Response of Maize (*Zea mays* L.) Grain Yield and Yield Components to Irrigation and Nitrogen Fertilization

Utjecaj navodnjavanja i gnojidbe dušikom na urod i komponente uroda zrna kukuruza (*Zea mays* L.)

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Abstract

Grain yield of maize is mostly affected by amount of available water and nitrogen and correlated to yield components. In this 2-years study the influence of different irrigation water amounts (a1=rainfed; a2=60-100% field water capacity (FWC); a3=80-100% FWC), nitrogen fertilizer levels (b1=0 kg*N*ha^{-1}; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}) and hybrids (c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885) on grain yield and yield components was tested. Furthermore the correlation analysis as well as direct and indirect path coefficients were used to analyse the connection between yield and yield components (grain number/cob, grain weight, 1000 grain weight, cob length, cob weight) across tested treatments. The influence of all tested factors was significant (P<0.05) in both years of study. Specific study results were obtained in extremely wet year 2010 when irrigation water reduced grain yield and yield components (a1=9.9; a2=8.8; a3=7.8 t*ha^{-1}). Opposite to year 2013 when irrigation water increased grain yield as well as yield components (a1=8.9; a2=9.7; a3=10.3 t*ha^{-1}). Nitrogen fertilizer was significant to all tested variables in both years of the study (b1=5.7; b2=9.2; b3=11.7 t*ha^{-1} in 2010 and b1=6.3; b2=8.9; b3=10.6 t*ha^{-1} in 2013). Generally, the greatest amount of nitrogen fertilizer the larger yield or yield components are achieved. The influence of hybrid was significant for all tested variables with exemption to 1000 grain weight and grain weight/cob during growing season 2013. In both years of the study hybrid c2 OS5997 achieved the highest yield as well as yield components. Correlation analysis showed strong positive correlation between yield and cob weight (r=0.77 (2010); r=0.84 (2013)) what is confirmed with direct and indirect path analysis test.

Key words: correlation, irrigation, nitrogen fertilizer, maize hybrids, path analysis, yield, yield components

Sažetak

Urod zrna kukuruza varira u odnosu na količinu pristupačne vode i dušika te o komponentama uroda. Cilj ovoga rada bio je proučiti utjecaj različitih tretmana navodnjavanja (a1= bez navodnjavanja; a2=60-100% poljskog vodnog kapaciteta (PVK); a3=80-100% PVK), gnojidbe dušikom (b1=0 kg*N*ha-1; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}) te hibrida (c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885) na urod zrna i komponente uroda. Nadalje proučiti korelacijsku povezanost između uroda i komponenti uroda (mase zrna/klipu, apsolutna masa, broj zrna/klipu, dužina klipa, masa klipa). Svi čimbenici u istraživanju značajno (P<0.05) su utjecali na ispitivana svojstva u obje godine istraživanja. Tijekom ekstremno vlažne 2010. godine navodnjavanje je neočekivano snizilo urod zrna na oba tretmana navodnjavanja (a1=9.9; a2=8.8; a3=7.8 t*ha^{-1}) dok je tijekom vegetacije 2013. godine urod zrna povećan na oba tretmana navodnjavanja (a1=8.9; a2=9.7; a3=10.3 t*ha^{-1}). Gnojidba dušikom povećala je urod zrna na oba gojidbena tretmana i obje godine (b1= 5.7; b2=9.2; b3=11.7 t*ha^{-1} u 2010. i b1=6.3; b2=8.9; b3=10.6 t*ha^{-1} u 2013. godini). U pravilu urod zrna jednako kao i komponente uroda rastao je povećanjem količine dodanoga gnojiva. Hibrid je značajno utjecao na sva ispitivana svojstva s izuzetkom apsolunte mase i mase zrna/klipu tijekom 2013. godine. Analiza korelacijske povezanosti ukazala je na jaku pozitivnu vezu između uroda zrna i mase klipa ((r=0.77 (2010); r=0.84 (2013)) što je potvrđeno rezultatima direktne i indirektne path analize.

Ključne riječi: gnojidba dušikom, hibrid kukuruza, komponente uroda, korelacija, navodnjavanje, path analiza, urod

Introduction

Maize (*Zea mays* L.) is important cereal used as human and animal feed as well as a raw material for different agro-based industries. Maize growing is influenced by many environmental factors (Wolf and Van Diepen, 1995; Olesen and Bindi, 2002; Kovačević et al., 2009; Olesen et al., 2011), management systems (Tsai et al., 1992; Tolk et al., 1999; Pandey et al., 2000; Kirda et al., 2005; Josipović et al., 2012) and genetic factors. Clark et al. (1999), Abbas et al. (2005), Hammad et al. (2012) and Azizian and Speaskhah (2014) have stated that amount of plant available water and nitrogen are the most important factors for plant production. Grain yield (GY) in maize like other cereals is the product of cobs number (CN) per unit area, number of grains cob^{-1} (GN cob^{-1}) and 1000-grain weight (Abbas et al., 2005). Some previous studies have shown that maize yield and yield components are significantly affected by amount of available nitrogen (Abbas et al., 2005; Carpici and Celik, 2010), available water (Abbas et al., 2005; Dağdelen et al., 2008) and environment (Carpici and Celik, 2010). Khayatnezhad et al. (2010) have found that the cob weight (CW) and rows number (RN) are significantly increased when 150 kg*N*ha^{-1} was added compared to the control plots (0 kg*N*ha^{-1}). Also, nitrogen fertilization increased cob number (CN), number of plants m^2, 1000-grain weight (1000-GW) and grain number (GN) (Abbas et al., 2005). As for irrigation, significantly higher values for grain weight (GW), cob length (CL), plant height (Carpici and Celik, 2010; Istanbulluoglu et al., 2002; Dağdelen et al., 2008), CN plant^{-1}, CN m^2, GN cob^{-1} and 1000-GW (Abbas et al., 2005.; Oktem, 2008) are obtained in fully irrigated plots compared to rainfed plots (control). Yield of maize grain is potentially correlated to yield components. Khayatnezhad et al. (2010) stated that the following yield components have the most significant direct influence on GY: leaf area index (LAI), leaf area (LA), CW, GN, CL, cob diameter (CD), 1000 GW and plant height (PH). Geetha and Jayaraman (2000), Kumar and Kumar (2000), Mohan et al. (2002) and Oktem (2008) stated that GN*have the most significant direct influence on GY. According to some other research results strong, positive correlation was determined between the GY and the RN cob^{-1} (Agrama, 1996; Corke and Kannenberg, 1998; Manivanannan, 1998; Mohan et al., 2002), between the GY and CL (Mohan et al., 2002) and between the GY and CW (Kumar and Kumar, 2000). Furthermore, Khayatnezhad et al. (2010) found that the strongest positive correlation (r=0.796**) was between GY and 100-GW. The objectives of this study where to: (1) quantify the GY and yield components response to different irrigation water levels, nitrogen fertilizer levels and hybrid, (2) to analyse which of yield components correlated best to GY, (3) to quantify the efficiency of different irrigation treatment and nitrogen fertilizer level and (4) to provide some useful hybrid performance testing information under the ecological conditions of the eastern Republic of Croatia.

Materials and methods

Site description

Field experiment was carried out in the 2010 and 2013 growing seasons on silty clay loamy soil at the trial site of Agricultural Institute Osijek, eastern Republic of Croatia (45^{o}32'' N and 18^{o}44'' E, altitude 90 m). The field experiment was set up as a split split-plot design in three replicates. The soil at the trial site is hypogley (hydro-meliorated) with its main characteristics presented in Table 1 (Marković et al., 2015). Weather data were collected from Meteorological and hydrological serivse. The automatic weather station was located 1.5 km from the trial location. Average weather conditions at Osijek area during the study are shown in Table 2. Both growing seasons were warmer and wetter than long term average (LTA, 1961 – 1990 = 368 mm, 17.5 ^{0}C).

The growing season 2010 was characterised by extreme weather events. Total amount of rainfall in April – September period was 676.6 mm which is for 84% above the LTA for Osijek area (Table 2). Rainfall aberration was followed by extreme weather events when 107 mm of rainfall was registered in one day (22. July). Varieties of problems occurred for summer crops on farms which came as a result of natural disaster of flooding and excessive rainfall. Despite the water logging there was no yield reduction in our study since the surface water was removed by temporary drainage ditches. As for second year of our study amount of rainfall was for 22% higher than LTA (Table 2). However lack of rainfall occurred during summer months when the water shortage was redeemed with irrigation water.

Table 1. Properties of the soil

Tablica 1. Svojstva tla

Depth (cm)	WC[a] (%)	AC[b] (%)	BD[c] ($g*cm^{-3}$)	Porosity (%)	CC[d] %	Humus (%)	pH (H_2O)	N (%)
0-32	36.57	5.25	2.58	41.82	32.5	1.56	7.5	0.13
32-50	35.59	6.24	2.65	41.83	31.3			

[a] = water capacity

[b] = air capacity

[c] = bulk density

[d] = clay content

Table 2. Values of daily average air temeperature (Ta, ^{0}C), maximum air temperature (Tmax, ^{0}C), minimum air temperature (Tmin, ^{0}C), sunshine hours (S, h), relative humidity (RH, %), winds speed (WS, $m*s^{-1}$), rainfall (R, mm)

Tablica 2. Vrijednosti srednje dnevne temperature zraka (T, ^{0}C), maksimalne temperature zraka (Tmax, ^{0}C), minimalne temperature zraka (Tmin, ^{0}C), sati sijanja sunca (S, h), relativna vlažnost zraka (RH, %), brzina vjetra (WS, $m*s^{-1}$), oborine (R, mm)

Year	Month	Ta	Tmax	Tmin	S	RH	WS	R
2010								
	April	12.4	26.5	2.6	6.9	74	1.8	71
	May	16.5	28.4	7.0	5.5	76	2.1	121
	June	20.4	34.2	9.4	7.3	78	1.8	234
	July	23.2	34.2	11.7	9.5	74	1.7	32
	August	21.7	35.0	9.0	9.9	75	1.5	111
	September	15.6	27.2	6.0	4.8	82	1.5	108
	Average/Total	18.3	30.9	7.6	7.3	77	1.7	677
2013								
	April	13.1	30.4	0	7.8	70	1.7	45
	May	16.7	30.3	6.4	6.6	75	2.0	119
	June	20.0	35.5	8.6	8.8	74	1.7	64
	July	22.9	38.4	8.6	11.8	65	1.5	64
	August	22.9	38.2	11.2	9.3	64	1.6	33
	September	15.9	28.0	5.2	5.6	75	1.6	124
	Average/Total	18.6	33.5	6.7	6.7	71	1.7	448
1961-1990								
	April	11.0	28.5	-0.5	5.8	73	1.8	54
	May	16.5	29.6	3.9	6.8	73	1.7	59
	June	19.5	32.3	7.9	7.6	74	1.6	88
	July	21.2	34.2	9.6	8.4	72	1.5	65
	August	20.3	33.7	8.3	8.0	74	1.5	59
	September	16.6	31.2	4.6	6.5	78	1.4	44
	Average/Total	17.5	31.1	5.6	7.2	74	1.6	368

Although the average air temperature during growing seasons (Table 2) was 1 ^{0}C above LTA, it is important to emphasise the extremely warm summer months when air temperatures in July and August where for 2.1 ^{0}C and 1.7 ^{0}C (2010) and for 1.5 ^{0}C and 2.6 ^{0}C (2013) above LTA (Table 2).

Irrigation treatment

Each growing season, three irrigation treatments were studied included rainfed treatment (a1=control) which received no irrigation water. Treatments on irrigated plots were designed to attain soil water content on: a2=60-100% field water capacity (FWC) and a3=80-100% FWC. Plots were irrigated with a traveling gun sprinkler system. The system operated at the average speed of 15 $m*h^{-1}$. Water for this system was pumped from a well (37 m deep) located near the experimental site. Working width of sprinkler system was up to 30 m and average speed of system was 18 cm/min. Amount of irrigation water added in one irrigation event was same for both irrigation treatments (35 mm, 1.5 $l*min^{-1}$). Amounts of irrigation water added on each irrigated plot (a2 and a3 plots) are presented in Table 3.

Table 3. Irrigation events, amount of water added on irrigated plots and rainfall during growing seasons 2010/2013

Tablica 3. Obroci navodnjavanja i oborine tijekom razdoblja vegetacije 2010/2013

Irrigation treatment	a2[a]		a3[b]		Rainfall (April-September)
Year	n[c]	(mm)	n[c]	(mm)	(mm)
2010	1	35	3	105	676.6
2013	3	105	6	210	447.6

[a] 60-100% FWC

[b] 80-100% FWC

[c] n=number of irrigation events

Irrigation efficiency (IE) was tested according to Takac et al. (2008) procedure: IE = (Yi/Yd) * 100, where Yi is the yield in irrigated plots while Yd is yield in dry farming. Efficiency of applied irrigation water (irrigation water use efficiency, IWUE) on each irrigation treatment are tested according to Boss (1979), IWUE = Yi – Yd/I, where Yi stands out for yield on irrigated plots, Yd stands out for yield on dry farming while I represents the amount of water (mm) added on each irrigation plots during growing season.

Irrigation scheduling was based on direct measuring of soil water content with electrical resistance sensing device GMS (granular matrix sensor, Watermark 200SS). GMS measures soil moisture that can be converted to soil water potential (Ψ_{soil}) by using a different calibration formula provided in literature or calibrating them for specific soil type (Intrigliolo et al., 2004). Sensors were buried at two depths (20 and 30 cm). Soil moisture represents the average of measurements for two sensors depths. Measurements were taken twice a week or after irrigation and rainfall events.

Fertilization treatment

Each growing season, three nitrogen fertilization treatments were studied including control plot (b1 = control). Total amounts of nitrogen fertilizer was: b2=100 kg*N*ha^{-1} and b3=200 kg*N*ha^{-1}. Basic NPK fertilization was performed in autumn with following amounts of fertilizer: 1/3 of nitrogen and ½ of P and K. Spring fertilizer application was performed in April with urea (46%), ½ P and K 0:20:30 – 250 kg*ha^{-1}, P_2O_5 (45%) – 50 kg*ha^{-1} and K_2O (60%) – 75 kg*ha^{-1}. Side dressing with CAN (27%) was performed along with two inter row cultivations during growing season. Yield response to applied N was calculated according to O'Neeil et al. (2004), N response (%) = (Adequate N yield – Deficit N yield)/Deficit N yield * 100. Fertilization use efficiency (FUE) was calculated as follows: (GY on fertilized plot (kg) – GY on unfertilized plot (kg))/Amount of fertilizer applied (kg).

Maize hybrids

Maize hybrids were planted on May 6 (2010) and May 4 (2013) and harvested on November 12 (2010) and October 29 (2013). Following maize hybrids were used in this research: OSSK515 (c1), OS5997 (c2), OS5775 (c3) and OS5885 (c4). Hybrid performance testing was performed to compare the results (yield and yield parameters) of tested hybrids with the ones who are already registered in the Republic of Croatia, or present in the list of authorised varieties in EU. Maize hybrids were planted in two 10 m long rows. Space between rows was 70 cm while 25 cm inter-row spacing.

Data collection and analysis

Five plants from the middle of each irrigation, N fertilization and hybrid plots were collected during harvest time to asses following yield components: cob height (CH), RN cob^{-1}, GN row^{-1}, GW and CL. The statistical analyses of GY and yield component data which included analysis of variance and Fisher's least significant differences test (LSD), where conducted using the SAS statistical software (SAS Institute, Inc., Cary, NC, USA) for Windows. Pearson correlation coefficient (average across irrigation, nitrogen fertilizers and hybrid treatments, n = 108) method was conducted using STATISTICA 7 (StatSoft, Inc. Tulsa, OK, USA) statistics and analytics software package. Path analysis was performed by using Microsoft excel in order to determine direct and indirect effects of tested variables related to GY (Akintunde, 2012).

Results and discussion

Influence of irrigation (a)

The effects of irrigation scheduling, nitrogen levels and hybrids in growing period 2010 are presented in table 4. GY was significantly ($P<0.05$) affected by irrigation scheduling in both years of the study. Reduction in GY occurred on irrigated plots (a2=11%; a3=22% lower in compare to rainfed) during extremely wet growing period 2010. As previously described by Marković et al. (2015) GY reduction came as a result of excessive amount of water caused by irrigation events. Same author clams that the sensor depth installation (20 – 30 cm) is adequate for average climatic years yet for extreme growing season like 2010 the installation depth should be deeper. In conditions like that slow response of GMS to drying and wetting cycles gives unreliable data. It is clear that in growing season 2010 IWUE was negative: -3.14 kg*mm^{-1} (a2) and -2 kg*mm^{-1} (a3, table 4). In the same growing season IE was 88.9% (a2) and 78.8% (a3).

Table 4. Effect of irrigation scheduling, nitrogen levels and hybrids on grain yield, yield components, IE, IWUE, Nresponce and NUE (2010)

Tablica 4. Utjecaj navodnjavanja, gnojidbe dušikom i hibrida na urod zrna, komponente uroda, učinkovitost navodnjavanja, učinkovitost norme navodnjavanja, učinkovitost N gnojidbe (2010)

Treatment	Grain yield	1000 grain weight	Grain weight	Grain number/ row	Cob length	Cob weight	IE[IV]	IWUE[V]
			Irrigation scheduling[I]					
a1	9.9^{a}	299.4^{a}	185.7^{a}	41^{a}	19.2^{a}	1.05^{a}		
a2	8.8^{b}	272.8^{b}	150.7^{b}	37^{b}	17.5^{b}	0.87^{b}	88.9	-3.14
a3	7.8^{c}	264.4^{b}	148.9^{b}	38^{b}	17.8^{b}	0.84^{b}	78.8	-2
$LSD_{0.05}$	0.48	24.67	12.39	2	0.75	0.07		
F-value	36.93	4.4	22.3	8.8	11.4	3.2		
			Nitrogen level[II]				Nr.[VI]	NUE[VII]
b1	5.7^{c}	256.9^{b}	122.5^{c}	34^{c}	15.9^{c}	0.7^{c}		
b2	9.2^{b}	271.0^{b}	163.4^{b}	39^{b}	18.5^{b}	0.9^{b}	61.4	35
b3	11.7^{a}	308.6^{a}	199.3^{a}	42^{a}	20.0^{a}	1.2^{a}	105.3	30
$LSD_{0.05}$	0.48	24.67	12.39	2	0.75	0.07		
F-value	307.5	9.3	76.5	38.0	58.2	3.2		
			Hybrid[III]					
c1	7.98^{c}	264.4^{b}	146.4^{b}	37^{c}	17.3^{b}	0.8^{b}		
c2	9.95^{a}	303.6^{a}	179.1^{a}	40^{a}	19.2^{a}	1.0^{a}		
c3	8.19^{c}	272.3^{b}	153.5^{b}	38^{bc}	18.3^{b}	0.9^{b}		
c4	9.28^{b}	275.2^{ab}	168.0^{a}	40^{a}	17.9^{b}	0.9^{a}		
$LSD_{0.05}$	0.56	28.49	14.30	2	0.87	0.07		
F-value	22.1	2.9	8.3	3.2	7.2	2.8		

[I] a1=rainfed; a2=60-100% FWC; a3=80-100% FWC

[II] b1=0 kg*N*ha-1; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}

[III] c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885

[IV] IE=irrigation efficiency (%)

[V] IWUE=irrigation water use efficiency (kg*mm^{-1})

[VI] N*=response (%)

[VII] NUE=nitrogen use efficiency (kg*kg^{-1})

[a, b, c]=Mean followed by different letters indicate statistically significant differences at the level of 5% for Duncan's Multiple Range Test

The GY results in growing season 2010 are opposite to growing season 2013 when GY in irrigated plots was increased by 11% (a2) and 13% (a3) when compared to rainfed (table 5). Similar results are obtained for yield components. Oktem (2008) stated that the highest GY was achieved in fully irrigated plots (100% evapotranspiration). Plavšić et al. (2007) in 2-years study with irrigation treatment and maize hybrids in Osijek area (trial site of Agricultural institute Osijek) found that the irrigation significantly increased GY.

Table 5. Effect of irrigation scheduling, nitrogen levels and hybrids on grain yield, yield components and (2013)

Tablica 5. Utjecaj navodnjavanja, gnojidbe dušikom i hibrida na urod zrna, komponente uroda, učinkovitost navodnjavanja, učinkovitost norme navodnjavanja, učinkovitost N gnojidbe (2013)

Treatment	Grain yield	1000 grain weight	Grain weight	Grain number /row	Cob length	Cob weight	IE[IV]	IWUE[V]
				Irrigation scheduling[I]				
a1	8.85^{b}	309.9^{b}	181.9^{c}	37^{b}	18.61^{b}	1.08^{c}		
a2	9.86^{a}	336.7^{a}	198.2^{b}	37^{b}	$19.02^{a,b}$	1.16^{b}	111	9.62
a3	10.03^{a}	343.7^{a}	224.9^{a}	38^{a}	19.43^{a}	1.28^{a}	113	5.62
$LSD_{0.05}$	0.34	19.52	3.15	1	0.45	0.07		
F-value	27.6	8.2	10.3	4.4	7.6	15.8		
				Nitrogen level[II]			Nr.[VI]	NUE[VII]
b1	6.26^{c}	263.3^{b}	201.7^{c}	29^{c}	15.19^{c}	0.96^{b}		
b2	8.88^{b}	312.8^{a}	232.3^{b}	33^{b}	17.26^{b}	1.02^{b}	41.9	43.8
b3	11.78^{a}	331.4^{a}	240.8^{a}	39^{a}	19.53^{a}	1.20^{a}	69.9	12.1
$LSD_{0.05}$	0.34	19.52	3.15	1	0.45	0.07		
F-value	585.5	7.7	60.8	90.6	93.8	61.8		
				Hybrid[II]				
c1	7.09^{b}	242.7^{a}	147.9^{a}	27^{b}	13.37^{b}	0.83^{b}		
c2	7.75^{a}	255.7^{a}	162.3^{a}	29^{a}	14.34^{a}	0.95^{a}		
c3	6.96^{b}	254.3^{a}	146.2^{a}	29^{a}	14.07^{a}	0.86^{b}		
c4	6.94^{b}	242.6^{a}	148.7^{a}	27^{b}	14.31^{a}	0.88^{b}		
$LSD_{0.05}$	0.39	22.5	15.02	1	0.515	0.08		
F-value	13.1	1.4	6.6	11.3	23.2	4.8		

[I] a1=rainfed; a2=60-100% FWC; a3=80-100% FWC

[II] b1=0 kg*N*ha-1; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}

[III] c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885

[IV] IE=irrigation efficiency (%)

[V] IWUE=irrigation water use efficiency (kg*mm^{-1})

[VI] Nr=response (%)

[VII] NUE=nitrogen use efficiency (kg*kg^{-1})

[a, b, c]=Mean followed by different letters indicate statistically significant differences at the level of 5% for Duncan's Multiple Range Test

Considerably higher IE and IWUE was during growing season 2013 compared to 2010. The IE was 111% (a2) and 113% (a3), while the IWUE was 9.62 kg*mm^{-1} (a2) and 5.62 kg*mm^{-1} (a3). Higher IE as well as the IWUE was in extremely warm and dry summer 2013. This result is similar to previous findings of Marković et al. (2012). Authors claim that IE and IWUE was better in dry growing season in compare to average one. According to previous findings of Dağdelen et al. (2008) the WUE and IWUE in their study were different depending upon the treatments and did not significantly change when irrigation amount increased. In their study IWUE in average ranged from 1.37 to 1.90 kg*m^{-3}.

Dağdelen et al. (2008) have found some statistically significant differences (P<0.01) in GY and yield components between the different irrigation treatments. In their study GW ranged from 389.4 to 378.5 g where the highest GW was obtained in full irrigated plots. Furthermore, they found that KN was reduced (21 – 23%) when plants were exposed to water stress at tasselling stages while the CL ranged from 19 to 22 cm in irrigated plots.

In growing season 2010 irrigation scheduling significantly (P<0.05) reduced yield components as follows: 1000 grain weight for 8.9% (a2) and 11.7% (a3); GW for 18.9% (a2) and 19.8% (a3); CL for 8.9% (a2) and 7.14% (a3); CW for 17% (a2) and 20% (a3). There was no significant differences between a2 and a3 for all yield components in growing season 2010 (table 4). In the growing season 2013 irrigation scheduling significantly increased following yield components: 1000 grain weight for 8.6% (a2) and 10.9% (a3); GW for 9% (a2) and 23.6% (a3); CL for 2.2% (a2) and 4.4% (a3); CW for 7.4% (a2) and 18.5% (a3, table 5).

Influence of nitrogen fertilizer level (b)

Maize response to N fertilization was significant (P<0.05) for all tested variables in both years of the study. As shown in table 4 and 5 both nitrogen fertilizer rate gave significantly higher grain yield than control treatment in both growing seasons. GY was increased for 62% (a2) and 105.3% (a3) in growing season 2010 and for 41.9% (a2) and 70% (a3) in growing season 2013. The greater yield increment in growing season 2010 was due to greater amount of available water. This is in accordance to Djaman et al. (2012) and Prasad and Prasad (1988) statement. Author claim that N, P and K uptake increased with water supply. In our study generally, the greater N supply, the tested yield parameter is increased. In our study following yield components in growing season 2010 are increased for: 1000 grain weight for 5.5% (b2) and 20.1% (b3); GW for 33.4% (b2) and 62.7% (b3); CL for 16% (b2) and 25.2% (b3); CW for 40.3% (b2) and 71.6% (b3, table 4). This is in accordance to Abbas et al. (2005) and Khayatnezhad et al. (2010). They claim that increasing rates of nitrogen significantly enhanced the GW and GN. Ibrahim and Kandil (2007), El-Douby et al. (2001), Al-Aref et al. (2004) and Salwa and Al-Shormillesy (2005) also found that CL was significantly higher by increasing N rates as compared with control. However, Khazaei et al. (2010) indicated that the lowest N rate (120 kg*N*ha^{-1}) produced the most RN cob^{-1}. Also, Plavsić et al. (2007) stated that the lowest N rate (100 kg*N*ha^{-1}) produced the most KN cob^{-1}. The greater increase of yield components in extremely wet 2010 came as a result of available water. In growing season 2013 following yield components are increased for: 1000-GW for 18.8% (b2) and 25.9% (b3); GW for 15.2% (b2) and 19.4% (b3); CL for 13.6% (b2) and 28.6% (b3); CW for 6.25% (b2) and 25% (b3, table 5).

Considerably better N response was during extremely wet growing season 2010 compared to 2013 on both nitrogen fertilizer level (table 4, 5). As for different fertilizer level better N response was on b3 compared to b2 in both growing seasons. Nitrogen use efficiency (NUE) ranged from 30 kg*ha^{-1} (b3) to 35 kg*ha^{-1} (b2) during 2010 and from 12.1 kg*ha^{-1} (b3) to 43.8 kg*ha^{-1} (b2) during 2013. NUE increased with N rate in extremely wet 2010 and decreased with N rate in growing season 2013.

Abbas et al. (2005) reported that irrigation scheduling as well as nitrogen rate significantly affected GN and 1000-GW. In their study the highest GN and 1000-GW was obtained in irrigation treatments with -4 and -8 bar in compare with rainfed and -12 bar. As for nitrogen rates increasing rates of nitrogen application significantly enhanced the GN and 1000-GW. Increasing rate of nitrogen application increased 1000-GW up to 200 kg*ha^{-1} which is in accordance to results of our study (table 5).

Influence of maize hybrid (c)

The influence of hybrid on GY and yield components was year dependent. In average GY ranged from 7.98 (c1) to 9.95 t*ha^{-1} (c2, 2010) and from 6.94 to (c4) 7.75 t*ha^{-1} (c2, 2013). Result of our study agreed with the results of Wagar et al. (2007). They found significant differences among hybrids and stated that the differences among the various hybrids for the various components may be due to differences in genetic background of the hybrids. As it is shown in table 4 and 5, the c2 hybrid had significantly greater yield as well as tested yield components in both growing seasons. During the first year of our study hybrid had significant influence on all tested variables while in the second year of our study significant influence was on GY, GN, CL and CW. Plavšić et al. (2007) stated that in theirs study CL significantly varied depending on maize hybrids.

Interaction of tested factors

In this study only significant interactions are presented for both years of the study. During a first year of our study the only significant (P<0.05) interaction of tested factors on variables was the influence of irrigation x nitrogen interaction (a x b) on CL. An effect of a x b interaction on CL is presented with Figure 1 with 5% errors bars. In average CL ranged from 14.7 cm (a3b1) to 20.6 cm (a3b3).

In the second year of our study the significance of the interactions were variable dependent. As it is presented in Table 6 all combinations of the tested factors were significant (P<0.01) for GY. Furthermore, a x b (P<0.01) interaction GY ranged from 5.4 t*ha^{-1} (a2b1) to 12.2 t*ha^{-1} (a2b3, a3b3). In a x c interaction (P<0.05) GY ranged from 8.1 t*ha^{-1} (a1c2) to 10.3 t*ha^{-1} (a3c4). GY in b x c (P<0.01) interaction ragned from 5.4 t*ha^{-1} (b1c2) to 13 t*ha^{-1} (b3c4) while in a x b x c interaction GY ranged from 4.2 t*ha^{-1} (a2b1c2) to 13.9 t*ha^{-1} (a3b3c4). Plavšić et al. (2007) found that the highest grain yield was obtained in plots irrigated with the highest amount of irrigation water (80 – 100% FWC) and the 200 kg*N*ha^{-1} (a x b). The only significant interaction for 1000 GW was the effect of a x b. The interaction is presented with Figure 2 with 5% errors bars. In average 1000-GW ranged from 275 g (a1b1) to 370 g (a3b1).

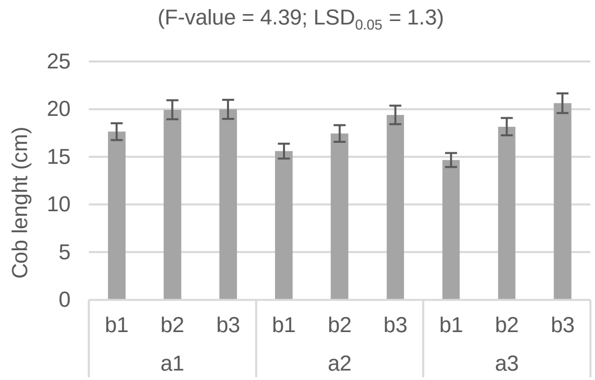

Figure 1. The effect of irrigation x nitrogen (a x b) interaction on cob length (CL) during growing season 2010 (cm, a1=rainfed; a2=60-100% FWC; a3=80-100% FWC; b1=0 kg*N*ha^{-1}, b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1})

Grafikon 1. Utjecaj interakcije navodnjavanje x dušik na dužinu klipa 2010. godine (cm, a1 = bez navodnjavanja; a2=60-100% PVK; a3=80-100% PVK; b1=0 kg*N*ha^{-1}, b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1})

Table 6. The effect of interactions irrigation, nitrogen, hybrid on grain yield (2013)

Tablica 6. Utjecaj interakcije navodnajvanja, dušika, hibrida na urod zrna (2013)

	b1 [II]				b2 [II]				b3 [II]			
	c1	c2	c3	c4	c1	c2	c3	c4	c1	c2	c3	c4
a1 [I]	6.4	4.7	6.7	6.8	10.2	10.2	6.7	10.1	10.9	9.3	11.8	12.5
a2 [I]	5.6	4.2	5.9	5.9	11.5	12.4	11.3	12.4	12.1	12.0	12.1	12.7
a3 [I]	7.5	7.2	6.9	7.2	9.6	11.6	10.4	11.3	11.4	11.6	11.7	13.9
bc [IV]	6.5	5.4	6.5	6.7	10.4	11.4	9.5	11.3	11.5	10.9	11.9	13.0
	Interaction ab [IV]					Interaction ac [IV]						
	b1 [II]	b2 [II]	b3 [II]			c1	c2	c3	c4			
a1 [I]	6.2	9.3	11.1			9.2	8.1	8.4	9.8			
a2 [I]	5.4	11.9	12.2			9.7	9.6	9.8	10.4			
a3 [I]	7.2	10.7	12.2			9.5	10.1	9.7	10.8			
Analysis of variance	ab [IV]	ac [IV]	bc [IV]	abc [IV]								
$LSD_{0.05}$	0.59	0.68	0.68	1.19								
$LSD_{0.01}$	0.78	0.91	0.91	1.57								
F test	19.81**	2.66*	9.98**	3.57**								

[I] a1=rainfed; a2 = 60 – 100% FWC; a3 = 80 – 100% FWC

[II] b1=0 kg*N*ha-1; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}

[III] c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885

[IV] ab=irrigation x nitrogen; ac=irrigation x hybrid; bc=nitrogen x hybrid; abc=irrigation x nitrogen x hybrid

[V] = *=P<0.05; **=P<0.01

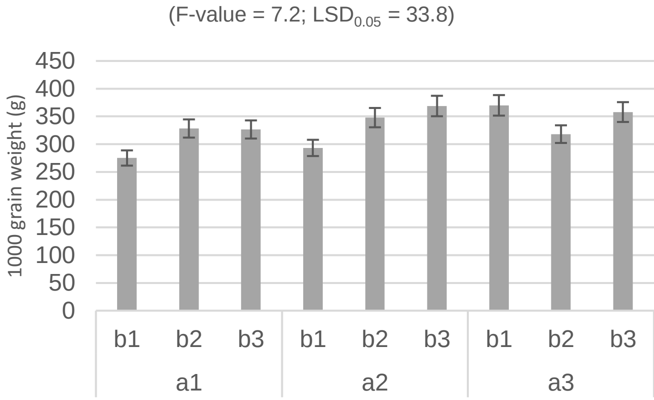

Figure 2. The effect of irrigation x nitrogen (a x b) interaction on 1000 grain weight during growing season 2013 (g, a1=rainfed; a2=60-100% FWC; a3=80-100% FWC; b1=0 kg*N*ha-1, b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1})

Grafikon 2. Utjecaj interakcije navodnjavanje x dušik (a x b) (g, a1 = bez navodnjavanja; a2=60-100% PVK; a3=80-100% PVK; b1=0 kg*N*ha-1, b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1})

Table 7. The effect of interaction irrigation, nitrogen, hybrid on grain weight in growing season 2013

Tablica 7. Utjecaj interakcije navodnjavanje, dušik, hibrid na masu zrna 2013. godine

	b1 [II]				b2 [II]				b3 [II]			
	c1	c2	c3	c4	c1	c2	c3	c4	c1	c2	c3	c4
a1 [I]	142	109	162	159	182	207	196	231	185	189	188	233
a2 [I]	123	123	125	148	204	219	201	225	233	247	259	272
a3 [I]	328	221	180	200	153	220	203	231	225	250	240	248
bc [IV]	198	151	156	169	180	215	200	229	214	229	229	251

	Interaction ab [IV]			Interaction ac [IV]			
	b1 [II]	b2 [II]	b3 [II]	c1	c2	c3	c4
a1 [I]	143	204	198	170	168	182	208
a2 [I]	130	212	253	187	196	195	215
a3 [I]	232	202	241	235	230	208	226

Analysis of variance	ab [IV]	ac [IV]	bc [IV]	abc [IV]
LSD 0.05	22.5	26.0	26.0	45.0
LSD 0.01	29.9	34.5	34.5	59.8
F test	19.8**	n.s.	4.8**	3.4**

[I] a1=rainfed; a2 = 60 – 100% FWC; a3 = 80 – 100% FWC

[II] b1=0 kg*N*ha-1; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}

[III] c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885

[IV] ab=irrigation x nitrogen; ac=irrigation x hybrid; bc=nitrogen x hybrid; abc=irrigation x nitrogen x hybrid

[V] = *=P<0.05; **=P<0.01

Table 8. The effect of interaction irrigation, nitrogen, hybrid on cob length in growing season 2013

Tablica 8. Utjecaj interakcije navodnajvanje, dušik, hibrid na dužinu klipa 2013. godine

	b1[II]				b2[II]				b3[II]			
	c1	c2	c3	c4	c1	c2	c3	c4	c1	c2	c3	c4
a1[I]	16.9	16.0	16.7	17.4	18.5	20.6	19.0	20.5	18.1	19.5	19.3	20.7
a2[I]	16.0	17.0	15.9	16.5	18.3	20.9	19.3	20.5	19.8	21.7	20.5	21.7
a3[I]	16.8	20.7	18.2	19.0	17.2	19.7	19.8	20.5	18.9	21.9	20.1	20.9
bc[IV]	16.6	17.9	16.9	17.6	18.0	20.4	19.4	20.5	18.9	21.0	19.9	21.1

	Interaction ab[IV]			Interaction ac[IV]			
	b1[II]	b2[II]	b3[II]	c1	c2	c3	c4
a1[I]	16.8	19.6	19.4	17.8	18.7	18.3	19.5
a2[I]	16.4	19.8	20.9	18.0	19.9	18.6	19.6
a3[I]	18.7	19.3	20.5	17.6	20.8	19.4	20.1

Analysis of variance	ab[IV]	ac[IV]	bc[IV]	abc[IV]
$LSD_{0.05}$	0.77	0.89	0.89	1.54
$LSD_{0.01}$	1.02	1.18	1.18	2.05
F test[V]	10.9**	2.6*	n.s.	n.s.

[I] a1=rainfed; a2 = 60 – 100% FWC; a3 = 80 – 100% FWC

[II] b1=0 kg*N*ha^{-1}; b2=100 kg*N*ha^{-1}; b3=200 kg*N*ha^{-1}

[III] c1=OSSK515; c2=OS5997; c3=OS5775; c4=OS5885

[IV] ab=irrigation x nitrogen; ac=irrigation x hybrid; bc=nitrogen x hybrid; abc=irrigation x nitrogen x hybrid

[V] *=P<0.05; ** = P<0.01

The effect of interaction irrigation, nitrogen, hybrid on CL (2013) is presented in Table 8. In interaction a x b (P<0.01) CL ranged from 16.4 cm (a2b1) to 20.9 (a2b3) while on a x c interaction (P<0.05) CL ranged from 17.6 (a3c1) to 20.1 cm (a3c4).

Correlation and regression analysis

Geetha and Jayaraman (2000), Kumar and Kumar (2000), Mohan et al. (2002) and Oktem (2008) have stated that GW have the most significant direct influence on maize GY, while Khazaei et al. (2010) indicated that highly significant positive correlation was observed between GY and GN. As it is shown in table 9., in the first year our study very strong and positive correlation was between GY and GW (r=0.66), CW (r=0.77), CL (r=0.75) and GN (r=0.74). In the second year of our study very significant (* = P<0.01) strong and positive correlation was between GY and CL (r=0.73), CW (r=0.84) and GN (r=0.71).

Table 9. Correlation coefficients (P<0.01) between tested variables (2010 and 2013)

Tablica 9. Koeficijenti korelacije (P<0.01) između promatranih varijabli (2010. i 2013. godine)

	Yield	CL[a]	GW[b]	CW[c]	1000 GW[d]	GN[e]
Yield		0.75	0.66	0.77	0.32	0.74
CL[a]	0.73		0.72	0.89	0.28	0.80
GW[b]	0.82	0.86		0.89	0.48	0.65
CW[c]	0.84	0.89	0.95		0.37	0.79
1000GW[d]	0.43	0.37	0.37	0.40		0.33
GN[e]	0.71	0.85	0.83	0.88	0.35	

[a] Cl = cob length

[b] GW = grain weight

[c] CW = cob weight

[d] 1000GW = 1000 grain weight

[e] GN = grain number

As previously stated by Caprici et al. (2010) the relationship between yield and yield related components vary with the ecological conditions. Geetha and Jayaraman (2000), Kumar and Kumar (2000), Mohan et al. (2002), Oktem (2008) stated that GN*has the most significant direct influence on maize yield. Furthermore, the results of our study are in accordance to Mohan et al. (2002), since author's claim that in their research results there is strong positive correlation between the GY and CL.

The results from our study indicate that the CW had the highest direct effect on GY. Also indirect effect of these variable via CL, GW and GN was highest in both years of our study (Table 10 (2010); Table 11 (2013).

Table 10. Path coefficient values for yield and yield components (2010)

Tablica 10. Path analiza uroda i komponenti uroda (2010)

Variable	Direct path coefficient	Indirect path coefficients				
		CL[a]	GN[b]	1000 GW[c]	GW[d]	CW[e]
Cob lenght	-0.05	-	-0.04	0.12	-0.04	-0.04
Grain number	-0.14	-0.12	-	-0.01	-0.11	-0.12
1000 grain weight	0.12	0.05	0.04	-	0.05	0.05
Grain weight/cob	0.19	0.16	0.15	-0.04	-	0.18
Cob weight	0.78	0.69	0.69	0.07	0.74	-
Total indirect coefficient		0.78	0.84	0.31	0.63	0.06

[a] CL = cob length

[b] GN = grain number

[c] 1000 GW = 1000 grain weight

[d] GW = grain weight

[e] CW = cob weight

Table 11. Path coefficient values for yield components (2013)

Tablica 11. Path analiza uroda i komponenti uroda (2013.)

Variable	Direct path coefficient	Indirect path coefficients CL[a]	GN[b]	1000 GW[c]	GW[d]	CW[e]
Cob length	0.18	-	0.15	0.05	0.13	0.16
Grain number	0.29	0.24	-	0.09	0.19	0.23
1000 grain weight	0.04	0.01	0.02	-	0.02	0.02
Grain weight/cob	-0.05	-0.04	-0.03	-0.02	-	-0.05
Cob weight	0.40	0.36	0.32	0.15	0.36	-
Total indirect coefficient		0.57	0.45	0.27	0.71	0.37

[a] CL = cob length

[b] GN = grain number

[c] 1000 GW = 1000 grain weight

[d] GW = grain weight

[e] CW = cob weight

Conclusions

In this study (1) the influence of irrigation water levels was year dependent. Maize grain yield as well as yield components was significantly reduced in extremely rainy growing season while significantly increased in average growing season; (2) the larger amount of nitrogen fertilizer increased yield and yield components as well; (3) consequently the irrigation water use efficiency as well as nitrogen use efficiency where year dependent; (4) while regardless of whether condition the most significant correlation as well as direct and indirect connection was established between grain yield and cob weight.

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