Original scientific paper

Precipitation and temperature regimes impacts on maize yields

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Abstract

Maize yield variations over the years, in the 1996-2005 period were from 2.44 to 5.78 t/ha (Serbia) and from 3.86 to 6.92 t/ha (Croatia). Weather data (June-August) of two growing seasons (2000 as less favourable year or LFY and 2005 and more favourable year or MFY: Novi Sad and Osijek Weather Bureaus) could be used as an example weather influences on maize yields. Precipitation and mean air-temperatures for LFY 2000 were 62 mm and 22.5 ^{o}C (Novi Sad), 78 mm and 22.6 ^{o}C (Osijek). Maize yields in LFY were 3.48 t/ha (NS municipality or NS in Serbia) and 3.96 t/ha (Osijek-Barannya County or OBC in Croatia). In MFY 2005, analogical data were 392 mm and 20.0 ^{o}C (Novi Sad), 521 mm and 20.1 ^{o}C (Osijek), maize yields 5.86 t/ha (NS) and 6.98 t/ha (OBC) or 68% higher (NS) and 76% higher (OBC) compared to yields in these areas under LFY conditions.

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

Introduction

Maize is the first-ranged field crop in Serbia and Croatia (harvested area status in 2007: 1201832 ha and 288380 ha, for Serbia and Croatia, respectively). In general, maize yields in Serbia are about 23% lower than in Croatia (means 2005-2007: 4.69 t/ha and 6.12 t/ha, respectively). Global climatic changes (Anđelković, 2007; Marinković et al., 2008) reflecting correspondingly on field crop growing. Climate and soil limitations could be responsible for relative low yields of maize in both countries (Josipović et al., 2005; Kovačević, 2008; Kovačević et al., 1994, 2008, 2009, Starčević et al., 1991). Aim of this study was testing maize yield variations over the years in Serbia and Croatia with emphasis on precipitation and temperature regime impacts.

Material and methods

The data of State Bureaus for Statistics (Statistical Yearbooks) were used as source of maize yield data for Novi Sad and Nis municipalities (Serbia), Osijek-Barannya (OBC) and Zagreb (ZC) Counties (Croatia). State Hydrometeorological Institutes (Belgrade and Zagreb) were source of meteorological data for Nis and Novi Sad (Serbia), Osijek and Zagreb (Croatia).

Municipality of Novi Sad or NS-area (699 km^2) and municipality Niš or Nis-area (597 km^2) participating with 1,5% in total territory of Serbia (88.361km^2). In general, NS-area had more fertile soils (prevailing soil type: carbonate chernozem) in comparison with Nis-area (prevailing soil types stagnic albeluvisol). Annual precipitation in Serbia have decreasing trend in north-western direction (1961-1990: Novi Sad = 731mm, Niš = 626 mm), while temperatures increase (10.8 ^{o}C and 11,7 ^{o}C, respectively).

OBC (4155 km^2) and ZC (3060 km^2) participating with 12.7 % in total territory of Croatia. However, their contribution in arable land capacities (harvested area only) of the country is 28.4 % (status 2006: 200710 ha and 42724 ha, respectively) and in maize harvested area 26.0 % (56513 ha and 20619 ha, respectively). In general, OBC had more fertile soils (the higher share of eutric cambisol) in comparison with ZC (prevailing soil type: stagnic albeluvisol). Annual precipitation in northern Croatia have increasing trend in EW direction (1961-1990: Osijek = 650 mm, Zagreb-Maksimir = 852 mm), while temperatures have decreasing trend (10.8 ^{o}C and 10.3 ^{o}C, respectively).

Results and discussion

Maize harvested area in Serbia in the three decade period (1960-1989) were close to three times higher (1435000 ha) than in Croatia (509068 ha). However, at same time maize yields in Serbia were 24% lower than in Croatia (2.90 t/ha and 3.81 t/ha, respectively). In the least decade period (1996-2005), maize harvested areas in Croatia were decreased by third for comparison with 1960-1989. However, in Serbia maize harvested area remained mainly similar (Table 1).

Table 1. Harvested areas and yields of maize in Serbia and Croatia (Statistical Yearbooks)

Maize harvested areas (ha) and yields (t/ha): OBC (Osijek-Barannya), ZC (County of Zagreb), Nis and Novi Sad municipalities (* not included Kosovo)

Year	Serbia				Croatia			
	Serbia		Harvested (ha)		Croatia		Harvested (ha)	
	ha	t/ha	NS	Nis	ha	t/ha	OBC	ZC
	1960-69 (a), 1970-79 (b), 1980-89 (c)				1960-69 (a), 1970-79 (b), 1980-89 (c) periods (Kovacevic et al., 1994)			
a	*1473000*	*1.99*			*520050*	*2.90*		
b	*1407000*	*3.14*			*500580*	*3.85*		
c	*1425000*	*3.57*			*506575*	*4.68*		
	The period 1996-2007				The period 1996-2007			
1996	1433432	3.73	21606	6286	361268	5.22	52882	37325
1997	1363680	5.09	19037	6430	371273	5.88	56951	36363
1998	1345978	3.83	20017	6315	374531	5.27	63852	38684
1999	1263234*	4.85	22540	6446	384184	5.56	68826	37456
2000	1202367*	2.44	20152	6738	388639	3.93	68430	37519
2001	1216607*	4.85	17454	6352	405910	5.45	70649	39278
2002	1196353*	4.67	17178	6040	407272	6.14	70696	39364
2003	1199871*	3.18	17800	6292	405947	3.86	73562	39016
2004	1199921*	5.50	18140	6240	-	-	-	-
2005	1220174*	5.78	15680	6414	318891	6.92	55197	27813
Mean	*1264162*	*4.39*	*18960*	*6355*	*344663*	*5.36*	*57718*	*34202*
2006	1169976*	5.08	14159	6250	296251	6.53	56513	20619
2007	1201832*	3.20	15928	6080	288380	4.90	53292	22064

In the 1996-2005 period variations of annual yields were from 2.44 t/ha to 5.78 t/ha in Serbia and from 3.86 t/ha to 6.92 t/ha in Croatia (Table 1). In Serbia, the lowest annual yield was even 58 % lower than the highest yield. In Croatia, analogical difference was 45%. Weather characteristics are the most responsible factors of maize yield variations over the years (Kovacevic et al, 2008; Josipovic et al., 2005; Marinkovic et al., 2008).

NS area and Nis area participating in maize harvested area in Serbia with 2%, while analogical comparison for OBC and ZC in Croatia is 27%. Regarding yields of maize, NS area is more favorable for maize growing because yields have been 9% higher, while in Nis area it is 23% lower in comparison with the state mean (1996-2005). Also, maize yield in NS area is 42% higher than in Nis area (Table 2). At the same time, maize yields in OBC has been 17% higher

and in ZC 20% lower in comparison with the state mean and in OBC for 45% higher than in ZC (Table 3).

Table 2. Maize yields (Statistical Yearbooks) and meteorological data (Hydro-meteorological Institute Belgrade) variations for 1996-2007 period in Serbia

Maize yield (t/ha) in Novi Sad and Nis municipalities and weather data for Novi Sad (NS) and Nis

Year	Maize yield t/ha		Precipitation (mm) and mean air-temperatures (°C) Novi Sad June		July		August		Nis June		July		August	
	NS	Nis	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C
1996	5.26	1.85	79	20.6	84	20.0	113	20.7	21	20.0	9	21.4	14	22.3
1997	5.33	4.83	62	20.7	130	20.1	125	20.1	17	20.9	68	20.9	109	20.2
1998	3.64	2.25	104	21.5	124	21.6	82	21.7	21	22.7	45	22.7	38	22.9
1999	4.94	3.67	91	20.1	209	21.2	28	21.3	104	21.4	182	21.4	23	22.5
2000	3.48	1.47	28	21.4	29	22.1	5	24.1	35	25.7	50	25.7	6	24.5
2001	4.97	3.91	233	18.3	56	22.3	30	22.7	81	23.7	45	23.7	73	24.1
2002	5.25	3.71	27	21.8	33	23.6	55	22.2	58	24.4	67	24.4	103	21.9
2003	3.65	2.65	31	24.0	60	22.6	30	24.6	23	23.4	38	23.4	40	25.2
2004	5.37	4.44	97	19.8	63	22.0	39	21.7	112	22.7	43	22.7	24	22.2
2005	5.86	4.95	135	19.3	123	21.4	134	19.4	49	22.0	45	22.0	83	21.0
x	*4.78*	*3.37*	*89*	*20.8*	*91*	*21.7*	*64*	*21.9*	*52*	*22.7*	*59*	*22.8*	*51*	*22.7*
2006	5.99	4.37	104	19.7	31	23.5	125	19.7	93	21.0	30	23.0	114	22.0
2007	4.95	3.61	71	22.0	39	23.2	80	23.4	70	24.3	21	25.4	42	24.5
Means 1961-1990			*81*	*19.4*	*69*	*21.2*	*56*	*20.6*	*66*	*19.6*	*55*	*21.3*	*50*	*20.9*

Precipitation in NS for the 1961-1990 period for three summer months (June-August: long-term means or LTM) were 206 mm and they were 20% higher than in Nis (171 mm). At the same time air-temperature differences were low (20.4°C and 20.6°C, for Novi Sad and Nis, respectively). Lower precipitation in Nis could be participated in the lower maize yields in Nis area compared to NS area, but we presume that soil fertility levels are main factors for yield differences between two tested areas. In the decade period 1996-2005, air-temperatures in Novi Sad and Nis were 1.1 °C higher in comparison with 1961-1990, probably due to tendency of global warming (Table 2). Also, LTM June-August precipitations in Zagreb were 278 mm and 32% higher than in Osijek (211 mm), while air-temperatures were 1.0 °C lower (19.3 and 20.3 °C, for Osijek and Zagreb, respectively). Regarding this phenomenon, water shortage and high temperature stresses are less possible in Zagreb area compared to Osijek area. However, maize yields in Zagreb area are considerably lower (means 1996-2005: 4.31 t/ha and 6.25 t/ha, for OBC and ZC, respectively – Table 3), mainly because of soil limitations.

Weather characteristics of two growing seasons (2000 as less favourable year or LFY and 2005 and more favourable year or MFY: comparison data of Novi Sad and Osijek Weather Bureaus; air distance between Novi Sad and Osijek = 100 km) could be used as a typical example of precipitation and temperature regime influences on maize yields under middle and eastern European environmental conditions. Precipitation for three months (June-August) period of LFY 2000 was in Novi Sad 62 mm or only 30% of LTM and in Osijek 78 mm or 37% of LTM. At the same time, air-temperatures were 22.5 °C (Novi Sad) and 22.6 °C (Osijek) or 2.1 °C (Novi Sad) and 2.3 °C (Osijek) higher in comparison with LTM. As result of water shortage and high temperatures stresses, maize yields in tested areas were only 3.48 t/ha (NS municipality in Serbia) and 3.96 t/ha (OBC in Croatia). However, under MFY 2005 conditions, precipitation in three summer months in Novi Sad were 392 mm (or 90% higher than LTM) and in Osijek even 521 mm (or 1.5 times more than LTM), while air-temperatures were in lower 0.4 °C (Novi Sad) and 0.2 °C (Osijek) compared to LTM. As results of favorable weather conditions were maize yields 5.86 t/ha (NS) and 6.98 t/ha (OBC) or 68% higher (NS) and 76% higher (OBC) compared to yields in these areas under LFY conditions (Tables 2 and 3).

Table 3. Maize yields (Statistical Yearbooks) and meteorological data (Hydro-meteorological Institute Zagreb) variations for 1996-2007 period in Croatia

Maize yield (t/ha) in Osijek-Barannya(OBC) and Zagreb (ZC) Counties and meteorological data for Osijek and Zagreb

Year	Maize yield (t/ha)		Precipitation (mm) and mean air-temperatures (°C) Osijek						Zagreb-Maksimir					
			June		July		August		June		July		August	
	OBC	ZC	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C	mm	°C
1996	6.46	4.33	30	21.1	95	19.9	77	20.6	63	20.4	69	19.4	144	20.0
1997	7.35	4.81	86	20.8	91	20.3	41	20.5	87	20.1	81	20.6	58	20.6
1998	6.53	4.18	26	21.4	84	22.2	99	21.8	134	20.5	135	21.2	99	21.1
1999	6.60	4.00	150	20.3	95	21.9	74	21.3	85	19.8	101	21.5	76	20.7
2000	3.96	3.31	10	22.5	63	21.7	5	23.7	47	21.6	79	20.9	10	23.0
2001	6.79	4.18	240	18.1	77	21.6	7	22.7	121	18.4	55	21.8	14	22.5
2002	7.34	5.35	36	21.1	59	22.3	77	20.9	71	21.1	124	22.3	143	20.9
2003	4.23	2.72	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	6.98	5.90	112	19.5	171	21.5	238	19.3	69	19.9	137	21.5	175	18.9
x	*6.25*	*4.31*	*81*	*20.8*	*84*	*21.5*	*76*	*21.5*	*85*	*20.5*	*101*	*21.3*	*79*	*21.4*
2006	6.94	5.70	91	20.1	15	23.5	134	19.3	40	20.5	32	23.8	178	18.9
2007	4.90	5,70	33	22.3	27	23.9	45	22.2	97	22.2	49	22.9	102	21.3
Means 1961-1990			*88*	*19.5*	*65*	*21.1*	*58*	*20.3*	*99*	*18.5*	*83*	*20.1*	*95*	*19.3*

Kovacevic et al. (1994) showed results of maize production in Croatia in the 1960-1989 period. Maize yield in Vukovar municipality (now part of Vukovar-Syrmium County) was higher (mean 6.00 t/ha: annual yield variation from 3.14 to 8.43 t/ha), while in Podravska Slatina municipality (now Slatina and part of Virovitica-Podravina County) it was olny 4.13 t/ha or 31% lower (from 2.94 t/ha to 5.81 t/ha). Soil characteristic differences are main responsible factors for yield differences in Vukovar and Slatina areas. In general, maize yields under „dry conditions“ were lower.

Maize yields for three decade period of the last century (1961-1990) were in Hungary 15% higher than in Croatia (means 3.81 and 4.39 t/ha, respectively) and this trend was continued in the 1996-2007 period (Kovacevic et al., 2009). However, differences over the years (for the 1996-2007) in Hungary were higher (from 3.60 to 7.56 t/ha) than in Croatia (from 3.86 to 6.92 t/ha). Mean yield in Békés County (BC) for 1996-2007 period was 21% higher than in Fejér County (FC). Yields in three less favorable years (LFY: 2000, 2003 and 2007) were considerably lower (means 3.78 and 3.79 t/ha, for BC and FC, respectively) than in three more favorable (MFY: 1997, 2002 and 2005) years (means 6.13 and 7.30 t/ha, respectively). Precipitation (means of two sites: Békéscsaba and Székesfehérvár) in 3-months period June-August was in LFY 51% lower (115 mm and 235 mm, respectively) and air-temperatures were 1.9 °C higher (22.1 and 20.2 °C, respectively) than in MFY.

Growing of more tolerant maize hybrids and adequate soil management practices (for example, liming of acid soils, balanced mineral fertilization etc.) could be contributed to alleviation of drougt stress. Kovacevic (2008) and Kovacevic et al. (2008) showed survey of ameliorative fertilization effects (phosphorus and potassium fertilization, liming) on maize yield under drought stress (Table 3) in 2000, 2003 and 2007. P application up to 1750 kg P_2O_5 t/ha in spring of 2005 increased maize yield in 2007 for 38%. Application of both P and K (spring 2003) yield of maize increased in 2003 for 14%. By using 45 t ha^{-1} of lime (spring 2000) yields in 2000 and 2003 were increased for 101% and 50 %, respectively. Limiting in amount of 15 t /ha in spring of 2005 increased maize grain yield in 2007 for 43%.

Conclusions

Maize yield variations over the years are closely related to precipitation and temperature regimes during individual growing seasons, especially in three summer months (June, July and August). In general, low yields connected with drought and high-temperatures stresses.

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