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Genotype and Year Effect on Grain Yield and Nutritive Values of Maize (*Zea mays* L.)

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Abstract: The aim of this study was to estimate the effects of genotype and year on the dry matter yield, grain yield and nutritive value in six maize genotypes (ZP 434, NS 444, ZP 684, NS 6010, ZP 735 and Dunav). Studied genotypes belong to different maturity groups FAO 400 (ZP 434, NS 444 ultra), FAO 600 (ZP 684, NS 6010) and FAO 700 (ZP 735, Dunav). The field experiments were carried out in dry land farming in the region of Southwest Vojvodina province (Serbia), during the years 2006 and 2007. Genotype had significant effect on the Dry Matter Yield (DMY), Grain Yield (GY), Grain Starch Content (GSC), Grain Protein Content (GPC), Starch Yield (SY) and Protein Yield (PY). The genotype NS 6010 among the 6 genotypes had the highest DMY (24.0 ton ha^{-1}), GY (12695 kg ha^{-1}), SY (8951.8 kg ha^{-1}) and PY (1225.9 kg hawe^{-1}). Genotype NS 444 ultra statistically had the lowest DMY (17.8 ton ha^{-1}), GPC (9.29%) and PY (925.0 kg ha^{-1}). Also, the year have a significant effect on the all studied traits. Two years differed significantly in distribution of precipitation. In 2006, averages for genotypes, DMY, GY, GSC, GPC, SY and PY were significantly higher then in 2007 because of higher amount and distribution of precipitation, especially during the summer months of June to August. The GPC decreased with increasing GSC and GY.

Key words: Maize genotype, grain yield, starch, crude protein, dry matter yield, starch yield, protein yield

INTRODUCTION

Maize (*Zea mays* L.) is a multipurpose crop, provides food for humans, feed for animals, poultry and fodder for livestock. In the complete forage mixtures, corn is present with 50-80%, depending on the type and categories of animals. Maize (grain, silage or green fodder) can be used as feed for all farm animal species (Di Marco *et al*., 2002; Filya, 2004; Jensen *et al*., 2005). The genetic yielding potential of maize genotypes depends on climatic conditions and the level of growing practices (Kresovic *et al*., 2004; Videnovic *et al*., 2007). Genetic variability for grain yield and protein content has been reported by Saleem *et al*. (2008) and Idikut *et al*. (2009). Baye *et al*. (2006) reported that relative composition of protein, oil and starch in the maize kernel has a large genetic component.

Maize grain had high starch content and low protein content. The inverse relationship between grain yield and grain protein content were demonstrated by many researchers (Fabijanac *et al*., 2006; Saleem *et al*., 2008). Megyes *et al*. (2005) and Halof and Sarvari (2007) reported that the grain yield of maize is primarily influenced by sunshine, temperature, available nutrients and water supply. Huzsvai and Nagy (2005) concluded that in different years, deviation in the temperature and in the quantity and distribution of precipitation may significantly influence yields of maize even under very similar growing conditions. Aildson *et al*. (2005) reported that environmental factors and genetic properties determine the chemical composition the grain of maize. Duvick (2005) reported that genetic yielding potential of maize has been increasing by 100 kg ha^{-1} annually for the last 40 years while a contribution of selection to this increase approximately amounted to 50%.

The aim of this investigation was to estimate, the effects of genotype and year on the dry matter yield, grain yield and chemical composition of maize grain in six maize genotypes (ZP 434, NS 444, ZP 684, NS 6010, ZP 735 and Dunav). Also, the aim of this experiment was to determine, relationship among studied traits of different maize genotypes. Quality of maize grain is closely related to starch and protein contents which could be significant data to compare genotypes.

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MATERIALS AND METHODS

Field experiments: Experiments were conducted in southwest Vojvodina province (Serbia) in region Srem at location Ruma (45°00" 17 N Lat., 19°49' 12 E Long., 111 m a.s.l). The experiment was carried out during two growing seasons 2006 and 2007 on calcareous chernozem soil type. The main characteristics of the soil (depth: 0-50 cm) were: pH in KCl-7.1 (neutral reaction); pH in H_2O-7.3 (weakly alkaline reaction); $CaCO_3$-7.8% (carbonate); humus-2.15%, total N-0.19%. The soil contained 16.9 and 23.9 mg/100 g of soil phosphorus and potassium, respectively (Table 1).

Average temperatures of months and total precipitation of months during the time of the experiment are shown in Table 2. Precipitation and air temperature records were taken from the closest meteorological station (Sremska Mitrovica). Glamoelija stated for Serbia that the maize water requirements were 490 mm for the growing season or 50 mm in April, 75 mm in May, 90 mm in June, 100 mm in July, 95 mm in August and 80 mm in September. In Vojvodina province, maize during the vegetation rarely meets the needs of water from rainfall. The situation is particularly acute in the summer months of June to August. Total precipitation of the years 2006 and 2007 (611 and 617 mm, respectively) was almost the same with long term means (614.6 mm) (Table 2). In 2006, the amount of total precipitation in growing season of maize was higher for 38 mm than in 2007 (361 mm). The amount of precipitation for the period June to August was higher in 2006 for 100 mm than in 2007 (188 mm). It was crucial for the formation of higher maize biomass and the formation of maize grain yield in 2006. Average temperatures of the years 2006 and 2007 (18 and 18.9°C, respectively) were higher then long term means (17.4°C). Medium monthly air temperatures in 2006 during the summer months (June to August) were lower compared to the same period of 2007.

Names and origins of maize genotypes used in the study are shown in Table 3. Six maize genotypes, ZP 434 (FAO 400), NS 444 ultra (FAO 400), ZP 684 (FAO 600), NS 6010 (FAO 600), ZP 735 (FAO 700) and Dunav (FAO 700) were used as material. Genotype NS 444 ultra is tolerant to Cycloxydim (Cycloxydim Tolerant Maize (CTM)). It is not genetically modified. Genotypes ZP 434, ZP 684, NS 6010, ZP 735 and Dunav belong to stay-green type and they could serve as silage. Stay-green is an indicator of good plant health later in the season, reduced progressive senescence, tolerance to post-flowering drought and stalk lodging what ensure superiority of stay-green genotypes in comparison to non-stay-green ones, especially in drought conditions.

Table 1: Chemical characteristics of soil on the observation field (Ruma, Serbia)

Parameters	Values
pH in KCl	7.10
pH in H_2O	7.30
$CaCO_3$ (%)	7.80
Humus (%)	2.15
Total nitrogen (%)	0.19
P_2O_5 mg/100 g of soil	16.90
K_2O mg/100 g of soil	23.90

Table 2: Monthly air temperature (°C) and total precipitation (mm) in 2006 and 2007 with long term precipitation means (1961-1990)

	Average temperatures			Total of precipitation		
Months	1961-1990	2006	2007	1961-1990	2006	2007
October to March	-	-	-	258.1	212	256
April	11.5	12.6	13.0	51.1	63	0
May	16.5	16.4	18.5	58.2	32	79
June	19.3	19.6	22.1	84.3	92	86
July	20.7	22.7	22.6	64.6	39	39
August	20.2	19.2	22.2	54.2	157	63
September	16.5	17.5	14.3	44.1	16	94
Mean	17.4	18.0	18.9	-	-	-
Growing season	-	-	-	356.5	399	361
Total	-	-	-	614.6	611	617

Table 3: Name of the maize genotypes and their origins used in the experiment

Names of genotypes	FAO	Origin
ZP 434	400	Maize Research Institute, Zemun Polje
NS 444 ultra	400	Institute of Field and Vegetable Crops, Novi Sad
ZP 684	600	Maize Research Institute, Zemun Polje
NS 6010	600	Institute of Field and Vegetable Crops, Novi Sad
ZP 735	700	Maize Research Institute, Zemun Polje
Dunav	700	Institute of Field and Vegetable Crops, Novi Sad

The experiment was made using a randomized complete block design with four replications. The size of each plot was 6.0×2.8 m. In both years, sowing was done in 19th April. Plant density was 60.000 plants ha^{-1} (70×24 cm). Preceding crop was winter wheat. A standard cultivation practice was applied. Shallow inter-row cultivation was carried out on two occasions: first at the stage of 3-4 leaf and the second in the stage of 7-9 leaves. Calcium Ammonium Nitrate (CAN) was applied in 2 doses of 300 kg ha^{-1} at the time of sowing and at the stage of 3-4 leaf with the first cultivation. The harvest was performed during the silage stage (30-35% dry matter whole plant) for measuring the Dry Matter Yield (DMY). Maize harvest was performed manual. Ten plants from each plot were taken for measuring of Grain Yield (GY). GY is calculated on a 14% moisture basis.

Chemical analysis: After harvest, samples were taken for chemical analysis. The nitrogen present in each sample was determined by Kjedhal method. The method is described by Anonymous (1990). GP content was calculated as N ×6.25. Grain Starch Content (GSC) was determined by titration method (Saleem *et al*., 2008).

Starch Yield (SY) and Protein Yield (PY) were calculated by multiplying their concentrations in the grain with grain yield per ha:

$$\text{Starch yield (kg ha}^{-1}\text{)} = \text{Grain yield (kg ha}^{-1}\text{)} \times \text{Grain starch content (\%)}$$

$$\text{Protein yield (kg ha}^{-1}\text{)} = \text{Grain yield (kg ha}^{-1}\text{)} \times \text{Grain protein content (\%)}$$

Statistical analysis: Data were processed by ANOVA. Test of difference significance between treatments were estimated by LSD. For identifying of links between two linearly dependent variables, it is used correlation coefficient. Positive correlation ranges were between 0 and +1 and negative from 0 to -1.

RESULTS AND DISCUSSION

The effect of genotype and year on the DMY, GY and chemical composition of maize grain is shown in Table 4. The genotype had a significant effect on the DMY, GY, GSC, GPC, SY and PY (Table 5). The year had a significant effect on the DMY, GY, GSC, GPC, SY and PY. The interaction genotype x year was significant for all traits, except for the GSC. MY in average for 2 years and six genotypes was 21.7 ton ha^{-1}. In 2006, average DMY was higher by 3 ton ha^{-1} (12.93%) then in 2007 (20.2 ton ha^{-1}). These higher DMY in 2006 primarily were associated with higher amount of precipitation during the summer months (June to August) than in 2007. Also, Zsubori *et al*. (2010) reported in wetter years the genotypes were taller and had greater DMY per plant than in the dry year. Genotypes significantly differed in regard to DMY. These results are in agreement with research of Kamalak *et al*. (2003). DMY varied between 17.8 ton ha^{-1}(NS 444 ultra) and 24.0 ton ha^{-1} (NS 6010). Interaction between genotype and year was significant. Average GY for years and genotypes was 10612 kg ha^{-1}. GY of maize was under the influence of weather conditions, especially precipitation and temperature regimes. In 2007, average GY was significantly lower 2511 kg ha^{-1} (21.16%) then in 2006 (11867 kg ha^{-1}). In 2006, there was more favorable rainfall regime then in 2007. Drought and high air-temperature stresses in summer months are in close connection with the lower GY (Kovacevic *et al*., 2009; Randjelovic *et al*., 2010). Naderi *et al*. (2009) reported that water deficit stress decreased GY 12.75% in stage V8, 16.3% in stage of blister and 33% in stage of grain filling. In average for both years, genotype NS 6010 produced maximal GY (12695 kg ha^{-1}) while genotype Dunav minimal (9375 kg ha^{-1}). Interaction between genotype and year

Table 4: Dry Matter Yield (DMY), Grain Yield (GY), Grain Starch Content (GSC), Grain Protein Content (GPC), Starch Yield (SY) and Protein Yield (PY) in studied maize genotype

		Genotype (B)						
Traits	Years (A)	ZP 434	NS 444 ultra	ZP 684	NS 6010	ZP 735	Dunav	M
DMY ton ha^{-1}	2006	18.90	18.60	24.90	25.30	25.60	25.90	23.20
	2007	17.30	16.90	21.50	22.60	21.90	20.90	20.20
	M	18.10	17.80	23.20	24.00	23.80	23.40	21.70
GY kg ha^{-1}	2006	11248.00	11788.00	13115.00	14590.00	10610.00	9850.00	11867.00
	2007	9587.00	8200.00	9700.00	10800.00	8950.00	8900.00	9356.00
	M	10418.00	9994.00	11408.00	12695.00	9780.00	9375.00	10612.00
GSC %	2006	71.36	72.33	71.48	70.89	70.02	70.00	71.01
	2007	70.55	71.92	70.88	69.99	69.30	69.22	70.31
	M	70.96	72.12	71.18	70.44	69.66	69.61	70.66
GPC %	2006	9.54	9.88	9.66	10.47	10.85	10.91	10.22
	2007	9.67	8.69	9.32	10.02	10.63	10.75	9.85
	M	9.61	9.29	9.49	10.25	10.74	10.83	10.04
SY kg ha^{-1}	2006	8026.90	8522.40	9374.50	10343.70	7429.40	6952.00	8441.50
	2007	6767.10	5895.80	6875.70	7559.80	6202.10	6159.70	6576.70
	M	7397.00	7209.10	8125.10	8951.80	6815.80	6555.90	7509.10
PY kg ha^{-1}	2006	1053.40	1057.70	1201.70	1291.10	1024.20	989.10	1102.90
	2007	981.70	792.40	1029.70	1160.60	834.70	937.40	956.10
	M	1017.60	925.00	1115.70	1225.90	929.40	963.20	1029.50

	Dry matter yield			Grain yield			Grain starch content		
LSD (%)	A	B	A*B	A	B	A*B	A	B	A*B
5	0.1794	0.3108	0.4459	258.04	446.94	641.24	0.2707	0.4689	0.6726
1	0.2410	0.4175	0.6042	346.67	600.45	868.96	0.3636	0.6298	0.9114
	Grain protein content			Starch yield			Protein yield		
5	0.3661	0.6340	0.9097	193.21	334.65	480.12	37.45	64.87	93.07
1	0.4918	0.8518	1.2327	259.57	449.58	650.63	50.32	87.15	126.12

Table 5: Combined analysis of variance for dry matter yield, grain yield and grain quality traits of maize genotypes

Source of variation	Dry matter yield	Grain yield	Grain starch content	Grain protein content	Starch yield	Protein yield
Genotype (G)	***	***	***	*	***	***
Year (Y)	***	***	***	***	***	***
G×Y	***	***	NS	**	***	*

NS = Not Significant; *Significant at p = 0.05; **Significant at p = 0.01; ***Significant at p = 0.001

Table 6: Correlation coefficients (r) between dry matter yield, grain yield, grain protein and grain starch contents, protein and starch yields

Traits	Grain yield	Dry matter yield	Grain starch content	Grain protein content	Starch yield
Dry matter yield	+0.442	-	-	-	-
Grain starch content	+0.337	-0.367	-	-	-
Grain protein content	-0.581	-0.123	-0.452	-	-
Starch yield	+0.997	+0.406	+0.401	-0.601	-
Protein yield	+0.857	+0.462	+0.131	+0.100	+0.841

was significant. Starch is the largest single components in maize grain and the primary energy source. Average GSC for 2 years and six genotypes was 70.66%. Synthesis of starch in maize grain was higher in 2006 (71.01%) than in 2007 (70.31%).

The genotypes had a significant effect on the GSC. These results are in agreement with researches of Miao *et al.* (2006), Harrelson *et al.* (2008) and Idikut *et al.* (2009). The GSC ranged from 69.61% (Dunav) to 72.12% (NS 444 ultra). Idikut *et al.* (2009) found that GSC ranged from 69.29-73.71%.

Average GPC, 4 years and genotypes was 10.04%. As the year effect on GPC of maize was significant, higher GPC was recorded in 2006 (10.22%) than 2007 (9.85%). Also, Fabijanac *et al.* (2006) reported significant variation in GPC across years. Values for GPC ranged from 9.29-10.83%.

It is evident that Dunav had maximum GPC and NS 444 ultra had the lowest GPC of all the genotypes. Genotypes ZP 434 and ZP 684 showed non-significant variation in comparison with NS 444 ultra. Genotypes NS 6010 and ZP 735 showed significant variation in comparison with NS 444 ultra. Saleem *et al.* (2008) and Idikut *et al.* (2009) were found that genotypes had a significant effect on the GPC. Fabijanac *et al.* (2006) identified that highest average GPC had genotype Bc 462 (115 g kg^{-1}) and in contrast, the two highest yielding genotypes (Zlatko and PR38F70) had significantly lower GPC than Bc 462.

SY in average for years and genotypes was 7509.1 kg ha^{-1}. High SY recorded in 2006 (8441.5 kg ha^{-1}) then 2007 (6576.7 kg ha^{-1}). Higher SY in 2006 primarily associated with higher GSC and GY than in 2007. In average for both years, the SY ranged from 6555.9 kg ha^{-1} (Dunav) to 8951.8 kg ha^{-1} (NS 6010). This is related to the fact that genotype NS 6010 produced the highest GY (12695 kg ha^{-1}) while the genotype Dunav produced the lowest GY (9375 kg ha^{-1}).

Paulsen *et al.* (2003) concluded that maize starch yield is affected by variety, environmental growing conditions and drying conditions. PY, in average for 2 years and six genotypes was 1029.5 kg ha^{-1}. In 2007, average PY was lower by 146.8 kg ha^{-1} (13.31%) then in 2006 (1102.9 kg ha^{-1}). Higher PY in 2006 primarily associated with higher GPC and GY than in 2007. Fabijanac *et al.* (2006) concluded that growing season showed significant effect on PY. PY ranged from 963.2 kg ha^{-1} (Dunav) to 1225.9 kg ha^{-1} (NS 6010). Despite having the highest GPC, a check genotype Dunav failed to produce the largest PY due to its relatively low grain yield potentials.

Idikut *et al.* (2009) found that the PY for maize ranged from 1065.9-1249.0 kg ha^{-1}. Correlation coefficients showed medium positive correlation between GY and DMY (r = +0.442) and GY and GSC (r = +0.337), Table 6. Iptas and Yavuz (2008) concluded in their investigation that the GY is in strong correlation with DMY (r = +0.83). Many researchers found medium and positive correlation between GY and GSC (Fabijanac *et al*., 2006; Saleem *et al*., 2008; Idikut *et al*., 2009).

GY was negatively and significantly correlated with GPC (r = -0.581). The results showed that an increase in GPC may decrease GY. The results are in accordance with Idikut *et al*. (2009) and Saleem *et al*. (2008). GY was in very strong positive correlation with SY (r = +0.997) and PY (r = +0.857). DMY was in negative medium correlation with GSC (r = -0.367) and weak negative correlation with GPC (r = -0.123). DMY was in medium positive correlation with SY (r = +0.406) and PY (r = +0.462).

GSC was in medium negative correlation with GPC (r = -0.452), medium positive correlation with SY (r = +0.401) and low positive correlation with PY (r = +0.131). Harrelson *et al.* (2008) found a significant negative relationship (r = -0.41) between GSC and PY. The CPC decreased with increasing GSC. Negative correlation between GSC and GPC has been reported by Idikut *et al.* (2009) and Fabijanac *et al.* (2006). GPC was in medium negative correlation with SY (r = -0.601) and low positive correlation with PY (r = +0.10). Also, Idikut *et al.* (2009) found medium negative relationships between GPC and SY. SY was in strong positive correlation with PY (r = +841).

CONCLUSION

The genotype and year had a significant effect on the dry matter yield, grain yield, grain starch content, grain protein content, starch yield and protein yield. All traits had higher values in 2006, primarily associated with higher amount of precipitation and lower medium monthly temperatures during the summer months (June to August) than in 2007. The grain protein content decreased with increasing grain starch content and grain yield. The inverse relationship between grain yield and grain protein content may prevent breeders from improving these two traits simultaneously. When choosing genotypes, it is necessary to take into account the inverse relationship between these two traits in order to obtain, a high grain yield of good quality.

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