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Impact of Precipitation and Temperature on Wheat (*Triticum Aestivum* L.) Yields in Eastern Croatia

Marija Marijanović, Antonela Markulj, Monika Tkalec, Anita Jozić, Vlado Kovačević

University J. J. Strossmayer in Osijek, Faculty of Agriculture, Osijek, Croatia

Abstract: Wheat after maize is the most commonly cultivated field crop in Croatia. In 2005-2007, it was cultivated on 165,721 ha/year or on about 20% of arable land. The majority of wheat acreage (about 76 %) is located in eastern Croatia. Considerable yield variations among years are mainly caused by weather characteristics, especially precipitation and temperature regimes. For example, during three favorable growing seasons (MFS: years of harvest 1984, 1988 and 1989), the mean yield of wheat in eastern Croatia was 5.53 t/ha, while during the three less favorable years (LFS: 1978, 1980 and 1982) it was 4.22 t/ha or 24% lower. Precipitation values (the data of Osijek Weather Bureau) during the growing season (a = October –June; b = November + December) were higher in LFS (a =522 and 463 mm, b = 146 mm and 79 mm, for LFS and MFS, respectively). During 1996-2007, differences in wheat yield in the region ranged from 3.62 to 5.00 t/ha. Precipitations during the growing season (a = October-June; b = November + December of the previous year: 3-year means in Osijek) were higher in the LFS, especially during November + December period (a =522 and 463 mm, b = 146 mm and 79 mm, for the LFS and MFS, respectively). Wheat yields in Vukovar-Syrmium and Osijek-Barannya Counties were 12 % (mean 4.61 t/ha) higher than in Virovitica-Podravina and Brod-Posavina Counties (mean 4.12 t/ha). Irrespective of the complex relationship between wheat yields and weather characteristics (precipitation and mean air-temperatures), there are indications that moderate well-distributed precipitation coupled with mild winter are more favorable for wheat growing than excess precipitation, especially in autumn, and colder winters.

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

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Introduction

Wheat is the second-ranking field crop on arable lands in Croatia. According to the data of the State Bureau for Statistics for the last three-year period (2005-2007), wheat was grown on 165721 ha/year or 20% of arable land of the country. The majority of wheat growing area (about 76%) is located in Eastern Croatia occupying about 22% of the state territory. Yield variations of wheat among years are mainly associated with weather characteristics, especially precipitation and temperature regimes. In general, under environmental conditions of Eastern Croatia, there are indications that low wheat yields are mainly related to precipitation excess, especially during autumn/winter period (Kovacevic and Josipovic 1995, Kovačević *et al*. 2009). The objective of this study was to evaluate wheat yield variations among years in Eastern Croatia, focusing on precipitation and temperature regimes.

Material and Methods

The data of the State Bureau for Statistics were used as the source of grain yield data, whereas data on weather characteristics (precipitation and mean air temperatures) were obtained from the State Hydrometeorological Institute. Until the end of 1992, the territory of Eastern Croatia was divided into 14 municipalities, their area totaling 11090 km^2 or 19.6% of the state territory. Since 1992, according to the new territorial division, Eastern Croatia includes five counties (c) of total area 12.452 km^2 (22.0% of the state territory) as follows: Vukovar-Sirmium (VSc), Osijek-Baranya (OBc), Brod-Posavina (BPc), Pozega-Slavonia (PSc) and Virovitica-Podravina (VPc) County. Due to the war escalation in Croatia in the period 1991 to 1995, incomplete data were reported by the official statistics. Also, wheat yields in this period were low mainly due to war-induced factors. Therefore, only data for the 1996-2007 period were shown.

Results and Discussion

Considerable variations in wheat grain yield in Eastern Croatia among years during 1961-1990 were observed. The increasing trends of wheat yields for the three-decade period (means 2.81, 4.09 and 5.26 t/ha, respectively) were due to the improvement of crop and soil management practices as well as due to the development of high-yielding cultivars (Table 1).

Weather differences among individual growing seasons were more responsible for short-term wheat yields (Table 1). For example, during three more favorable seasons (MFS=year of harvest 1984, 1988 and 1989) mean wheat yield in the region was 5.53 t/ha, while in three less favorable seasons (LFS= year of harvest 1978, 1980 and 1982) it was 4.22 t/ha or 24% lower. Precipitations during the growing season (a = October-June; b = November + December of the previous year: 3-year means in Osijek) were higher in the LFS, especially for the November + December period (a =522 and 463 mm, b = 146 mm and 79 mm, for the LFS and MFS, respectively).

Tab. 1. Wheat harvested area and grain yields in Eastern Croatia (Kovačević and Josipović 1995) and weather data in Osijek (Kovačević – unpublished data) for the period 1961-1990

Eastern Croatia: Wheat harvested area (ha) and grain yields (t/ha) for the period 1961-1990								
1961-1970			1971-1980			1981-1990		
Year	ha	t/ha	Year	ha	t/ha	Year	ha	t/ha
1961	143108	2.08	*1971*	167330	3.76	*1981*	122538	4.03
1962	171798	2.52	*1971*	172435	3.63	*1982*	146980	4.49
1963	183548	2.63	*1973*	125849	3.70	*1983*	145549	5.27
1964	187963	2.18	*1974*	169089	4.70	*1984*	143874	5.58
1965	124314	2.29	*1975*	101251	3.42	*1985*	124065	5.32
1966	153437	3.41	*1976*	160114	4.93	*1986*	124395	5.16
1967	160182	3.25	*1977*	148555	4.47	*1987*	146235	5.22
1968	173554	3.68	*1978*	157790	4.04	*1988*	148954	5.85
1969	178674	3.44	*1979*	146122	4.10	*1989*	146266	5.15
1970	176564	2.59	*1980*	147556	4.14	*1990*	148908	6.50
X	165314	2.81	X	149609	4.09	X	139776	5.26
Osijek: precipitation (mm) during October-June and November+December								
1961-1970			1971-1980			1981-1990		
Year	Oct-June	Nov+Dec	Year	Oct-June	Nov+Dec.	Year	Oct-June	Nov+Dec.
1961	539	142	*1971*	409	75	*1981*	638	169
1962	504	123	*1971*	348	79	*1982*	494	165
1963	469	122	*1973*	507	109	*1983*	387	117
1964	546	162	*1974*	489	103	*1984*	437	28
1965	589	162	*1975*	527	105	*1985*	468	61
1966	581	209	*1976*	396	56	*1986*	464	127
1967	566	100	*1977*	485	110	*1987*	568	40
1968	354	73	*1978*	528	171	*1988*	548	151
1969	510	82	*1979*	322	53	*1989*	403	59
1970	613	188	*1980*	543	102	*1990*	351	60
X	*527*	*136*	X	*455*	*96*	X	*478*	*98*

A comparison of wheat yields for two growing seasons (1989/1990 and 1993/1994) in the agricultural holding (AH) Djakovo can be used to provide further explanation of possible weather impacts on wheat yields under Eastern Croatian conditions. Mild winter and moderate precipitation are main factors of bumper harvest (7.30 t/ha) in AH Djakovo (Table 2). However, during the less favorable growing season (1993/1994) characterized by water excess and considerably lower temperatures during the winter period, considerably lower wheat yields (4.46 t/ha or about 40% lower) were achieved.

In contrast to maize, there is a complex relationship between weather characteristics and wheat yields; therefore, it cannot be explained based solely on monthly precipitation and mean air-temperature regime. For example, Josipović *et al.* (2005) tested weather impacts on wheat and maize yield in Brod-Posavina County. In general, lower maize yields are mainly associated with drought and higher air temperatures especially during the three summer months, whereas moderate precipitation is related to higher yields of wheat (Table 3).

Tab. 2. Effect of precipitation and temperature regimes on wheat yields in Agricultural Holding (AH) Djakovo (Osijek-Baranya County)

Precipitation (mm) and mean air temp. (^{0}C) in Djakovo and wheat yield in Djakovo AH											
	Oct	Nov	Dec	Jan	Feb	March	April	May	June	Oct-June	AH Djakovo
	Especially favorable growing season for wheat (1989/1990)										
mm	46	30	24	19	40	29	47	52	61	348	7.30 t/ha
^{0}C	11.3	4.8	2.5	0.4	6.6	9.2	11.2	17.8	19.9	9.3	(7250 ha)
	Unfavorable growing season for wheat (1993/1994)										
mm	57	132	110	65	47	51	69	24	184	739	4.46 t/ha
^{0}C	13.0	1.8	2.1	26	1.8	9.8	11.9	17.1	20.3	8.9	(6303 ha)

Tab. 3. Effect of precipitation and temperature regimes on wheat and maize yields in the state-owned Jasinje farm, Slavonski Brod (Josipović *et al*. 2005)

Precipitation (mm) and mean air temperature (^{o}C) in less favorable (LFY) and more favorable (MFY) growing season (the data of Weather Bureau Slav. Brod)									
Winter wheat (year of harvest)					Maize				
	1980 (LFY)		1984 (MFY)			1988 (LFY)		1989 (MFY)	
	mm	^{o}C	mm	^{o}C		mm	^{o}C	mm	^{o}C
Oct.	58	9.0	30	10.1					
Nov.	59	6.1	17	2.4	April	48	10.8	72	13.5
Dec.	74	4.2	20	0.3	May	28	16.7	180	14.8
Jan.	44	-2.4	110	0.4	June	70	18.8	95	17.5
Feb.	60	2.7	40	0.5	July	27	23.3	61	21.0
March	47	5.9	47	5.1	August	50	21.4	88	20.0
April	102	7.8	48	10.2	Sept.	76	16.4	88	15.8
May	139	13.1	125	14.9	Oct.	46	10.4	49	10.2
June	113	18.6	67	17.5					
Σ	696		504		**Σ**	345		633	
X		7.2		6.8	X		16.8		16.1
Yield and harvested area (in the bracket: ha) in the Jasinje state-owned farm									
Wheat	3.63 t/ha (2950)		6.03 t/ha (3943)		Maize	4.35 t/ha (2963)		7.02 t/ha (2781)	

Tab. 4. Wheat harvested area and grain yields

Year	Wheat harvested area (ha) and grain yields (t/ha)								
	Croatia		Eastern Croatia		Wheat yields (t/ha) in the County*				
	ha	t/ha	ha	t/ha	VSc	OBc	VPc	BPc	PSc
1996	200813	3.69	99473	4.21	4.26	4.24	3.99	3.89	4.73
1997	208500	4.00	107613	4.57	4.73	4.83	4.10	4.16	4.76
1998	241706	4.22	136652	4.80	4.66	5.06	4.62	4.46	4.71
1999	169091	3.30	98690	3.62	3.72	3.69	3.30	3.34	3.80
2000	236156	4.37	144680	5.00	5.13	5.12	4.68	4.75	4.85
X	211253	3.92	117421	4.51	4.59	4.66	4.20	4.12	4.57
2001	240050	4.02	145365	4.70	4.79	5.02	4.52	4.09	3.92
2002	233570	4.23	141835	4.73	4.97	4.87	4.56	4.05	4.45
2003	205998	2.96	127747	3.30	3.50	3.28	3.21	3.13	3.11
2004	no data available for 2004								
2005	146411	4.11	107647	4.31	4.63	4.29	3.85	4.17	4.19
2006	175677	4.58	134709	4.76	4.84	5.01	4.49	4.06	4.46
2007	175075	4.64	134637	4.92	5.14	4.87	4.25	4.76	4.68

* Eastern Croatian counties: Vukovar-Sirmium (VSc), Osijek-Baranya (OBc), Virovitica-Podravina (VPc), Brod-Posavina (BPc) and Pozega-Slavonia (PSc)

During the last 12-year period 1996-2007, wheat yields among years ranged from 3.92 to 4.64 t/ha and from 3.62 to 5.00 t/ha, for Croatia and eastern Croatia, respectively. In that respect, yields in VSc and OBc were on average 12 % higher (mean 4.61 t/ha) than in VPc and BPc (mean 4.12 t/ha), while in PSc the values fell within the range for region (Table 4). Also, in the period 1996-2007 wheat harvested area in the region decreased 10 % as compared to the 10-year mean for 1981-1990, while yields showed a decreasing trend (Tabs.1 and 4). Since 1996, wheat yield variations among years as well as their dependences on water regime showed a similar trend as in the previous tested periods (Table 5). For example, yield differences in the region for the growing seasons (year of harvest) 1999 and 2000 (3.62 and 5.00 t/ha, respectively) were likely due to the amount of precipitation (Osijek, during October-June: 606 and 382 mm, respectively).

Tab. 5. Precipitation and mean air temperatures in Osijek (Kovačević *et al*. 2009)

Year of harvest	Osijek: precipitation (mm) and mean air temperature (°C)									
	Oct.*	Nov.*	Dec.*	Jan.	Feb.	March	April	May	June	
	Precipitation (mm)									**Σ**
1996	6	54	104	31	51	42	82	78	30	*478*
1997	61	99	67	44	43	23	59	38	86	*520*
1998	100	42	92	91	0.7	21	54	49	26	*476*
1999	97	69	30	36	61	29	45	89	150	*606*
2000	22	124	98	18	15	41	28	26	10	*382*
2001	10	42	37	75	23	83	72	60	240	*642*
2002	5	74	34	11	48	10	64	135	37	*418*
2003	59	40	24	66	16	5	12	18	44	*284*
2004	132	45	27	50	50	41	137	7	77	*566*
2005	94	115	42	36	66	34	55	46	112	*600*
X	***59***	***70***	***56***	***46***	***41***	***33***	***61***	***55***	***81***	*497*
2006	4	16	111	33	50	53	87	79	91	*524*
2007	31	33	6	25	47	76	3	56	33	*310*
	Mean air temperature (°C)									**X**
1996	12.1	3.6	1.4	-1.2	-2.4	2.9	11.5	18.0	21.1	*7.4*
1997	11.5	8.2	-0.3	-1.3	3.5	6.0	7.9	17.8	20.8	*8.2*
1998	8.9	6.2	2.8	2.8	5.0	4.8	12.6	16.2	21.4	*9.0*
1999	12.3	4.0	-3.3	0.4	1.1	8.2	12.6	17.3	20.3	*8.1*
2000	11.7	4.0	0.7	-1.6	4.2	7.0	14.9	18.4	22.5	*9.1*
2001	14.1	10.0	3.0	2.7	4.2	9.9	10.9	18.4	18.1	*10.1*
2002	13.9	3.5	-3.8	-0.2	6.0	8.4	11.2	18.6	21.1	*8.7*
2003	11.3	8.8	0.9	-2.4	-3.1	5.9	11.3	20.1	24.3	*8.6*
2004	9.4	7.5	1.4	-1.4	2.3	5.8	11.7	14.6	19.2	*7.8*
2005	13.2	6.2	1.9	0.0	-3.2	4.1	11.5	17.0	19.5	*7.8*
X	***11.7***	***6.2***	***0.5***	***-0.2***	***1.8***	***6.3***	***11.6***	***17.6***	***20.8***	***8.5***
2006	11.7	5.0	1.7	-1.6	1.1	5.3	12.7	16.2	20.1	*8.0*
2007	13.0	7.8	3.0	5.8	6.1	8.5	13.3	18.2	22.3	*10.9*
Long-term average (1961-1990) in Osijek										
mm	41	57	52	47	40	45	54	58	88	*492*
°C	11.2	5.4	0.9	-1.2	1.6	6.1	11.3	16.5	19.5	*7.9*
Precipitation and mean air temperature (Osijek) for the 1989/1990 growing season (bumper crop of wheat in eastern Croatia: 6.50 t/ha !)										
mm	49	43	18	12	39	26	38	26	101	*352*
°C	11.4	5.0	2.3	0.5	6.1	9.5	11.2	17.6	19.5	*9.2*

* Oct. + Nov. + Dec. of the previous year

Conclusions

Considerable variation in what yields among years was observed, being mainly due to more or less favorable weather characteristics. However, the relationship cannot be explained based on monthly values of precipitation and air temperature, regardless of indications that higher precipitation and lower temperatures during winter period are seen as adverse factors.

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UTICAJ PADAVINA I TEMPERATURNOG REŽIMA NA PRINOSE PŠENICE (*Triticum aestivum* L.) U ISTOČNOJ HRVATSKOJ

- originalni naučni rad -

Marija Marijanović, Antonela Markulj, Monika Tkalec, Anita Jozić, Vlado Kovačević

Sveučilište J.J. Strossmayer u Osijeku,Poljoprivredni fakultet, Osijek, Hrvatska

Rezime

Pšenica je, pored kukuruza, najzastupljenija ratarska kultura na oranicama Hrvatske. U periodu 2005.-2007. godine uzgajana je prosečno na 165721 ha ili oko 20% oranica. Većina površine pod pšenicom (oko 76%) se nalazi u istočnoj Hrvatskoj. Značajna variranja prinosa pšenice po godinama najvećim delom su rezultat vremenskih prilika, posebno padavinskog i temperaturnog režima. Tako je u tri povoljne godine (MFS: godine žetve 1984, 1988 i 1989) prosečni prinos pšenice u regiji istočne Hrvatske iznosio 5,53 t/ha, a u tri nepovoljne godine (LFS: godine žetve 1978, 1980 i 1982) bio je u proseku 4,22 t/ha ili za 24% niži. Količina padavina u Osijeku tokom vegetacije (a = oktobar – juni; b = novembar + decembar) bila je veća u LFS (a =522 i 463 mm, b = 146 mm i 79 mm, za LFS i MFS). U razdoblju 1996.-2007, razlike u prinosima pšenice u regiji po godinama bile su rasponu od 3,62 do 5,00 t/ha. Prinosi pšenice u županijama Vukovarsko-srijemska i Osječko-baranjska bili za 12% (prosek 4,61 t/ha) veći nego u Virovitičko-podravskoj i Brodsko-posavskoj županiji (prosek 4,12 t/ha), dok je u Požeško-slavonskoj županiji bio na nivou proseka regije. Iako je veza između prinosa pšenice i vremenskih prilika (padavine i srednje temperature vazduha) dosta složena, postoje indikacije da umerena količina dobro raspoređenih padavina i blage zime su povoljnije za pšenicu od viška padavina, posebno u jesen, i oštrijih zima.