10.7251/AGSY1203081K
UDK 633.15-152(497.5)

PRECIPITATION AND TEMPERATURE REGIMES AND YIELD OF MAIZE IN CROATIA

Vlado KOVACEVIC[1*], Mirta RASTIJA[1], Marko JOSIPOVIC[2]

[1]University J. J. Strossmayer, Faculty of Agriculture, Croatia
[2]Agricultural Institute Osijek, Croatia.
(Corresponding author: vkovacevic@pfos.hr)

Abstract

Maize is main field crop on arable lands in Croatia. According data of State Bureau of Statistics, maize in the 2010 growing season was grown on 296195 ha or 22% of utilized arable land of the country. In the period 2001-2010 mean yield of maize in Croatia was 6.33 t ha^{-1} (mean harvested area 303946 ha) with variation among the years from 4.2 t ha^{-1} (2003) to 8.0 t ha^{-1} (2008). Weather characteristics, especially precipitation and temperature regimes, are mainly the most responsible factors for these yield differences. In general, the higher and good distributed precipitations as well as lower air-temperatures during three summer months (June-August) are mainly in connection with high yields of maize. The growing season 2003 was the most unfavorable for maize growing among ten tested years because precipitation in June-August period was for 30% lower (Osijek) and for 48% lower compared to 30-year average. At the same period, air-temperature was for 3 ^{o}C (Osijek) and even 4.7 ^{o}C (Zagreb) higher. This phenomenon is main reason for considerable yield reduction (mean yield 4.2 t ha^{-1}) in Croatia. In accordance with global climatic changes, frequency occurrence of „dry years“ (below 150 mm in June-August) has increasing trend.

Key words: *grain yield, maize, precipitation, air-temperature, Croatia*

Introduction

Weather characteristics, especially precipitation and temperature regimes, have considerable effects on yields of field crops. The influences of weather characteristics on maize plants start seven before sowing. The lower the soil-moisture reserve is in connection with the higher precipitation requirements in this crop-season. It is desirable that by preseason precipitation soil is supplied by water in level or above field water capacity, but without too much excess. In the early vegetative growth needs of maize for water are mainly moderate and cold weather decreasing growth rate. However, in the late vegetative stage, tasseling, silking and pollination, the relationships between weather and yield of maize are more marked (Shaw, 1988). The experiences from USA Corn Belt (Thompson, 1963) indicated low correlations between maize yield and both June temperature and June precipitation. However, optimum July precipitation is much above normal for the Corn Belt states. Also, August temperatures are higher than those associated with optimum maize yields in the Corn Belt. During the ear-filling stage, significant reduction in yield can occur from water shortage and the higher air-temperatures (Thompson, 1986). The higher and good distributed precipitations as well as lower air-temperatures during three summer months (June-August) and especially in July and August are in connection with high yields of maize in Croatia (Josipovic et al., 2005; Kovacevic and Josipovic, 2005; 2010b; Markulj et al., 2010). Also, similar effects of weather conditions on maize yields were found in Serbia (Jelic et al., 2009; Kovacevic et al., 2009a; Maklenovic et al., 2009) and Hungary (Kovacevic et al., 2009a, 209b). Aim of this

study was testing of precipitation and temperature regime status in three months period (June-August: Osijek Weather Bureau) and maize yields in Croatia for the 2000-2010 period.

Material and methods

For this study, the data from State Hydrometeorological Institute (precipitation and air-temperature: Osijek and Zagreb-Maksimir Weather Bureaues) and State Institute for Statistics (statistical yearbooks: maize yields) were used. Rain factor (RFm) was calculated monthly as quotient of precipitation (mm) and mean air-temperatures (°C) according Gracanin (1950).

Results and discussion

Maize is main field crop on arable lands in Croatia. According data of State Bureau of Statistics (SYB, 2011) utilized arable land area in Croatia (status 2010) was 1334825 ha with harvested areas of main field crops as follows: maize 296195 ha, wheat 168507 ha, soybean 56524 ha, barley 52524 ha, silage maize 30 145 ha, alfalfa-hay 27207 ha, sunflower 26412 ha and rape seed 16339 ha. Maize growing in Croatia is characterized with high yield variations among years. In the period 2001-2010 mean yield of maize in Croatia was 6.33 t ha^{-1} (303946 ha) with variation among the years from 4.2 t ha^{-1} (2003) to 8.0 t ha^{-1} (2008). Weather characteristics are mainly the most responsible factors for these yield differences.

Table 1. The harvested area, grain yield of maize in Croatia and meteorological data

Maize	Year (The Weather Bureaues: OS = Osijek; ZG =Zagreb-Maksimir)									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Harveted area (ha) and grain yield (t ha^{-1}) of maize in Croatia for 2001-2010 period									
ha	304035	305625	304762	319855	297692	290816	313125	313125	295000	295428
t ha^{-1}	5.7	6.4	4.2	6.3	6.9	6.5	4.9	8.0	7.4	7.0
	Precipitation (mm) in 3-month (June-August) period*									
OS	324	172	146	216	521	240	105	201	138	377
ZG	190	338	145	228	381	250	248	244	243	298
	Mean air-temperature (^{o}C) in 3-month (June-August) period*									
OS	20.8	21.4	23.3	20.6	20.1	21.0	22.8	21.7	21.8	22.2
ZG	20.9	21.3	24.0	20.4	20.1	21.1	22.1	21.4	21.6	21.5
* 30-year (1961-1990) averages: 211 (OS) and 278 (ZG) mm, 20.3 (OS) and 19.3 (ZG) ^{o}C										

Precipitation and air-temperature regimes in three summer months (June-August) are considerable factors of maize yields in Croatia. With that regard, the growing season 2003 was the most unfavorable for maize growing among ten tested years because precipitation in June-August period was for 30% lower (Osijek) and for 48% (Zagreb) lower in comparison with 30-year average. At the same period, air-temperature was for 3.0 ^{o}C (Osijek) and even 4.7 ^{o}C (Zagreb) higher. This phenomenon is main reason for considerable yield reduction (mean yield 4.2 t ha^{-1}). The growing season 2007 was also unfavorable for maize growing, especially in the eastern part of the country. For example, precipitation in June-August in Osijek was 50% lower and air-temperature for 2.5 ^{o}C higher from 30-year mean (Table 1).

Monthly distribution of precipitation and air-temperatures in Osijek and Zagreb (Table 2) were specific with high variations for the same month among different years. Excess of precipitation accompanied with cold weather in June and very low precipitation with the higher air-temperatures in August characterized 2001 growing season. Two growing seasons (2003 and 2007) were unfavorable for maize. For example, mean June temperature in Osijek was 24.3 ^{o}C or 4.8 ^{o}C and in August 23.6 ^{o}C or for 3.3 ^{o}C higher than LTM. August air-

temperature in Zagreb was 25.0 °C or even for 5.7 °C higher than LTM and this stress was accompanied with only 17 mm precipitation. The 2007 growing season was especially unfavorable for maize in the eastern part of Croatia. Adequate June and August precipitation and water deficit in July characterized the 2010 growing season. Monthly precipitation and temperature regimes in remaining tested years were less or more close to LTM.

Table 2. Precipitation and mean air-temperature in June-August period

Year	Osijek Weather Bureau						Zagreb-Maksimir Weather Bureau					
	June		July		August		June		July		August	
	Precipitation (mm) and mean air-temperature (°C): LTM = average 1961-1990											
	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C
2001	240	18.1	77	21.6	7	22.7	121	18.4	55	21.8	14	22.5
2002	36	21.1	59	22.3	77	20.9	71	21.1	124	21.9	143	20.8
2003	44	24.3	61	22.1	41	23.6	66	23.9	62	23.0	17	25.0
2004	77	19.2	43	21.5	96	21.0	102	19.1	70	21.1	56	21.0
2005	112	19.5	171	21.5	238	19.3	69	19.9	137	21.5	175	18.9
2006	91	20.1	15	23.5	134	19.3	40	20.5	32	23.8	178	18.9
2007	33	22.3	27	23.9	45	22.2	97	22.2	49	22.9	102	21.3
2008	76	21.5	79	21.8	46	21.8	103	20.9	86	21.9	55	21.4
2009	63	19.2	14	23.2	61	22.9	68	19.8	96	22.3	79	22.6
2010	234	20.4	32	23.2	111	21.7	104	20.4	53	23.2	141	20.8
Mean	101	20.6	58	22.5	86	21.5	84	20.6	77	22.3	96	21.3
LTM	88	19.5	65	21.1	58	20.3	100	18.5	83	20.1	95	19.3
	Rain factor (RFm): precipitation / mean air-temperature (Gracanin, 1950)											
	June		July		August		June		July		August	
2001	13.2 h		3.6 sa		0.3 a		6.6 h		2.5 a		0.6 a	
2002	1.7 a		2.6 a		3.7 sa		3.4 sa		5.7 sh		6.9 h	
2003	1.8 a		2.8 a		1.7 a		2.8 a		2.7 a		0.7 a	
2004	4.0 sa		2.0 a		4.6 sa		5.3 sh		3.3 sa		2.7 a	
2005	5.7 sh		8.0 h		12.3 h		3.5 sa		6.4 sh		9.2 h	
2006	4.5 sa		0.6 a		6.9 h		2.0 a		1.3 a		9.4 h	
2007	1.5 a		1.1 a		2.0 a		4.4 sa		2.1 a		4.8 sa	
2008	3.5 sa		3.6 sa		2.1 a		4.9 sa		3.9 sa		2.6 a	
2009	3.3 sa		0.6 a		2.7 a		3.4 sa		4.3 sa		3.5 sa	
2010	11.3 h		1.4 a		5.1 sh		5.1 sh		2.4 a		6.8 h	
Mean	4.9 sa		2.6 a		4.0 sa		4.1 sa		3.5 sa		4.5 sa	
LTM	4.5 sa		3.1 a		2.9 a		5.4 sh		4.1 sa		4.9 sa	

Legend: a = arid (<3.3), sa = semiarid (3.3-5), sh = semihumid (5-6.6), h = humid (6.6-13.3), ph = perhumid (>13.3)

Table 3. Response of maize to fertilization (Stojic et al., 2012)

Response of maize (2004-2011) to ameliorative fertilization (April 2004)								
Fertilization (2004)			Year (residual effects 2006-2011)					
	P_2O_5	K_2O	2004	2006	2008	2009	2011	Mean
	kg ha^{-1}		Grain yield of maize (t ha^{-1})					
a) STD*	0	0	12.28	10.37	10.93	9.00	7.58	10.03
b) a + P	1000	0	12.62	10.84	11.30	9.74	8.42	10.58
c) a + K	0	1000	12.73	10.58	11.36	9.78	8.42	10.57
d) a + PK	1000	1000	13.75	11.17	11.70	10.27	8.83	11.14
		$LSD_{0.05}$	0.52	0.64	0.50	0.49	1.02	
* P2K2 effects (STD = 100)			112	108	107	114	116	
* STD = basic (standard) fertilization in kg ha^{-1}: 160 N + 60 P_2O_5 + 80 K_2O								
Daruvar Weather Bureau (June-August period: 1961-90 = 30-year averages)								1961-90
Precipitation (mm)			225	274	314	169	205	276
Mean air-temperature (^oC)			19.8	20.1	20.7	20.8	21.2	19.7

RFm average values for 30-year period in Osijek characterizing semiarid climate in June and arid climate in July and August, while in Zagreb these values were in level of semihumid (June) and semiarid climate (July and August) and for this reason something more favorable for maize growing. However, for 2001-2010 decade period these values have tendency for increasing aridity degree. Especially unfavorable for maize growing was the growing season 2003 because rain factor in June-August period both in Osijek and Zagreb characterized arid climate (Table 3).

Kovacevic et al. (1994) reported survey of maize yields and precipitation regime in Slavonija and Barannya region for the 1960-1989 period. Average yield of maize in the region was 4.82 t ha^{-1} with yield variation among years from 2.74 to 7.08 t ha^{-1} (Croatia: 3.81 t ha^{-1} and from 2.45 to 5.33 t ha^{-1}). Precipitation quantities in June-August (Osijek) was 201 mm and variation among years from 138 to 460 mm and in eight year they were below 150 mm. The 2001-2010 period characterized by the higher precipitation (mean 244 mm), their higher variation among years from 105 to 521 mm and below 150 mm precipitation in three years (Table 1). However, by addition of the last two years 2011 and 2012 in consideration (precipitation in Osijek for June-August period: 129 and 120 mm, respectively), frequency of occurrence „dry years“ at beginning of 21 century have increasing trend.

Additional factor of relative low yields of maize and yield variation among years could be growing under soil conditions characterizing different soil fertility. By adequate soil and crop management practice is possible to alleviate detrimental effects of unfavorable weather conditions on field crops yields (Butorac 1999; Kovacevic, 2010a). Stojic et al. (2012) reported that by ameliorative fertilization with phosphorus and potassium were increased maize yields under drought stress of 2009 and 2011 for 14% and 16%, respectively (Table 3). Kovacevic et al. (2011) found effects of KCl fertilization and genotype on nutritional status and yield of maize, soybean and wheat.

Conclusion

Maize is main field crop on arable lands in Croatia. Weather characteristics, especially precipitation and temperature regimes, have considerable effects on yields of maize. In general, the higher and good distributed precipitations as well as lower air-temperatures during three summer months are in connection with the higher yields of maize. In accordance

with global climatic changes, frequency occurrence of „dry years“ (below 150 mm in June-August) has increasing trend.

References

Butorac A. (1999): Opca agronomija (General Agronomy), Školska knjiga Zagreb.

Gracanin M. (1950): Mjesecni kisni faktori i njihovo znacenje u pedoloskim istrazivanjima. Poljoprivredna znanstvena smotra 12, 51.

Jelic M., Kovacevic V., Djalovic I., Biberdzic M. (2009): Climate change influences on maize yields in Serbia and Croatia. University of Agricultural Sciences and Veterinary Medicine of the Banat Timisoara, Research Journal of Agricultural Science, 41 (1): 44-48.

Josipovic M., Kovacevic V., Petosic D., Sostaric J. (2005): Wheat and maize yield variations in the Brod-Posavina area. Cereal Research Communications, 33. (1): 229-233.

Kovacevic D. (2010a): Opste ratarstvo, II izdanje (General Crop Production, 2nd Edition) Univerzitet u Beogradu, Poljoprivredni fakultet Zemun.

Kovacevic V., Jolankai M., Birkas M., Loncaric Z., Sostaric J. (2009a): Influences of precipitation and temperature trend on maize yields. In: Proceedings of the XLIV Croatian Symposium on Agriculture with International Participation (Loncaric Z. and Maric Sonja Eds.), 16-20 February 2009, Opatija, Croatia, p. 541-545.

Kovacevic V., Josipovic M. (2005): Maize yield variations among the years in the Eastern Croatia. In: Proceedings of the XL Croatian Symposium on Agriculture with International Participation (Kovacevic V. and Jovanovac Sonja Eds.), 15-18 February 2005, Opatija, Croatia, p. 455-456.

Kovacevic V., Josipovic M., Grgić D. (1994): Pregled rezultata proizvodnje kukuruza u Slavoniji i Baranji (1960-1980) /The survey of corn production results in Slavonia and Barannya province (1960-1989), Poljoprivredne aktualnosti 30(1-2): 141-151.

Kovacevic V., Josipovic M., Kaucic D., Iljkic D. (2010b): Weather impacts on yields of maize, sugar beet, soybeans and sunflower. In: Proceedings of 45th Croatian and 5th International Symposium of Agriculuture, Opatija 15-19 February 2010 (Maric S. and Loncaric Z. Editors), Faculty of Agriculture in Osijek, p. 796-800.

Kovacevic V., Maklenović V., Jolankai M. (2009b): Oborinski i temperaturni režim kao faktori prinosa kukuruza u Hrvatskoj, Srbiji i Mađarskoj (Precipitation and temperature regime as a factors of maize yields in Croatia, Serbia and Hungary). Agroznanje (Agro-knowledge Journal) 10 (3): 67 - 75.

Kovacevic V., Simic D., Rastija M., Rastija D. (2011): Potassium fertilization and genotype effects on field crops in crop rotation. In: Proceedings / Zbornik radova International Scientific Symposium of Agriculture "Agrosym Jahorina 2011, Hotel Bistrica, November 10-12, 2011, p. 17-25.

Maklenović V., Vučković S., Kovačević V., Prodanović S., Živanović Lj. (2009): Precipitation and temperature regimes impacts on maize yields In: Proceedings of 44th Croatian and 4th International Symposium on Agriculture (Maric S. and Loncaric Z. Editors.), 16 th – 20 th Febraury 2009, Opatija; Faculty of Agriculture Osijek, p. 569-573.

Markulj A., Marijanovic M., Tkalec M., Jozic A., Kovacevic V. (2010): Effects of precipitation and temperature regimes on maize (*Zea mays* L.) yields in northwestern Croatia. Acta Agriculturae Serbica, XV (29): 39-45.

Shaw R. H. (1988): Climatic requirement. In: Corn and corn improvement, Agronomy Monograph No 18 (Sprague G.F. ed.) ASA-CSSA-SSSA, Madison, Wisconsin, USA, p. 609-638.

Stojic B., Kovacevic V., Seput M., Kaucic D., Mikoc V. (2012): maize yields variation among years as function of weather regimes and fertilization. Növénytermelés 61: 85-88.

SYB (2011): Statistical Year Book, State Bureau for Statistics, Zagreb.

Rastija M., Iljkic D., Kovacevic V., Brkic I. (2012): Weather impacts on maize productivity in Croatia with emphasis on 2011 growing season. Növénytermelés 61: 329-332.

Thompson L. M. (1963): Weather and technology in the production of corn and soybeans. Center for Agric. Econ. Dev. Rep. 17. Iowa State Univ., Ames.

Thompson L. M. (1986): Climatic change, weather variability and corn production. Agronomy Journal 78: 649-653.