Yield and Yield Components of Maize (*Zea Mays* L.) Hybrids as Affected by Irrigation Scheduling and Meteorological Conditions

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Summary

During the last decade eastern Republic of Croatia have experienced several drought and flood events which seriously affected not only the crop production but also the effectiveness of irrigation practice, meaning irrigation scheduling and water use efficiency. This study was conducted to quantify the effect of irrigation scheduling on yield and yield components (hectolitre weight (HW), 1000-grain weight, cob weight (CW), cob length (CL), cob height (CH), grain weight (GW) and grain number/cob (GN/C) of maize (*Zea Mays* L.) hybrids during three growing seasons (2010 – 2012) characterised by extreme weather conditions. The study was conducted at the research site of Agricultural Institute in Osijek, Croatia. Three irrigation treatments (a1 = rainfed, a2 = 60 – 100% field water capacity (FWC), a3 = 80 – 100% FWC) and four maize hybrids (b1 = OSSK 596; b2 = OSSK 617; b3 = OSSK 602; b4 = OSSK 552) were studied. During the study grain yield ranged from 7.4 t ha^{-1} (2012, a1) to 10.3 t ha^{-1} (2012, a3) and was yearly-dependent. In 2010 irrigation significantly reduced CW (a1 = 0.8 kg; a3 = 0.7 kg), CH (a1 = 72 cm, a3 = 38 cm), 1000-GW (a1 = 284 g; a3 = 254 cm) and CL (a1 = 16 cm; a3 = 15 cm). In 2011 irrigation significantly increased only 1000-GW (a1 = 305 g; a3 = 330 g) while in 2012 irrigation increased all tested yield components as follows: 1000-GW (a1 = 340 g; a2 = 361 g); CH (a1 = 116 cm; a2 = 126 cm); CW (a1 = 1,15 kg; a3 = 1,79 kg), GN/C (a1 = 578; a2 = 701) and HW (a1 = 67 kg; a3 = 69 kg). As for maize hybrids (b), according to results of our study yield of maize grain varied ($p<0.01$) across tested hybrids in all three growing seasons while the significance for tested yield components was year dependent.

Key words

maize hybrids, yield, yield components, irrigation, climate change

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Received: May 23, 2017 · Accepted: September 25, 2017

Introduction

Irrigated areas are increasing in many parts of the Republic of Croatia. Some of the reasons for this increase include frequent periods of droughts especially during the growing period of the summer crops. This statement is confirmed by results of Šoštarić et al. (2012). Author claims that according to Hydrothermal coefficient by Seljaninov during 1973 – 1993 period 11 years were average, nine years were dry and one year was extreme wet. Yet during the next 14 years (1994 – 2011) drought period was more frequent and sever. Eight years were extreme wet while five years were extreme dry and average. Extreme drought 2011/2012 was analysed by Cindrić et al. (2015). Author stated that the above mentioned drought is characterised by extremely long duration in the continental region (eastern Croatia), with the highest magnitudes since the beginning of the twentieth century. Direct losses in agriculture caused by 2011/2012 drought were more than 64 and 105 million euros, respectively. In a term of plant production lack of water as well as excessive amount of water causes not only the yield reduction but the lower quality as well. For example, Marković et al. (2015) stated that during extremely dry years, irrigation linearly increased the yield of maize grain and maximum yields were obtained in fully irrigated treatment. As opposed to extremely wet growing season when the yield in fully irrigated treatment was almost 8% lower compared to rainfed treatment under excessive rainfall. Marković et al. (2017) concluded that it seems that future maize production based on dry farming might decline in eastern Croatia doe to more frequent drought stress conditions. Knowledge about the sensitivity of maize plants to drought stress has been widely studied. According to previous results of Eck (1984), Pandey et al. (2000), Banziger et al. (2002), Oktem (2008), Shirazi et al. (2011), Lack et al. (2012) water deficit reduces grain numbers/cob (GN/C), 1000-grain weight (1000-GW), cob weight (CW), cob length (CL) and grain yield (GY). Salemi et al. (2011) stated that the significance of hybrid was for GY, 1000-KW, grain number/row (GN/R) was significant while the effects of irrigation treatments on 1000-KW, GN/C and grain number per row (GN/R) were not significant. Many studies are giving some insights how will water (rainfall or irrigation water) affect yield or quality of crops yet little has been said about the impact of irrigation water in conditions were no N fertilizers is added. The main goal of this study was to determine the impact of (a) irrigation treatments and (b) maize hybrids in 0 kg N fertilized conditions on maize grain yield and yield components in three growing seasons characterised with weather extremes.

Materials and methods

A field trial was conducted at the research station of Agricultural institute in Osijek (45°32" N and 18°44" E, altitude 90 m) during the 2010 – 2012 period. The experimental site was a hydromeliorated hypogley (silty clay, loamy soil) with pH 7.5, humus content 1.56%, with a water holding capacity 36.6% and air capacity 5.3% in a 0 – 32 cm soil profile (Marković et al., 2015). The field study was conducted using three replications in a split – plot design with the irrigation scheduling as main plots and maize hybrids as subplot. Main plot had three irrigation treatment as follows: a1 = rainfed; a2 = 60 – 80% of field capacity (FC) and a3 = 80 – 100% FC while subplots were: (b1 = OSSK 596; b2 = OSSK 617; b3 = OSSK 602; b4 = OSSK 552). Irrigation scheduling was based upon measuring of soil water content (SWC) with the use of Granular Matrix Sensors (GMS, Watermark 200SS model). Sensors were buried at two depths (20 and 30 cm) on each irrigation plots. In average the SWC was measured two times per week or after irrigation and significant amount of rainfall (> 5 mm). GMS were calibrated for the soil at experimental site by comparing gravimetric measurements and sensor readings. The calibration curve is presented in Figure 1 (Marković, 2013).

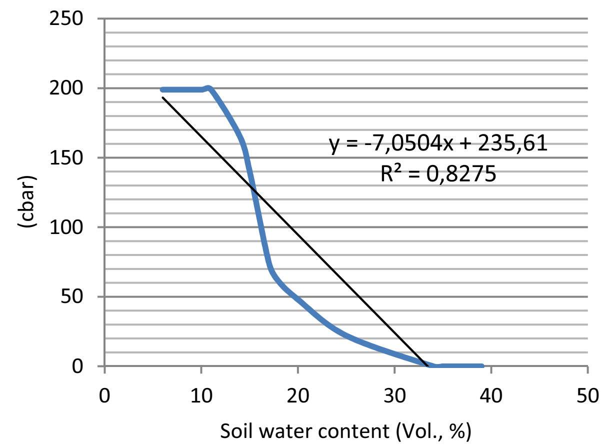

Figure 1. Calibration curve

Maize crop was irrigated by traveling sprinkler system (Typhon). The water was pumped from well (37 m, 5 – 7 l sec^{-1}) located near the experimental plot. The result of water quality analysis indicated that there is no restriction in use. The size of main plot was 235 m^2 while the size of subplot was 19.6 m^2. Each plot (main as well as subplot) was separated by 3 m pass to prevent lateral water movement. Maize hybrids were planted on May 6 (2010), May 3 (2011) and April 28 (2012) while harvested on 12 November (2010), 3 November (2011) and 5 November (2012). Planting space between the rows was 0.70 m, 0.25 m inter row spacing and 10 m long plant rows. 75 kg ha^{-1} of P and K was applied in autumn while the remaining amount was applied before planting (75 kg P and K kg ha^{-1}). Plant samples were collected at harvesting time from each experimental plot. Grain yield was expressed at 14% moisture. Five cobs were sampled for the centre of each rows to measure yield components: HW, 1000-GW, CW, CL, CH, GN/C and GW. Weather data were collected from automatic weather station located 1.5 km from the study site. Groundwater levels during the growing period (2010 – 2012) were measured by using an observation well located near the experimental site. The analysis of variance was conducted to evaluate main and interaction effects by using a STATISTICA 7 (StatSoft, Inc. Tulsa, OK, USA) statistics and analytics software. Means among treatments were compared using Least Significant Difference (LSD) at P<0.05 probability by using a SAS statistical software (SAS Institute, Inc., Cary, NC, USA) for Windows.

Results and discussion

Weather conditions

The average weather conditions at Osijek area during the study are shown in Figure 2. In general, first growing season (April – September) of the study was wetter than the other two (2010 = 677; m; 2011 = 245 mm; 2012 = 291 mm; long term average (LTA) 1961 – 1990 = 368 mm). Heavy rainfall events occurred in month of

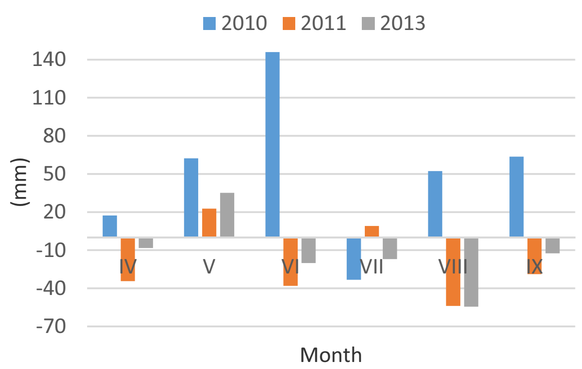

Figure 2. Rainfall aberration during 2010 – 2012 period

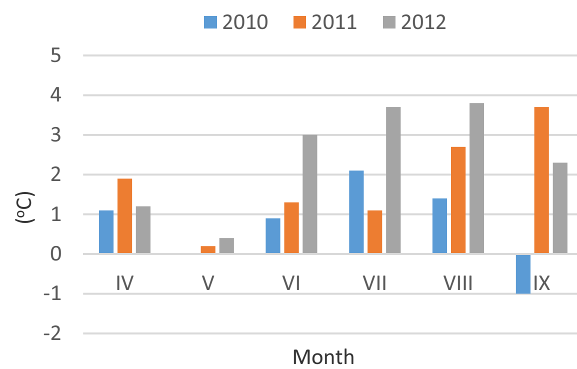

Figure 3. Average air temperature aberrations during 2010 – 2012 period

July with 146 mm of rainfall above long term average (LTA) and in month of August when amount of rainfall was 52 mm above LTA. Other two growing seasons where extremely dry (2011 = 244 mm) and dry (2012 = 291 mm) with lack of rainfall during the most sensitive stages for maize plant (June and July).

As for air temperatures as it is shown in Figure 3, they were above LTA during the period. Maximum air temperature during the 2010 growing season ranged from 26.5 to 35 ^{0}C, from 25.4 to 37.8 ^{0}C in 2011 and from 30.4 to 40.3 ^{0}C in 2012. Seasonal grass reference evapotranspiration (ET_o) in 2010 ranged from 2.2 to 4.2 mm day^{-1} (2010), from 2.8 to 4.1 mm day^{-1} (2011) and from 2.2 to 4.8 mm day^{-1} (2012) (Marković et al., 2015).

Soil moisture condition

Amount of irrigation water added in one irrigation event was 35 mm (35 l/m^2). This is for all irrigation treatments. Seasonal amount of irrigation water applied to each irrigation plot is presented in table 1. In total 35 (a2) and 105 mm (a3) irrigation water was added during the wet growing season 2010. Only one irrigation event was on a2 irrigation treatment while three irrigation treatment on a3 irrigation plots. The situation was considerably different during extremely dry 2011 and 2012 when in total 105 and 175 mm of irrigation water was added on a2 and 245 mm on a3 irrigation plots, respectively.

Table 1. Amount of irrigation water and number of irrigation events

Year	2010		2011		2012	
Irrigation scheduling	mm	n	mm	n	mm	n
a2	35	1	105	3	175	5
a3	105	3	245	7	245	7

mm = amount of irrigation water; n = number of irrigation events

Groundwater level considerably varied across growing seasons. In extremely wet growing season 2010 groundwater level was very high, it ranged from 20 cm in July to 140 cm at the end of the growing season (August). In 2011 and 2012 groundwater level was very low, it ranged from 180 (May) and 310 cm (June) to 350 and 420 cm (August), respectively.

The results of measuring SWC was previously presented by Marković et al. (2015). During the wet growing season SWC ranged from 0 cbar (July) to 91 cbar (August) on rainfed plot (a1), from 1.2 to 80 cbar on a2 and from 3.8 to 67 cbar on a3 irrigation treatment. In second year of the study SWC on rainfed plots ranged from 55 to 190 cbar. Furthermore, from 32 to 83 cbar on a2 and from 7 to 42 cbar on a3 irrigation treatment. In last year of the study SWC ranged from 0 to 188 cbar on a1, from 0 to 87 cbar in a2 and from 0 to 48 cbar in a3 irrigation treatment.

Yield and yield components

The yield results as well as yield components considerably varied across growing seasons doe to extreme weather conditions during the study period. Therefore, the effect of the irrigation scheduling as well as the impact of maize hybrid will be presented for each year separately.

Extremely wet growing season 2010

In average GY in irrigation treatment ranged from 5.9 t ha^{-1} (a3) to 6.3 t ha^{-1} (a2). Irrigation treatments in extremely wet growing season 2010 unexpectedly reduced grain yield for 1.7% on a3 irrigation treatment (Table 2). This result is previously explained by Marković et al. (2015) and Marković et al. (2017). Author claims that the yield reduction came as a result of excessive amount of irrigation water doe to the setup of GMS sensors on 30 cm deep. Author suggested that this depth is adequate for average climatic years yet for extreme wet growing season such as 2010 the installation depth should be deeper because the high groundwater level. Also Shirazi et al. (2011) reported that according to their findings the grain yields were strongly supported by the yield contributing characters. Furthermore, that yield increased up to a certain level of irrigation and then decreased. In our study similar result was obtained for CW (a1 = 0.78; a3 = 0.66), CL (a1 = 16.12; a3 = 14.94) and 1000-GW (a1 = 284; a3 = 254). This was opposite to CH since the irrigation treatment increased ($P<0.01$) CH for 16.4%.

As it is shown in table 3, all tested variables except the HW significantly ($P<0.01$) varied across maize hybrids. The highest yield (6.1 t ha^{-1}) and 100-GW (286 g) was recorded for b3 = OSSK602. The highest CL (16.1 cm) and CH (88.7 cm) was recorded for b1 = OSSK596. Furthermore, the highest GN/C (474) and HW (69.6) was recorded for b2 = OSSK617.

Table 2. Influence of irrigation scheduling on maize grain yield and yield components (2010)

	GY	CW	CL	CH	GN/C	1000-GW	HW
Rainfed	6.0	0.78	16.12	71.67	463	284	64.5
60-100%	6.3	0.67	14.95	84.09	438	259	69.9
80-100%	5.9	0.66	14.94	83.42	433	254	70.0
F	12.39**	10.37**	4.792*	9.568**	2.046$^{n.s.}$	18.138**	3.39$^{n.s.}$
$LSD_{0.05}$	0.561	0.06	0.905	6.590	32.89	10.906	3.227
$LSD_{0.01}$	0.755	0.08	1.227	8.931	44.58	14.780	4.373

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P<0.01

Table 3. Influence of maize hybrid on maize grain yield and yield components (2010)

	GY	CW	CL	CH	GN/C	1000-GW	HW
OSSK596	5.3	0.70	16.1	88.7	459	260	68.4
OSSK617	5.7	0.77	15.5	78.2	474	272	69.6
OSSK602	6.1	0.69	15.1	78.2	399	286	67.9
OSSK552	5.2	0.64	14.8	73.8	448	246	69.5
F	4.056*	10.37**	4.792**	9.568**	2.046**	18.138**	3.39$^{n.s.}$
$LSD_{0.05}$	0.561	0.061	0.906	6.590	32.89	10.906	3.227
$LSD_{0.01}$	0.755	0.083	1.228	8.932	44.58	14.780	4.373

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P<0.01

Table 4. Influence of irrigation scheduling on maize grain yield and yield components (2011)

	GY	CW	CL	CH	GN/C	1000-GW	HW
Rainfed	5.6	0.95	17.45	113	514	305	73.2
60-100%	6.0	0.80	16.38	111	517	269	73.0
80-100%	6.8	0.96	18.31	122	490	330	73.9
F	17.70**	1.452$^{n.s.}$	3.28$^{n.s.}$	1.82$^{n.s.}$	0.228$^{n.s.}$	20.774**	2.063$^{n.s.}$
$LSD_{0.05}$	0.399	0.209	1.552	12.22	89.48	19.66	0.983
$LSD_{0.01}$	0.541	0.283	2.104	16.56	121.26	26.65	1.332

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P<0.01

Extremely dry growing season 2011

Opposite to previous growing season in extremely dry growing season 2011 irrigation treatment (P<0.01) increased grain yield for 7.1% (a2) and 21.4% (a3). This result is in agreement Pandey et al. (2000). Author claims that the drought stress causes decrease in leaf area index and that the reduction in yield is observed because of low photosynthesis. Furthermore, they reported that the highest leaf area index for corn was obtained in well-irrigated conditions. Lack et al. (2010) stated that the highest grain yield in their study was obtained in optimum irrigation treatment. Also they reported that drought severe stress reduced grain yield by 63% compared to the optimum irrigation condition and that this reduction was mainly due to reduction in GN/C. As for yield components in our study only 1000-GW was significantly (P<0.01) increased for 8.2% (Table 4). This results are comparable to those observed earlier by Banzinger et al. (2000) who reported that as amount of water applied increased 1000-GW is increased. Although, author claims the same for GN/C which in our study is comparable to our results only in growing season 2012. Similarly, to results of our study also Shirazi et al. (2012) reported significant variation for 100-GW owing to differences in irrigation treatments.

As it is presented in table 5, the influence of maize hybrid was significant for GY and HW (P<0.01) and 1000-GW (P<0.05). Like in previous growing season the highest GY was recorded for b3 = OSSK602 (6.8 t ha^{-1}). Significantly (P<0.01) higher HW was recorded for b4 = 75.7 kg hl^{-1}. Significant influence of maize hybrid (P<0.05) was on 1000-GW. It ranged from 287 (b4) to 323 (b3).

Dry growing season 2012

During the last year of the study the influence of irrigation treatment was significant for all tested variables except the CL (Table 6). Irrigation treatment increased (P<0.01) GY for 2.6% (a2) and for 9% (a3). As for yield components the highest CL (24.4 cm); CH (136 cm); GN/C (701) was obtained on a2 irrigation treatment. The highest CW (1.79 kg) and 1000-GW was recorded on a3 irrigation treatment (P<0.01). Irrigation treatment reduced (P<0.05) HW on a3 as it is presented in table 6. The result is similar to one obtained by Oktem (2008) who reported that GN/C decreased with increasing deficiency in irrigation water while Pandey et al. (2000) stated that GN/C in their study were reduced from 20% to nearly 50% due to water stress. Shirazi et al. (2011) stated that the GN/C were

Table 5. Influence of maize hybrid on maize grain yield and yield components (2011)

	GY	CW	CL	CH	GN/C	1000-GW	HW
OSSK596	5.4	0.90	17.25	121	502	297	73.1
OSSK617	5.9	0.93	17.87	115	536	298	73.5
OSSK602	6.8	0.91	16.99	119	481	323	71.3
OSSK552	6.4	0.87	17.44	105	510	287	75.7
F	24.9**	$0.091^{n.s.}$	$0.348^{n.s.}$	$2.264^{n.s.}$	$0.401^{n.s.}$	3.811*	21.245**
$LSD_{0.05}$	0.346	0.241	1.79	14.11	103.3	22.71	1.135
$LSD_{0.01}$	0.469	0.327	2.43	19.13	140.0	30.77	1.538

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P < 0.01

Table 6. Influence of irrigation treatment on maize grain yield and yield components (2012)

	GY	CW	CL	CH	GN/C	1000-GW	HW
Rainfed	7.8	1.15	20.2	116	578	340	66.9
60-100%	8.0	0.82	24.4	136	701	361	69.9
80-100%	8.5	1.79	22.1	126	693	363	69.8
F	80.5**	0.47**	$1.514^{n.s.}$	17.14**	7.482**	16.159**	5.579*
$LSD_{0.05}$	0.487	0.217	4.991	7.093	73.499	9.003	2.106
$LSD_{0.01}$	0.659	0.293	6.764	9.612	99.606	12.201	2.854

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P < 0.01

Table 7. Influence of maize hybrid on maize grain yield and yield components (2012)

	GY	CW	CL	CH	GN/C	1000-GW	HW
OSSK596	6.2	1.17	21.9	132	648	355	68.4
OSSK617	7.9	1.31	21.1	122	670	359	69.2
OSSK602	8.7	1.29	20.4	127	613	373	67.9
OSSK552	9.7	1.24	25.5	121	698	332	70.1
F	5.96**	$0.471^{n.s}$	$1.303^{n.s.}$	3.493*	$1.524^{n.s.}$	23.08**	$1.298^{n.s.}$
$LSD_{0.05}$	0.422	0.250	5.763	8.189	84.869	10.396	4.312
$LSD_{0.01}$	0.571	0.339	7.811	11.099	115.02	14.089	3.295

GY = grain yield (t/ha); CW = cob weight (kg); CL = cob length (cm); CH = cob height (cm); GN/C = grain number/cob; 1000-GW = 1000 grain weight; HW = hectolitre weight (kg/hl); * = P<0.05; ** = P < 0.01

significantly affected due to application of irrigation water. In their study the lowest amount of grains was obtained in control plots.

GY varied (P<0.01) across maize hybrids (Table 7) and it ranged from 6.2 t ha^{-1} (b1) to 9.7 t ha^{-1} (b4). Like in previous two growing seasons the highest 1000-GW (P<0.01) was recorded for b3 hybrid (323). The CH ranged from 121 cm (b4) to 132 cm (b1).

As for irrigation x hybrid interaction (a x b) in the first year of our study the significant (P<0.01) interaction was recorded for 1000-GW and CW while in second year of our study for 1000-GW and GY.

Conclusion

Interests in how to moderate the negative impact of climate change to crop production is continuously increasing doe to frequent periods of drought as well as flood events in Republic of Croatia. Our study proves that the efficiency of irrigation management is closely connected to the environmental conditions, primarily due to amount of rainfall and groundwater level as well. It clearly demonstrates that not only the maize grain yield but also the quality of maize is influenced not only by environmental conditions but the efficiency of agricultural management in specific growing seasons. In extreme wet growing season the setup of irrigation sensors should be adjusted to groundwater level. It is recommended to use hybrid with good tolerance to drought as well the excessive amount of water.

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