (1991) and Otegui et al. (1995) emphasized the importance of the total dry matter accumulation and plant growth rate within 10 to 20 days after silking.

The total mean value of AGR and of CGR up to silking was higher in the Y2 than in the Y1. The coefficients of variation for AGR and CGR were 14.69 and 14.82 %, respectively. Pearson's coefficient of correlation between AGR and CGR up to silking was highly significant (r=0.99**).

The lowest mean values for AGR and CGR expressed the H-4 (5.03 g plant^{-1} day^{-1} and 23.62 g m^{2} day^{-1}, respectively). While the highest mean values for AGR and CGR expressed the H-6 (8.24 g plant^{-1} day^{-1} and 38.71 g m^{-2} day^{-1}, respectively) (Table 3). For both investigated traits (AGR and CGR), the H-6 showed significantly higher values than all other investigated hybrids; while the H-4 with lowest values was significantly equal to one or to six other hybrids, depending on traits and on probability level. As up to silking, the AGR and CGR were also highly correlated up to maturity.

About different results of AGR and CGR reported also other researchers. Berzsenyi and Lap (2004), reported different results of AGR (6.97 g plant^{-1} day^{-1}) as the results of increasing plant density. Late sowings increased CGR during the vegetative period because of high radiation use efficiency and higher percent radiation interception as suggested by Cirilo and Andrade (1994). CGR depends on the amount of intercepted photosynthetically active radiation, where the leaf area index play an important role (Subedi and Ma, 2005). According to data of Buttery (1970) the mean relative growth rate (RGR) and mean net assimilation rate (NAR) increased with higher density, while CGR and leaf area ratio (LAR) decreased. Also Molnarova and Szucs (2009) reported different results (18.38 till 22.05 g m^{-2} day^{-1}) on CGR at some maize hybrids.

Table 2. Values of Absolute Growth Rate (AGR) and Crop Growth Rate (CGR) up to silking of studied maize genotypes.

Hybrid	FAO group	AGR (g plant^{-1} day^{-1})					CGR (g m^{-2} day^{-1})				
		Y1	Y2	$\overline{X}$	Homog. groups*		Y1	Y2	$\overline{X}$	Homog. groups*	
H-1	400	5.16	7.73	6.45	a	x	24.3	36.34	30.30	ab	x
H-2	400	6.12	7.51	6.82	a	xy	28.8	35.30	32.03	b	x
H-3	400	5.73	7.59	6.66	a	x	26.9	35.68	31.30	ab	x
H-4	300	4.79	6.68	5.74	a	x	22.5	31.40	26.95	ab	x
H-5	400	4.70	6.57	5.64	a	x	22.1	30.80	26.44	a	x
H-6	600	6.95	10.21	8.58	b	y	32.7	47.99	40.33	c	y
H-7	400	5.85	7.13	6.49	a	x	26.4	33.52	29.95	ab	x
Mean		5.61	7.63	6.62			26.2	35.86	31.04		
LSD p=0.05				1.19					5.29		
LSD p=0.01				1.80					8.02		

* - the same letters indicate the same homogenous groups:
- a–c – homogenous groups at p=0.05;
- x–y – homogenous groups at p=0.01.

Table 3: Values of Absolute Growth Rate (AGR) and Crop Growth Rate (CGR) up to maturity of studied maize genotypes.

Hybrid	FAO group	AGR (g plant^{-1} day^{-1})				CGR (g m^{-2} day^{-1})			
		Y1	Y2	$\overline{X}$	Homog. groups*	Y1	Y2	$\overline{X}$	Homog. groups*
H-1	400	5.01	7.50	6.26	bc xy	23.55	35.25	29.40	bc x
H-2	400	5.99	7.35	6.67	c y	28.16	34.55	31.36	c xy
H-3	400	5.75	6.68	6.22	bc xy	27.03	31.40	29.22	abc x
H-4	300	4.57	5.48	5.03	a x	21.48	25.76	23.62	a x
H-5	400	4.48	6.27	5.38	ab xy	21.06	29.47	25.27	ab x
H-6	600	6.67	9.80	8.24	d z	31.35	46.06	38.71	d y
H-7	400	5.56	7.10	6.33	bc xy	26.14	33.37	29.76	bc x
Mean		5.44	7.17	6.31		25.54	33.70	29.62	
LSD p=0.05				1.00				5.66	
LSD p=0.01				1.51				8.09	

* - the same letters indicate the same homogenous groups:
- a–d – homogenous groups at p=0.05;
- x–z – homogenous groups at p=0.01.

Biological Dry matter (BDM), yield and harvest index (HI)

The mean values of BDM and yield were significantly different among maize genotypes, but not for HI (Table 4). The maize hybrids H-6 produced significantly higher BDM (1029.16 g plant^{-1}), while the hybrids H-4 realized the lowest value for BDM (635 g plant^{-1}). H-4 was found to be equal to two (p=0, 05) or to all other hybrids, except to H-6, (p=0, 01). The differences between hybrids regarding extreme values were +394.16 g plant^{-1} (51.01 %). The studied maize genotypes produced significantly more BDM in Y2 (893.1 g plant^{-1}) than in Y1 (652.5 g plant^{-1}), the difference was + 240.6 g plant^{-1}.

The coefficient of variation for BDM in maize genotypes was 16.80 %. Morgado and Willey (2008) observed some trend for physiological parameters, and in their study they found that the total biomass yield of maize under different cropping systems and nitrogen levels was from 7887 to 10513 kg BDM per ha^{-1}. Also, Khan et al., (2003) presented different results for biological yield in some maize genotypes from 9.62 to 20.04 t ha^{-1}, while Birch (2004) reported different results of biomass from 11.4 to 28.18 t ha^{-1}.

The final grain yield (t ha^{-1}) in maize is considered to be a combined effect of various yield components, like number of ear bearing plants, number of ears per plant, number of grains per ear, weight of grains per ear and 1000 grain weight. The total mean value of yield for all investigated maize hybrids was 8.69 t ha^{-1} and that was relatively high and could guarantee a high yield. Results of the grain yield exhibited significant differences among the investigated hybrids (Table 4). The H-6 had significantly the highest mean grain yield (9.9 t ha^{-1}), while H-4 the lowest (7.8 t ha^{-1}). The difference between H-6 and H-4 was +2.10 (24.2 %) while distinction between years was +0.96 t ha^{-1}.

Table 4. Values of Biological Dry matter (BDM), yield and harvest index (HI) of maize genotypes.

Hybrid	FAO group	BDM (g plant^{-1})				Yield (t ha^{-1})				HI (%)			
		Y1	Y2	$\overline{X}$	Homog. groups*	Y1	Y2	$\overline{X}$	Homog. groups*	Y1	Y2	$\overline{X}$	Homog. groups*
H-1	400	595.3	891.7	743.5	ab x	7.8	9.1	8.5	bc xy	42.5	31.9	37.2	a x
H-2	400	706.0	866.3	786.2	cd x	8.2	9.3	8.8	c xy	30.8	36.4	33.6	a x
H-3	400	678.3	898.3	788.3	cd x	8.8	9.5	9.2	c yz	38.3	33.3	35.8	a x
H-4	300	530.0	740.0	635.0	a x	7.1	8.5	7.8	a x	44.5	35.6	40.1	a x
H-5	400	541.6	758.0	649.8	a x	7.4	8.7	8.0	ab x	42.6	35.8	39.2	a x
H-6	600	833.3	1225.0	1029.2	d y	9.7	10.1	9.9	d z	36.5	23.2	29.9	a x
H-7	400	683.3	873.0	778.1	bc x	8.4	9.1	8.8	c xy	37.0	35.8	36.4	a x
Mean		652.5	893.1	772.8		8.2	9.2	8.7		38.9	33.1	36.0	
LSD p=0.05				135.7				0.66				23.0	
LSD p=0.01				205.6				1.01				32.8	

* - the same letters indicate the same homogenous groups:
- a–d – homogenous groups at p=0.05;
- y–z – homogenous groups at p=0.01.

Pearson's correlation coefficient between BDM and grain yield was strong (r=0.96**). Birch (2004) obtained grain yield from 6.1 to 11.5 t ha^{-1}. The physiological efficiency of maize plants to convert the total dry matter to grain yield can be estimated by calculating the harvest index (HI). The value of HI varied from 29.87 % (H-6) to 40.07 % (H-4), but no significant differences were found among these hybrids, while rather high difference was found between years (Y1 – 38.90 %, Y2 – 33.14 %). Many researchers have reported different results about HI. HI obtained by Worku and Zelleke (2007) varied from 31.1 % to 45.0 % whereas results by Subedi and Ma (2005) varied from 0.49 to 0.55 %.

4 CONCLUSION

The investigated seven maize hybrids differed significantly in all studied parameters, except for HI. The investigated hybrids come from two institutions and involve distinct genetic and morphological backgrounds. However, they were cultivated in same agroecological conditions. H-6 exhibited higher values of all measured traits. The hybrids realized more productivity for parameters AGR, CGR, BDM and yield in the 2^{nd} than in the 1^{st} year, because of more precipitations. However, physiological parameters' analysis include LA, AGR, CGR, HI and provide an excellent opportunity to monitor the independent and interactive effects of different factors affecting maize yields and open the way to managing these factors in plant.

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