

Effects of Precipitation and Temperature Regimes on Maize (*Zea mays L.*) Yields in Northwestern Croatia

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Abstract: Maize growing in Croatia is characterized by considerable yield variations among years. For example, during 1998-2007 annual yields of maize ranged from 3.93 t/ha to 6.92 t/ha. In general, the higher quantities and uniformly distributed precipitation coupled with lower air temperatures during the summer months were more favorable for maize as compared to lower precipitation and higher temperatures. The majority of maize acreage is located in the Pannonian region (eastern and northwestern Croatia) which occupies nearly 50% of the state territory and as low as 4 % of maize cultivated area is situated in the remaining part of Croatia. This study provides an overview of maize yields and cultivated areas in seven counties of northwestern (NW) Croatia for the 3-year period 2005-2007, along with weather data (precipitation and air temperatures: the data of the Sisak, Bjelovar and Zagreb Weather Bureaus). The region of NW Croatia occupies about 27 % of the state territory and accounts for 50 % of maize harvested area. Annual maize yields during the three years ranged from 5.18 to 6.78 t/ha. The growing season of 2007 was unfavorable for maize cultivation mainly due to drought and high temperatures. For example, according to the data of the Sisak Weather Bureau, the amount of precipitation for the three-month period (June-August) was only 100 mm or 60% lower than the long-term mean (LTM: 1961-1990) and the air temperature was 2.7 °C higher. During the same period of the remaining two years of study, precipitation was 26% (2005) and 34% (2006) higher than LTM. As a results of these favorable conditions, maize yields in NW Croatia were 30% (2005) and 25% (2006) higher than those during the unfavorable 2007 growing season (5.18 t/ha). Adequate soil management practices, especially fertilization and liming of acid soil, can alleviate consequences of drought and high temperature for maize yields.

Key words: precipitation, temperature, maize yield, Croatia.

Introduction

Maize growing in Croatia is characterized by high yield variations among years despite similar soil and crop management practices used. For example, in 1998-2007, annual maize yield variation ranged from 3.93 t/ha to 6.92 t/ha. In general, higher and well-distributed precipitations as well as lower air temperatures during the three summer months (June-August) were more favorable for maize (Kovačević *et al.*, 1994, 2009a, 2009b, Kovačević and Josipović 2005, Josipović *et al.* 2005, Šoštarić and Josipović 2006). The majority of maize acreage in Croatia is distributed in the Pannonian region (eastern and northwestern part of the country). The region is divided into 12 counties (5 located in the eastern part and 7 in the northwestern part), accounting for 48.8 % of the state territory. However, only 4 % of maize growing area is distributed in the remaining 52.2 % of Croatia (upland and mediteranean regions). The objective of this study was to evaluate the effect of precipitation and temperature regimes on maize yields in northwestern (NW) Croatia for the 3-year period 2005-2007.

Material and Methods

Data from the State Institute of Statistics (statistical yearbooks: maize yield, production and harvested areas) and the State Hydrometeorological Institute (precipitation and air temperature) were used for the study. The rain factor (RFm) was calculated monthly as a quotient of precipitation (mm) and mean air temperatures (°C) according to Gračanin (1950).

Northwestern (NW) Croatia (total area: 15136 km² or 26.8% of the state territory) includes seven counties (c), including: Bjelovar-Bilogora (BBc: 2640 km²), Sisak-Moslavina (SMc: 4468 km²), Koprivnica-Krizevci (KKc: 1748 km²), Zagreb (ZGc: 3060 km²), Varazdin (VZc: 1262 km²), Krapina-Zagorje (KZc: 1229 km²) and Medjimurje (MEc: 729 km²). It occupies the western part of the Pannonian region of Croatia characterized by continental temperate and mid-European climate with four clearly differentiated seasons. In general, major soil types found in NW Croatia are albic luvisol, haplic stagnosol, eutric and dystic planosol, and aric anthrosol (Škorić *et al.* 1985, Kovačević and Bašić 1997).

Results and Discussion

Maize is the first-raking field crop in Croatia. During the last 3-year period (2005-2007), it was grown on 301174 ha/year or 36% of arable land in the country. The region of NW Croatia accounts for about 50% (mean 2005-2007: 149967 ha or 49.8%) of maize growing area of the country (Table 1). Maize growing in NW Croatia is characterized by high yield variations among years. For example, during the three-year period, maize yield ranged from 5.18 to 6.78 t/ha (Table 1), mainly due to the effect of weather (Table 2).

Tab. 1. Harvested area, production and grain yield of maize

County*	Harvested area (ha), production (t) and grain yield (t/ha) of maize								
	2005			2006			2007		
	ha	t	t/ha	ha	t	t/ha	ha	t	t/ha
	Republic of Croatia								
	318891	2206729	6.92	296251	1934517	6.53	288380	1424599	4.94
	Northwestern (NW) Croatia								
Bjel.-Bilog.	34917	259783	7.44	38375	282442	7.36	32751	159171	4.86
Sisak-Mosl.	23582	153525	6.51	22822	140358	6.15	21298	112241	5.27
Kopr.-Kriz.	32472	231531	7.13	29367	191473	6.52	30640	157796	5.15
Zagreb	27812	164095	5.90	20618	117527	5.70	22063	125763	5.70
Varazdin	16355	108600	6.64	15576	95950	6.16	16175	68583	4.24
Krap.-Zagor.	8654	40938	4.73	8055	33189	4.12	9166	41342	4.51
Medijmurje	13869	110398	7.96	12963	98135	7.57	12372	84012	6.79
NW Region	157661	1068870	6.78	147776	959074	6.50	144465	748908	5.18
Region	Distribution of maize harvested areas(ha) and production (t) in the regions								
	ha	t		ha	t		ha	t	
NW Region	157661	1068870		147776	959074		144465	748908	
Eastern Reg.	148438	1080595		136712	922430		134327	633991	
Rest	12792	57264		11763	53013		9588	41700	
	Arable land capacities (ha) and percentage of maize growing area in Croatia								
Croatia	848620 ha			856249 ha			830088 ha		
	37.6 % of arable land			34.6 % of arable land			34.5 % of arable land		

* Bjelovar-Bilogora, Sisak-Moslavina, Koprivnica-Krizevci, Zagreb, Varazdin, Krapina-Zagorje and Medijimurje Counties.

Tab. 2. Precipitation and mean air temperatures in three towns of NW Croatia

Sisak (SI), Bjelovar (BJ) and Zagreb (ZG) Weather Bureaus data (LTM = long-term means 1961-1990 for Sisak)										LTM Sisak
Month	2005			2006			2007			
	SI	BJ	ZG	SI	BJ	ZG	SI	BJ	ZG	
	Precipitation (mm)									
a) June	32	82	69	63	46	40	43	60	97	91
b) July	104	123	137	73	21	32	27	50	49	77
c) Aug.	182	141	175	202	144	178	55	60	102	85
Σ	318	346	381	338	211	461	100	170	248	253
a+b+c	SI+BJ+ZG = 348 mm			SI+BJ+ZG =337 mm			SI+BJ+ZG = 173 mm			
	Mean air temperature (°C)									°C
a) June	20.1	19.7	19.9	20.5	20.3	20.5	22.5	22.4	22.2	19.1
b) July	21.7	21.4	21.5	23.3	24.0	23.8	23.5	23.2	22.9	20.8
c) Aug.	19.0	19.0	18.9	19.2	19.0	18.9	21.7	21.6	21.3	19.8
X	20.3	20.0	20.1	21.0	21.1	21.1	22.6	22.4	22.1	19.9
a+b+c	SI+BJ+ZG = 20.1 °C			SI+BJ+ZG = 21.1°C			SI+BJ+ZG = 22.4°C			
	Rain factor (RFm) by Gračanin*: precipitation (mm) / mean air temp. (°C)									
June	1.6a	4.2sa	3.5sa	3.1a	2.3a	2.0a	1.9pa	2.7a	4.4sa	
July	4.8sa	5.7sh	6.4sh	3.1a	0.9pa	1.3pa	1.1pa	2.1a	2.1a	
August	9.6h	7.4h	9.2h	10.5h	7.6h	9.4h	2.5a	2.8a	4.8sa	
	* a = arid; h=humid; sa=semiarid; sh=semihumid; pa=perarid; ph=perhumid									

The 2007 growing season was unfavorable for maize cultivation due to mostly arid and perarid conditions. For example, precipitation in Sisak for the three-month period June-August was only 100 mm or 60% lower as compared to the 30-year mean (LTM). At the same time, air temperature was 2.7 °C higher. During the same period of the remaining two growing seasons, precipitation in Sisak was 26 % (2005) and 34% (2006) higher, whereas air temperatures were close to LTM in both years. As a result of mainly favorable weather conditions, maize yields in the region were 30% (2005) and 25% higher (2006) than under unfavorable conditions of 2007 (Table 1).

Tab. 3. Response of maize to liming (Antunović 2008)

Year	Carbocalk Nov. 2000 t/ha (B)					X	Virovitica: Weather characteristics*					
(A)	0	15	30	45	60	(A)	June		July		August	
	Maize yield (t/ha)						mm	°C	mm	°C	mm	°C
2001	7.36	10.2	10.3	11.2	10.3	9.87	128	18.3	81	21.8	15	22.1
2002	9.89	10.5	10.7	11.2	12.5	10.9	53	21.6	90	22.4	92	20.8
2003	4.42	5.14	5.81	6.63	5.53	5.51	81	23.9	48	22.8	24	24.4
2005	7.48	7.96	7.66	7.80	8.00	7.78	59	19.7	165	21.3	178	18.9
X B	7.29	8.46	8.62	9.20	9.08	8.53	Mean 1971-1990					
							87	76	91	18.3	20.6	19.6
LSD 5%	A: 0.33		B: 0.38		AB: 0.77		*Precipitation (mm) and mean air temp. (°C)					
LSD 1%	0.47		0.50		1.01							

Tab. 4. Response of maize to fertilization in Bjelovar-Bilogora County
(Kovačević *et al.* 2008)

Maslenjaca experiment close to Daruvar										
Fertilization (kg/ha)*			Maize yield (t/ha)* and realized plant density (RPD) in % of planned (PD)							
			2003		2004		2005		2006	
	P ₂ O ₅	K ₂ O	t/ha	RPD	t/ha	RPD	t/ha	RPD	t/ha	RPD
a	125	125	7.37	63.6	13.33	91.4	10.71	94.9	8.70	73.7
b	375	125	7.44	57.5	13.33	93.0	11.11	95.4	9.66	72.4
c	625	125	7.57	56.5	13.70	94.5	11.09	92.1	9.64	75.0
d	825	125	8.07	60.6	13.76	95.4	12.23	95.4	10.10	70.6
e	125	625	7.21	64.2	14.28	93.0	12.10	94.0	9.57	72.4
f	625	625	8.46	65.6	14.07	96.0	12.51	93.0	9.55	70.0
Average			7.69	61.3	13.75	93.9	11.63	94.1	9.70	72.4
LSD 5%			0.46		0.50		0.82		0.77	
PD plants/ha				51948		58333		62111		54945
Daruvar*: Precipitation (mm) and mean air temperature (°C)										
June-August			mm	°C	mm	°C	mm	°C	mm	°C
			120	23.2	225	19.8	317	19.4	274	20.1
* 12 km from the trial			LTM (1961-1990)						270	19.7

* in spring 2003; ordinary fertilization (level a) of all treatments for the 2004-2006 period.

Conclusions

Weather characteristics, especially precipitation and temperature regimes, have an important role in maize yield formations under environmental conditions of NW Croatia. In this respect, drought coupled with high air temperatures are seen as important factors limiting maize yields. Soil management practices focusing on fertilization and liming of acid soil can be used to alleviate the negative effects of weather conditions on maize yields.

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UTICAJ PADAVINA I TEMPERATURNOG REŽIMA NA PRINOS KUKURUZA (*Zea mays* L.) U SEVEROZAPADNOJ HRVATSKOJ

- originalni naučni rad -

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Rezime

Proizvodnju kukuruza na oranicama Hrvatske karakterišu velika variranja prinosa po godinama. Tako u periodu od deset godina (1998.-2007.) prosečni prinosi kukuruza bili su u rasponu od 3.93 t/ha do 6.92 t/ha. Uopšteno, veće količine dobro raspoređenih padavina i niže temperature vazduha tokom letnjih meseci su povoljnije za kukuruz od manjka padavina i visokih temperatura. Većina površina pod kukuruzom nalazi se u Panonskoj regiji (istočna i severozapadna Hrvatska), koja zauzima blizu 50% državne teritorije, a samo 4% površine pod kukuruzom se nalazi u preostalom delu Hrvatske. U ovom radu, daje se pregled prinosa, proizvodnje i površina pod kukuruzom u sedam županija severozapadne (SZ) Hrvatske za trogodišnje razdoblje 2005.-2007. godine, i meteorološki podaci (padavine i temperature vazduha za Sisak, Bjelovar i Zagreb). Regija SZ Hrvatska zauzima oko 27% državne teritorije i učestvuje blizu 50% u požeitim površinama pod kukuruzom. U tri analizirane godine, godišnji prinos kukuruza u regiji varirao je od 5,18 do 6,78 t/ha. Vegetacija 2007. godine bila je nepovoljna za kukuruz uglavnom zbog suše i visokih temperatura. Tako je u Sisku za tri meseca (jun-avgust) palo samo 100 mm kiše ili 60% manje od višegodišnjeg (1961.-1990.) proseka, a istovremeno su temperature vazduha bile više za 2.7°C. U istom periodu, u preostale dve godine, bilo je za 26% (2005.g) i za 34% (2006.g) više padavina od višegodišnjeg proseka. Kao rezultat takvih okolnosti su viši prinosi kukuruza u regiji za 30% (2005.g), odnosno za 25% (2006.g) nego u nepovoljnoj 2007. (5,18 t/ha) godini. Odgovarajućom agrotehnikom, prvenstveno đubrenjem i kalcizacijom kiselih zemljišta, moguće je ublažiti posledice suše i visokih temperatura na prinose kukuruza.