PRECIPITATION AND TEMPERATURE REGIME IMPACTS ON MAIZE YIELDS IN EASTERN CROATIA

UTJECAJ OBORINSKOG I TEMPERATURNOG REZIMA NA PRINOSE KUKURUZA U ISTOČNOJ HRVATSKOJ

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Abstract: *In the decade period 1998-2007 maize harvested area in Croatia was, depending on year, from 288380 ha to 407272 ha while annual yield variation was in range from 3.93 t/ha to 6.92 t/ha. The region eastern Croatia represents 22 % of the state territory, it participating in maize harvested area near to 50 % and maize yield in this region is near to 20% higher compared to the state level. Mean air-temperature in Osijek for May-August period (the decade 1998-2007) was 20.7 ^oC or for 1.5 ^oC higher compared to 30-year (1961-1990) mean. At the same time, precipitation was for 9% higher. Depending on year, precipitation in May-Aug. period were in range from 104 mm to 567 mm and air-temperatures from 19.1 ^oC to 22.5 ^oC or from –61% to +110% (precipitation) and from -2 % to +17% (air-temperature) deviation from 30-year means. The growing seasons 2000, 2003 and 2007 were less favourable for maize because of drought and the higher air-temperatures. For example, in the period May-August precipitation in Osijek were for 61 % (2000), 39 % (2003) and 40 % (2007) lower (2003) in comparison with 30-year mean. At the same time, air-temperatures were for 2.3 ^oC, (2000 and 2007) and for 3.2 ^oC (2003) higher. Under these conditions, maize yields in the region were lower for 28% (2000), 25% (2003) and 18% (2007) compared to the decade mean (6.01 t/ha).*

Sažetak: *U dekadi 1998.-2007. požnjeveno je u Hrvatskoj, ovisno o godini, od 288380 ha do 407272 ha kukuruza, a prosječni prinosi bili u rasponu od 3,93 do 6,92 t/ha. Regija istočna Hrvatska čini 22% državnog teritorija, njen udjel u žetvenim površinama kukuruza je blizu 50%, a prinosi su blizu 20% veći od državnog prosjeka. Srednje temperature zraka u Osijeku za svibanj-kolovoz u razdoblju 1998-2007 bile su 20.7 ^oC ili za 1.5^oC toplije od prosjeka (1961-1990). Istovremeno, oborina je bilo za 9% više. Ovisno o godini, oborine u analiziranom razdoblju bile su u rasponu od 104 mm do 567 mm, a srednje temperature zraka od 19.1 ^oC do 22.5 ^oC, odnosno odstupanje od prosjeka od –61% do +110% (oborine) i od -2 % do +17% (temp.). Godine 2000., 2003. i 2007 bile su manje povoljne za uzgoj kukuruza zbog suše i visokih temperatura. Tako je u Osijeku (svibanj-kolovoz) bilo oborina manje za 61% (2000.), 39% (2003.) i 40% (2007.) od prosjeka, a temperature zraka bile su za 2.3 ^oC, (2000. i 2007.) i za 3.2 ^oC (2003.) više. U takvim uvjetima su u istočnoj Hrvatskoj ostvareni niži prinosi kukuruza za 28% (2000.), 25% (2003.) i 18 % (2007.) prema dekadnom prosjeku (6.01 t/ha).*

Key words: *precipitation, air-temperature, yield, maize, Croatia*
Ključne riječi: *oborine, temperature zraka, prinos, kukuruz, Hrvatska*

INTRODUCTION

Maize is the most widespread crop on arable lands in Croatia. In the recent 3-year period (2005-2007) mean maize harvested area was 309802 ha/year or near 30% of total arable lands of the country. Aim of this study was testing yield variations of maize in the eastern Croatia with emphasis on weather characteristic influences. Some aspects of these effects were elaborated in the previous studies (JOSIPOVIC et al., 2005; KOVACEVIC and

JOSIPOVIC, 2005; KOVACEVIC et al., 1994, 2009; SOSTARIC and JOSIPOVIC, 2006) and these findings are mainly in accordance with experiences from USA Corn Belt (SHAW, 1988).

MATERIAL AND METHODS

Source of the data and description of the area

The Statistical Yearbooks were source of maize yield data. Source of meteorological data (precipitation and mean air-temperatures) was State Hydrometeorological Institute in Zagreb. Rain factor (RFm) was calculated monthly as quotient of precipitation (mm) and mean air-temperatures (°C) according Gracanin (1950).

Since 1992, according to the new territorial division eastern Croatia includes five counties (c) as follows (total area: 12454 km^2): Vukovar-Sirmium (VSc), Osijek-Baranya (OBc), Brod-Posavina (BPc), Pozega-Slavonia (PSc) and Virovitica-Podravina (VPc) County.

Soil characteristics of the Eastern Croatia

Pedologic characteristics of the Eastern Croatia elaborated in detail by JANEKOVIC (1971), SKORIC et al (1985). Pleistocene terrace and plateaus of the eastern Croatia there is a succession of climatozonal soil complexes. From east to west there is a zonal decrease in soil fertility. As the physical and chemical soil properties deteriorate, the soil profile is increasingly impaired. Eutric cambisol is dominant soil type in the eastern part of the region (for example VSc), while in its western part (for example VPc) pseudoglay and similar soil types are dominant (Fig. 1).

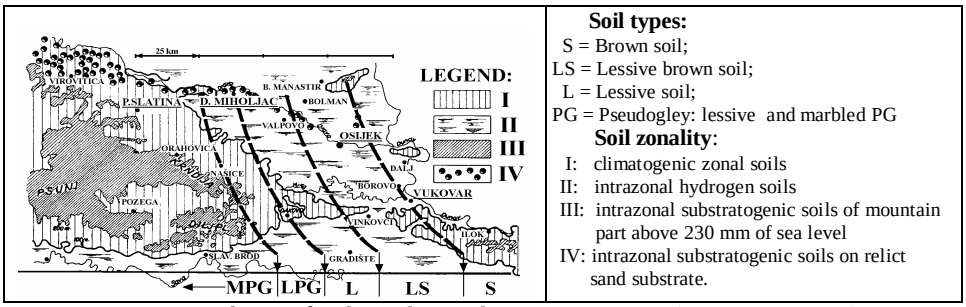

Figure 1. Scheme of soil zonality in the Eastern Croatia (JANEKOVIC 1971)

RESULTS AND DISCUSSION

In the decade period 1998-2007 maize harvested area in Croatia was, depending on year, from 288380 ha to 407272 ha while annualy yield variation was in wide range from 3.93 t/ha o 6.92 t/ha. Although the region eastern Croatia represents 22 % of the state territory it participating in maize harvested area near to 50 %. In general, maize yield in this region is near to 20% higher compared to the state level and yield variation among year has similar trend (Table 1). Also, maize yield in Vukovar-Syrmium County was higher (mean 6.56 t/ha) than in remaining four counties (means from 5.56 to 5.72 t/ha) of the region (Table 1) mainly as result prevailing of more fertile soils (Fig. 1).

Mean air-temperature in Osijek for May-August period for the decade 1998-2007 was 20.7 ^oC or for 1.5 ^oC higher compared to 30-year mean. At the same time, precipitation was for 9 % higher. Depending on year, precipitation in tested period were in range from 104 mm to 567 mm and air-temperatures from 19.1 ^oC to 22.5 ^oC or from –61% 39% to +110% (precipitation) and from -2 % to +17% (air-temperature) deviated from 30-year (1961-1990) means. These conditions had correspondingly effects on maize yields in the region.

The growing seasons 2000, 2003 and 2007 were less favourable for maize growing. For example, in the period May-August precipitation in Osijek was for 61 % (2000), 39 % (2003) and 40 % (2007) lower (2003) in comparison with 30-year mean. At the same time, air-temperatures were higher for 2.3 ^{o}C, (2000 and 2007) and for 3.2 ^{o}C (2003). Under these conditions, maize yields in the region were lower for 28% (2000), 25% (2003) and 18% (2007) compared to the decade mean. Perarid and arid conditions in the period May-August (Table 2) of less favorable years were main responsible factors of lower maize yields. However, the growing seasons 2002, 2005 and 2006 characterized more favorable weather conditions with aspects of maize growing. For this reason, maize yield was for 20% (2002 and 2005) and 12% (2006) higher compared to the decade mean (Table 2).

Table 1.

The harvested areas and yields of maize in five counties of eastern Croatia for the 1998 to 2007 period (State Bureau for Statistics in Zagreb)

County*	Maize harvested areas, yields and weather conditions in the 1998-2007 period										Mean
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
	The harvested areas of maize (ha) in eastern Croatia; 98-07 = 10-year means 1998-2007										98-07
VU-Syr.	43170	46411	48525	52633	48681	44646	data	32670	26990	30263	**41554**
OS-Bar.	63852	68826	68430	70649	70696	73562	not	55197	56513	53292	**64557**
BR-Pos.	22048	20977	22810	24615	25642	24210	availa	19281	17613	16667	**21540**
PZ-Slav.	14730	13777	13648	14137	13891	12841	ble	14674	11379	11026	**13345**
VR-Podr	26135	27362	26769	28102	28792	31859		27884	24220	23085	**27134**
Σ Region	**169935**	**177353**	**180182**	**190136**	**187702**	**187118**		**149706**	**136715**	**134333**	**168130**
Σ Croatia	**374531**	**384184**	**388639**	**405910**	**407272**	**405947**		**318891**	**322134**	**288380**	**366595**
	Maize yield (t/ha) of maize in eastern Croatia; 98-07 = 10-year means 1998-2007										**98-07**
VU-Syr.	6.49	7.29	4.72	7.37	6.82	5.15	data	8.38	7.44	5.39	**6.56**
OS-Bar.	6.53	6.60	3.96	6.79	7.50	4.32	not	6.98	6.94	4.85	**5.72**
BR-Pos.	5.48	5.62	4.30	5.77	6.42	3.98	availa	7.16	6.73	4.61	**5.56**
PZ-Slav.	5.59	5.97	4.67	5.94	6.46	4.53	ble	7.43	6.55	4.34	**5.72**
VR-Podr	5.88	5.82	4.30	5.94	7.67	4.57		6.59	5.63	3.80	**5.58**
X Region	**6.20**	**6.50**	**4.31**	**6.63**	**7.21**	**4.53**		**7.22**	**6.75**	**4.72**	**6.01**
X Croatia	**5.25**	**5.56**	**3.93**	**5.45**	**6.14**	**3.86**		**6.92**	**6.53**	**4.94**	**5.06**

* Vukovar-Syrmium (VU-Syr.), Osijek-Barannya (OS-Bar.), Brod-Posavina (BR-Pos.), Pozega-Slavonia (PZ-Slav.) and Virovitica-Podravina (VR-Podr.) County

Table 2

Precipitation and mean air-temperatures (Osijek Weather Bureau) for the 1998-2007 decade period and comparison with 1961-1990 means (State Hydrometeorological Institute in Zagreb)

OSIJEK: The growing season (98-07 = the decade means; 61-90 = 30-year means 1961-1990)											Averages	
Month	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	**98-07**	**61-90**
	Precipitation (mm)											
May	49	89	26	60	135	18	65	46	79	56	**62**	**58**
June	26	150	10	240	36	44	77	112	91	33	**82**	**88**
July	84	95	63	77	59	61	43	171	15	27	**70**	**65**
Aug.	99	74	5	7	77	41	96	238	133	45	**81**	**59**
Total	**258**	**408**	**104**	**385**	**307**	**164**	**281**	**567**	**318**	**161**	**295**	**270**
	Mean air-temperature (^{o}C)											
May	16.2	17.3	18.4	18.4	18.6	20.1	17.0	16.2	18.2	18.1	**17.9**	**16.5**
June	21.4	20.3	22.5	18.1	21.1	24.3	19.2	19.5	20.1	22.3	**20.9**	**19.5**
July	22.2	21.9	21.7	21.6	22.3	22.1	21.5	21.5	23.5	23.9	**22.2**	**21.0**
Aug.	21.8	21.3	23.7	22.7	20.9	23.6	21.0	19.3	19.3	22.2	**21.6**	**20.3**
Mean	**20.4**	**20.2**	**21.6**	**20.2**	**20.7**	**22.5**	**19.7**	**19.1**	**20.3**	**21.6**	**20.7**	**19.3**
	Rain factor (RFm) by Gracanin* RFm = precipitation (mm) **/ mean air-temp.** (^{o}C)										*a=arid, h=humid	
May	3.1a	5.2sh	1.4pa	3.3a	7.3h	0.9pa	3.8sa	2.8a	4.3sa	3.1a	sa = semiarid	
June	1.2pa	7.4h	0.4pa	13.3ph	1.7a	1.8a	3.9sa	5.7sh	4.5sa	1.5pa	sh = semihumid	
July	3.8sa	4.3sa	2.9a	3.6sa	2.6a	2.9a	2a	7.9h	0.6pa	1.2pa	pa = perarid	
Aug.	4.5sa	3.5sa	0.2pa	0.3pa	3.7sa	1.7a	4.6sa	12.3h	6.9h	2.1a	ph = perhumid	

KOVACEVIC et al. (1994) showed results of maize production in Croatia in the 1960-1989 period. Mean harvested area of maize was 509068 ha/year. Mean grain yield 3.81 t/ha and variation of annual yields was from 2.45 to 5.33 t/ha. Maize yield in Vukovar municipality (now part of Vukovar-Syrmium County) was 6.00 t/ha, while in Podr. Slatina municipality (now Slatina and part of Virovitica-Podravina County) it was 4.13 t/ha or 31% lower. Difference of precipitation quantities for 1961-1990 (Kovacevic et al., 1994) and 1996-2007 periods in eastern Croatia was low (225 mm and 240 mm, respectively) while air-temperature in the recent period was for 1.4 ^{o}C higher (KOVACEVIC et al., 2009). Similar trend of precipitation and temperature impacts on maize yields were found also under agroecological conditions in Hungary (KOVACEVIC et al., 2009) and Serbia (MAKLENOVIC et al., 2009).

PAVICIC et al. (2009) tested response of four maize hybrids (OsSK 373, OsSK 444, OsSK 552 and OsSK 602) under field conditions (three localities of the eastern Croatia: Vukovar, Osijek and Beli Manastir) during three growing seasons (2005-2007). Mean grain yields under drought stress in 2007 were 6.67 t/ha and it was for 37 % lower than in remaining two years. The OsSK444 and OsSK602 were more tolerant to drought stress in 2007 (yield decreasing for 31% compared to remaining two tested years) than OsSK552 (yield decreasing for even 46%).

CONCLUSIONS

Weather conditions, especially precipitation and temperature regimes, considerably influenced on maize yield in Croatia. With that regard, drought and high air-temperature stresses in summer months are in close connection with the lower grain yields. In the last decade period of 1998-2007, three growing seasons were especially unfavorable for maize growing and maize yield s under these conditions were from 18 % to 28% lower compared to the decade mean. Besides adequate soil and crop management practices, choice of more tolerant hybrids could be solution for alleviation of drought stress.

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