Influence of Irrigation Regimes at Different Growth Stages on Development and Yield in Maize (*Zea mays* L.)

H.S. Gharib[#], **A.S. EL-Henawy**[*] **and M.E. Meleha**[**]

*Agronomy Dept.; *Soil and Water Dept., Fac. Agric., Kafrelshiekh University, Kafr El-Shiekh and **Water Management Research Institute, National Water Research Center, Cairo, Egypt.*

$\mathbf{T}$HE MAIZE (*Zea mays* L.) was grown on a clay soil at Irrigation Development Area of Alwezaria, Kafr El-Shiekh, Egypt, during 2012 and 2013 seasons, to study the effect of irrigation regimes during different growth stages on growth, grain yield and water relations. Irrigation was applied at 50% (high level, H) and 65% (low level, L) depletion of available soil moisture (DAM) during different growth stages [vegetative stage (S_1) from the third leaf (V3) to onset tasseling (VT) stages, reproductive stage I (S_2) from VT to mid-milk (R3) stages, reproductive stage II (S_3) from mid R3 to physiological maturity (R6)].

I_{HHH} treatment (Irrigated at 50% DAM during three growth stages) or I_{HHL} (Irrigated with 65% DAM at S_3 stage only and 50% DAM was used during S_1 and S_2 growth stages), I_{LHH} (Irrigated with 65% DAM at S_1 growth stage only and 50% DAM was observed during S_2 and S_3 growth stages) and I_{LHL} (Irrigated with 50% DAM at S_2 growth stage only and 65% DAM was observed during S_1 and S_3 growth stages) resulted in significant increase in leaf area index (LAI) and dry weight/plant at 99 days after sowing (DAS), crop growth rate (CGR) at the period of 81-99 DAS, ear length, ear diameter, kernels number/ear, grain weight/ear, 100-grain weight and grain yield compared with I_{LLL} (Irrigated with 65% DAM during three growth stages) in the two seasons. There were no significant differences in grain yield among the irrigation treatments I_{HHH}, I_{HHL}, I_{LHH} and I_{LHL} in the mentioned traits in both seasons.

Abundance soil moisture in root zone during S_2 stage (containing tasseling, silking, blister and mid-milk stages) is necessary to achieve high grain yield equal to that during entire season. I_{HHH} treatment recorded the highest values of applied water (7286 and 7321 m^3/ha), while I_{LLL} recorded the lowest values 6171 and 6198 m^3/ha in the two seasons. Although, the treatments received irrigation at 50% DAM during S_2 stage (I_{HHL}, I_{LHH} and I_{LHL} treatments) were equivalent to those received irrigation at 50% DAM during entire seasons (I_{HHH} treatment), they were lower in amount of applied irrigation water and water consumptive use. They saved at least 11.3, 16.0 and 19.9% applied water parallel with the yield decrease at the most 3.1, 3.2 and 5.3% than I_{HHH} treatment, respectively. Also, they increased the productivity of applied water ($WP_{water\ applied}$) and water consumptive use (WP_{WCU}) (kg grain/m^3 water) compared with I_{HHH} in both seasons.

[#]Corresponding author email address: hanysony@yahoo.com

At North Delta, Penman Monteith equation can be used in determining the actual consumptive use and the average of crop Coefficient (Kc) for the two seasons was found to be 0.43, 0.54, 0.64, 0.58 and 0.51 during emergence, vegetative, tasseling to milk, milk to dent and dent to maturity stages, respectively. Therefore, when irrigation water becomes a limited factor for agriculture, we can apply I_{LHL} treatment which resulted in high grain yield and water productivity equal to I_{HHH} with less amount of applied irrigation water and consumptive use in Kafr El-Shiekh Governorate.

Maize (*Zea mays,* L.) is one of the most important summer crops in Egypt. Cultivated area was about750000 ha of land with 5.8 megatons produced in 2014(FAO, 2014). Agriculture consumes more than 85% of Egypt's share of Nile water annually(MWRIE, 2014).Although Egypt suffer from relative scarcity of water resources, we need more water to reclaim new lands to meet the increase in demand for food (Hafez & Gharib, 2016). Improvement and development water management is expected to increase water efficiency and saving some water for new reclaim territory. Knowledge of consumptive use is necessary for planning farm irrigation systems and improving irrigation practices. Managers of these crops can determine how much supplemental water is needed to achieve maximum productivity with less water (Kebede *et al.*, 2014).

Evapotranspiration (water consumptive use) is a Standard method for the estimation of water requirement which should be applied under field condition (Kullberg, 2015). Many experiments conducted to deficit irrigation scheduling during different growth stages (Ge *et al.*, 2012 and Igbadun *et al.*, 2008). Mansouri-Far *et al.* (2010) reveals that identifying the most sensitive stage of the plant development to water deficit is a way to enhance crop production.

Igbadun *et al.* (2008) showed that water deficit treatment which irrigation was skipped every other week at all growth stages of maize induced reduction in leaf area index, dry matter and grain yields and seasonal evapotranspiration. While the highest water use efficiency was under full irrigation, maximum irrigation water use efficiency was obtained in the deficit irrigation treatment at vegetative growth stage. Mansouri-Far *et al.* (2010) reported that the reproductive stage was more sensitive to water stress than the vegetative stage in yield reduction. The 100-kernel weight was the most sensitive yield component when the water deficit treatments occurred in low-sensitive growth stages. Leaf area index was reduced about 15% under water deficit at vegetative stage. Ge *et al.* (2012) pointed out that grain yield and ear kernel number decreased, respectively, by range from 20.4 to 26.1% and 12.1 to 19.7% for 55% field capacity (FC), and 59.2 to 84.5%and 39.8 to 88.1 % for 35% FC. However, 55 % FC reduced plant height, leaf area, biomass accumulation, net photosynthesis and ear length and diameter compare to 75% FC. Water use efficiency (WUE)

decreased at thirteenth leaf (V13) and harvest stage (R3), while WUE increased at sixteenth leaf (V16) and silking stage (R1) under 55% FC.

Farré & Faci (2009) indicated that flowering was the most sensitive stage of maize to water deficit. Grain yield was obtained under deficit irrigation around flowering treatment 691 g m^{-2},while well-irrigated treatments was1069 g m^{-2}. (Çakir, 2004) found that deficit irrigation during vegetative and tasseling stage reduced plant height and leaf area index as a result of reducing size of the leaves. Short-duration water stress at the rapid vegetative growth reduced final dry matter weight 28–32%. A single irrigation skip during one of the sensitive growth stages or both the tasseling and ear formation stages may cause a 30-40% and 66–93% grain yield loss respectively. Bahadori et al. (2015) stated that during flowering stage, one single day of water stress can potentially decrease yield up to 8%. Ghooshchi et al. (2008) indicated that yield reduction due to water stress before silking, silking and filling growth stages was 12.5, 42.0 and 22.5% respectively. Kuşçu & Demir (2012) observed that the full irrigation treatment (VFG) gave the highest seasonal evapotranspiration. There are insignificant differences between the VFG and 25% water deficit at grain-filling stage (VFG75) treatments ingrain yield and dry matter yield. The flowering and vegetative stages were recorded as the most sensitive stages to water deficit. Djaman (2011) concluded that Irrigation regime of 25% water saving could ensure satisfactory grain yield of maize and increment of WUE. Crop evapotranspiration increased with irrigation amounts while it decreased with irrigation regimes. Grain yield losses due to the water stress is varied between1 to 76% depending on the severity, timing and stage of occurrence (Mostafavi et al., 2011 and Zarabi et al., 2011).

The objectives of this work were to study the effect of irrigation water regime based on depletion of available soil moisture at different growth stages on growth, grain yield, yield attributes, water consumptive use and amount of applied water and water productivity of maize cv. SC10.

Materials and Methods

Two field experiments were conducted in summer 2012 and 2013at the field of Irrigation Development Area of Alwezaria (31°11'N, 30°57'E), Kafr El-Shiekh Governorate , in Northern Egypt. The experimental soil was clay in texture with a pH of 7.8. Organic matter, total nitrogen, available phosphorus and available potassium were 1.49 %, 0.14 % ,15.8 mg kg^{-1} and 250 mg kg^{-1}, respectively (Black et al., 1965). Depth of water table for experimental soil was 70-90 cm. The soil physical analysis were determined in the experimental sites as given in Table 1.Weather data from planting to harvest were collected from Sakha Meteorological Stations (Table 2).

SC10 single cross maize (Zea mays L.) was planted on 25th and 15th May in 2012 and 2013 seasons, respectively. The preceding crop was Egyptian clover in both seasons. Seeds of the maize cultivar "SC10" were sown on one side of ridge in hills 25 cm apart at the rate of 2-3 seed per hill. One plant per hill was maintained by thinning at 18 days after sowing. The plant population density was 57143 plants ha^{-1} for two seasons. Phosphorus at 360 kg of

Calcium superphosphate (15.5 % P_2O_5) and potassium at 100 kg of potassium sulphate (48 % K_2O) were applied per hectare during soil preparation. Maize plants were fertilized with 286 kg N/ha in form of urea (46% N) in two equal splits, before the first irrigation after 21 days from sowing and before the second irrigation. Other cultural practices were done as recommended.

TABLE1. Soil physical of the experimental site in 2012 and 2013 seasons.

Soil depth (cm)	Field capacity %		Wilting point %		Bulk density (g/cm^3)	
	2012	2013	2012	2013	2012	2013
0 - 20	44.17	44.74	24.03	24.34	1.03	1.02
20 - 40	39.12	38.94	21.27	21.17	1.16	1.16
40 - 60	36.79	36.65	19.82	19.75	1.23	1.24
Mean	40.03	40.11	21.71	21.75	1.14	1.14

TABLE2. Mean monthly of weather data during 2012 and 2013 seasons.

Month	Temperature (C^o)		Relative humidity (%)		Wind speed (km/day)	
	2012	2013	2012	2013	2012	2013
May	25.80	26.62	62.88	60.40	100.1	102.7
June	28.46	28.21	65.19	62.95	104.0	115.4
July	29.23	28.32	68.54	67.14	91.7	111.0
August	29.84	29.28	68.52	76.58	90.9	90.2
September	27.51	27.74	67.58	68.80	111.0	87.6

The treatments were irrigation at 50% (high level, H) or 65% (low level, L) depletion of the available soil moisture (DAM) during three growth stages as shown in Table 3. Vegetative corn growth stages was determined according Ritchie *et al.* (1993).

TABLE 3. Irrigation regime during different growth stages of maize.

Treatments		Growth stages			Description
		S_1	S_2	S_3	
1.	I_{HHH}	H	H	H	Irrigated with 50% depletion of available soil moisture (DAM) during three growth stages
2.	I_{HHL}	H	H	L	Irrigated with 65% (DAM) at S_3 growth stage only. 50% (DAM) was observed during S_1 and S_2 growth stages
3.	I_{HLH}	H	L	H	Irrigated with 65% (DAM) at S_2 growth stage only. 50% (DAM) was observed during S_1 and S_3 growth stages
4.	I_{HLL}	H	L	L	Irrigated with 50% (DAM) at S_1 growth stage only. 65% (DAM) was observed during S_2 and S_3 growth stages
5.	I_{LHH}	L	H	H	Irrigated with 65% (DAM) at S_1 growth stage only. 50% (DAM) was observed during S_2 and S_3 growth stages
6.	I_{LHL}	L	H	L	Irrigated with 50% (DAM) at S_2 growth stage only. 65% (DAM) was observed during S_1 and S_3 growth stages
7.	I_{LLH}	L	L	H	Irrigated with 50% (DAM) at S_3 growth stage only. 65% (DAM) was observed during S_1 and S_2 growth stages
8.	I_{LLL}	L	L	L	Irrigated with 65% (DAM) during three growth stages

where: S_1 = Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages.

   S_2 = Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stages].

   S_3 = Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].

A randomized complete block design with four replications was used. Each plot 42 m^2 size consisted of 10 ridges 70 cm apart and 6 m long to avoid the effect of lateral water leak of irrigation; plots were isolated by levees 1.5 m wide.

Irrigation treatments started after the first irrigation. In each plot, the two outside ridges were left to avoid border effects and the two following ridges were used for determination growth, while the 6 inner ridges were used for measuring of grain yield and its component. Five guarded plants were randomly taken from each plot at 60, 81 and 99 days after sowing (DAS) to estimate dry weight and leaf area per plant. The different plant fractions were washed and oven dried to a constant weight at 70°C. Portable Area Meter (Model LI-3000A) was used to measure leaf area. The growth analysis, viz. leaf area index, crop growth rate and net assimilation rate were computed according to Watson (1952).Ten maize plants from each plot was harvested to determine plant height, ear height, ear length (cm), ear diameter (cm), ear grains weight, shelling % and 100-seed weight (g). Maize plants of the 6 inner ridges of each plot were harvested to determine grain yield per hectare (ha).

Amount of applied irrigation water were measured by a portable pump equipped with a water meter for each plot. Actual need for irrigation was determined by drying the soil samples for 24 h to 105 °C and the percentage of moisture was expressed on oven dry weight basis. Soil samples were taken at each 20 cm soil depth to 60 cm before and after irrigation. Water consumptive use (WCU)was calculated from sowing to harvest using the method of Israelsen & Hansen (1962):

$$WCU = \frac{\theta_2 - \theta_1}{100} \times B.d \times D \times 4200$$

where:

WCU = Amount of water consumptive use (m^3/ha).

θ_2 = Soil moisture% after irrigation.

θ_1 = Soil moisture % before the irrigation.

B.d = Bulk density (g/cm^3).

D = Depth of soil layer (m).

Water productivity for applied water (WP $_{water\ applied}$) and water productivity for water consumptive use (WP $_{water\ consumptive\ use}$) were measured according to El-Bably *et al.* (2015)as follows:

$$WP_{water\ applied} = \frac{Yield\ (kg/ha)}{Applied\ water\ (m^3/ha)}$$

$$WP_{water\ consumptive\ use} = \frac{Yield\ (kg/ha)}{water\ consumpitive\ use\ (m^3/ha)}$$

Crop coefficient (Kc) was calculated according to Penman Monteith method as the ratio between actual crop evapotranspiration (ET$_a$) and reference evapotranspiration (ET$_o$) as follows:

$$Kc = \frac{\mathrm{ETa}}{\mathrm{ETo}}$$

Reference evapotranspiration (ET_o) was calculated by FAO Penman Monteith (Allen *et al.*, 1998).

Analysis of variance (ANOVA) was assessed according to Gomez & Gomez (1984) and the means were compared by Duncan's Multiple Range Test (Duncan, 1955). The data was analyzed using CoStat software for windows (version 6.3).

Results and Discussion

Growth

Table 4 shows significant effect of water deficit treatment in the leaf area index (LAI) and dry weight (g/plant) of the maize at 60, 81 and 99 days after sowing (DAS) for the 2012 and 2013 seasons. At 60 DAS, irrigation treatment I_H during S_1 stage resulted in a significant increase in LAI and dry weight/plant compared with I_L treatment in the two seasons.

TABLE 4. **Leaf area index and dry matter accumulation of hybrid maize cv. SC10 at 60, 81 and 99 days after sowing (DAS) as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.**

Irrigation treatments	Growth stages			Leaf area index		Dry weight (g/plant)	
	S_1	S_2	S_3	2012	2013	2012	2013
At 60 DAS							
I_H	H	-	-	4.66 a	4.59 a	204.0 a	221.4 a
I_L	L	-	-	4.07 b	4.23 b	189.4 b	200.8 b
F test				**	*	*	**
At 81 DAS							
I_{HH}	H	H	-	6.10 a	6.20 a	294.3 a	314.0 a
I_{HL}	H	L	-	5.45 b	5.39 b	279.3 b	289.0 b
I_{LH}	L	H	-	5.98 a	6.07 a	281.3 ab	297.1ab
I_{LL}	L	L	-	4.73 c	4.81 c	249.2 c	258.4 c
F test				**	**	**	**
At 99 DAS							
I_{HHH}	H	H	H	6.01 a	5.93 a	397.8 a	422.4 a
I_{HHL}	H	H	L	5.78 a	5.86 a	389.0 a	417.4 a
I_{HLH}	H	L	H	5.07 b	5.21 b	359.0 bc	369.6 b
I_{HLL}	H	L	L	4.51 c	4.89 c	351.0 c	355.2 b
I_{LHH}	L	H	H	5.61 a	5.73 a	381.3 a	401.8 a
I_{LHL}	L	H	L	5.52 ab	5.79 a	378.6 ab	395.9 a
I_{LLH}	L	L	H	4.17 cd	4.06 d	341.2 cd	351.7 bc
I_{LLL}	L	L	L	3.85 d	3.94 d	321.8 d	328.4 c
F test				**	**	*	**

S_1 = Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages; S_2= Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stage]; S_3= Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].

H=irrigation at 50% depletion of the available soil moisture (DAM); **L**= irrigation at 65% DAM.

* and ** indicate P<0.05 and P<0.01 respectively. Means in each column designated by the same letter are not significantly different at 5% level using Duncan's Multiple Range Test

At 81 DAS, treatments I_{HH} or I_{LH} during the two stages S_1 and S_2 produced higher LAI and dry weight/plant than did the other irrigation treatments. At 99 DAS,I_{HHH} , $I_{HHL,}$ I_{LHH} and I_{LHL} treatments which plants irrigated at 50 % DAM during the reproductive stage, IVT- R3 markedly exceeded I_{HLH}, I_{HLL}, I_{LLH} and I_{LLL} treatments than those irrigated at 65 % DAM at these stages in LAI and dry weight/plant in the two seasons.

Thus, sufficient soil moisture in the root zone through irrigation at 50% DAM during entire season or from onset tasseling to mid milk stage increased the capacity of maize plants to accumulate dry matter.

However, plants under favorable moisture conditions resulted in good leaf emergence, extension and number (Ge *et al.*, 2012).This may be attributed to the increase in the area of photosynthesizing leaves which in turn resulted in more photosynthates available for dry matter accumulation. These results are in harmony with those of Pandey *et al.* (2000), who stated that increasing moisture stress resulted in progressively less shoot dry matter. Also, Çakir (2004) and Yılmaz *et al.* (2010) found that deficit irrigation during vegetative reduced leaf area index as a result of reducing size of the leaves. Short-duration water stress at the rapid vegetative growth reduced final dry matter weight. Total dry matter accumulation was accelerated after each irrigation application. Igbadun *et al.* (2008) reported that omitted irrigation every other week during the crop growing season gave the least values leaf area index and dry matter of in the two seasons, while weekly irrigation recorded the highest values.

The effects of water regime at different growth stages on crop growth rate (CGR) and net assimilation rate (NAR) were determined for maize (Table 5). Results showed that there is a significant effect in the two seasons.

At the first period 60-81 DAS, the highest CGR and NAR of maize obtained from (I_{HH}) and (I_{LH}) treatments compare to (I_{HL}) and (I_{LL}) at the S_1 and S_2 stages in 2003 and 2004 seasons. At the period of 81-99 DASI_{HHH}, $I_{HHL,}$ I_{LHH} and I_{LHL} treatments, being insignificant, resulted in a substantial increase in CGR compared with I_{HLH}, I_{HLL}, I_{LLH} and I_{LLL} treatments in both seasons. This may be attributed to the effect of the mentioned treatment on increasing photosynthetic area, which was reflected in higher dry matter accumulation per unit ground area (crop growth rate). Similar results were reported by Abayomi *et al.*(2012) and Udomprasert *et al.*(2005)**.**

On contrary, data in Table 5 at the period of 81-90 DAS show that the irrigation treatment I_{LLH} produced higher NAR than all the other treatments. Such reduction in NAR obtained from irrigation at 50% DAM during entire season or during the reproductive stageIVT-R3 may be attributed to very large leaf area which led to increase mutual-shading and transpiration and in turn caused a reduction in rate of assimilation per unit of leaf area (NAR). However, the reduction in NAR at low soil moisture level during entire season (I_{LLL}) may be attributed to decrease LAI which might have decreased light interception and in

turn decreased dry matter accumulation. These results are accordance with those reported by Abayomi *et al.* (2012) and Udomprasert *et al.* (2005), who reported that net assimilation rate was reduced by water stress.

TABLE 5. Crop growth rate (CGR) and net assimilation rate (NAR) of hybrid maize cv. SC10 as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.

Irrigation treatments	Growth stages			CGR (g/m²/week)		NAR (g/m²/week)	
	S_1	S_2	S_3	2012	2013	2012	2013
At the period of 60-81 DAS							
I_{HH}	H	H	-	172.0 a	176.2 a	32.25 ab	33.02 a
I_{HL}	H	L	-	143.5 b	128.7 b	28.61 bc	26.06 b
I_{LH}	L	H	-	175.0 a	183.4 a	35.14 a	35.85 a
I_{LL}	L	L	-	113.8 c	109.7 c	25.88 c	24.41 b
F test				**	**	*	**
At the period of 81-99 DAS							
I_{HHH}	H	H	H	230.0 a	241.0 a	38.13 b	40.05 b
I_{HHL}	H	H	L	210.5 ab	230.0 ab	35.19 bcd	38.09 b
I_{HLH}	H	L	H	177.1 c	179.1 c	33.21 cd	33.53 c
I_{HLL}	H	L	L	159.2 c	157.1 cd	31.75 d	28.36 d
I_{LHH}	L	H	H	222.3 ab	232.7 a	38.46 b	39.78 b
I_{LHL}	L	H	L	216.1 ab	219.5 ab	37.29 bc	37.14 bc
I_{LLH}	L	L	H	204.6 b	207.2 b	46.06 a	46.84 a
I_{LLL}	L	L	L	161.4 c	155.5 d	37.72 b	35.6 bc
F test				**	**	**	**

S_1= Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages; S_2= Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stage]; S_3= Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].

H=irrigation at 50% depletion of the available soil moisture (DAM); **L**= irrigation at 65% DAM.

* and ** indicate P<0.05 and P<0.01 respectively. Means in each column designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Plant and ear height were significantly affected by irrigation regime during different growth stages in the two seasons (Table 6). I_{HHH}, I_{HHL}, I_{HLH} and I_{HLL} treatments which plants irrigated at 50 % DAM during vegetative growth stage, being insignificant, were taller than I_{LHH}, I_{LHL}, I_{LLH} and I_{LLL} treatments which Irrigated at 65 % DAM during vegetative stage in both seasons. Generally, water stress through irrigation based on low soil moisture level during entire season and during vegetative stage caused a depression in plant and ear height as a result of losing turgidity and inhibition of cell enlargement. In these connections, Kramer & Boyer (1995) stated that the plant growth is correlated by rates of cell division and enlargement. Water deficit checked or stopped cell enlargement which it inhibit the degree of cell turgor and stem and leaf elongations. Çakir (2004) found that irrigation applied at the beginning of two growth stages (vegetative and tasseling) affected plant height growth significantly. Ghooshchi *et al.* (2008) reported that missing one irrigation at different reproductive growth stages significantly reduced plant height and plant leaf area as compared with the control. They stated that the depression in these growth parameters as results of water deficits may effect on the loss of turgor which affects the rate of cell division and enlargement. Such result is

in agreement with those of Aydinsakir *et al.* (2013), Farré & Faci (2009) and Pandey *et al.* (2000).

Irrigation regime during different growth stages had a significant effect on ear dimensions (length and diameter) in both seasons (Table 6). Plants irrigated at 50 % DAM during entire season or during the reproductive stage I VT-R3 (I_{HHH}, I_{HHL}, I_{LHH} and I_{LHL}) produced significantly longer and thicker ears than those irrigated at 65 % DAM during this growth period (I_{HLH}, I_{HLL}, I_{LLH} and I_{LLL}) in the two seasons.

Data indicated that increasing available soil moisture in root zone during ear formation resulted in substantially increase in ear dimensions. The decrease in ear diameter and length may be assigned to the reduction of photosynthetic assimilation under drought stress (Bänziger *et al.*, 2000). Our results are coincidence with findings by Aydinsakir *et al.* (2013), Kebede *et al.* (2014) and Moosavi (2012).

TABLE 6. Plant height, ear height, ear dimensions and number of kernels/ear of hybrid maize cv. SC10 as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.

Irrigation treatments	Growth stages			Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	Kernels (No/ear)
	S_1	S_2	S_3					
Season 2012								
I_{HHH}	H	H	H	286.0 a	160.0 a	21.75 a	5.36 a	567 a
I_{HHL}	H	H	L	283.9 a	157.9 ab	21.64 a	5.29 a	557 a
I_{HLH}	H	L	H	280.8 ab	156.8 ab	20.71 b	5.06 b	499 b
I_{HLL}	H	L	L	277.6 abc	152.6 bc	20.6 b	4.91 b	483 b
I_{LHH}	L	H	H	272.4 bc	146.3 cd	21.54 a	5.28 a	546 a
I_{LHL}	L	H	L	271.1 c	148.5 cd	21.43 a	5.26 a	540 a
I_{LLH}	L	L	H	262.1 d	142.6 d	20.09 b	4.68 c	444 c
I_{LLL}	L	L	L	255.1 d	135.2 e	19.89 c	4.14 d	418 c
F test				*	**	**	*	**
Season 2013								
I_{HHH}	H	H	H	308.0 a	171.0 a	22.48 a	5.35a	611 a
I_{HHL}	H	H	L	304.5 a	168.6 a	22.06 a	5.35a	599 a
I_{HLH}	H	L	H	302.2 a	167.4 a	21.0 bc	5.01b	555 b
I_{HLL}	H	L	L	302.1 a	165.1 ab	20.79 c	4.88bc	557 b
I_{LHH}	L	H	H	291.6 b	155.6 c	21.85 a	5.26a	590 a
I_{LHL}	L	H	L	288.1 b	157.9 bc	21.54ab	5.21a	587 a
I_{LLH}	L	L	H	281.8 c	152.2 c	19.89 d	4.81c	520 c
I_{LLL}	L	L	L	271.1 d	143.1 d	19.19 e	4.27d	487 d
F test				**	**	**	**	**

S_1= Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages; S_2 = Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stage]; S_3= Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].

H=irrigation at 50% depletion of the available soil moisture (DAM); **L**= irrigation at 65% DAM.

* and ** indicate P<0.05 and P<0.01. Means in each column designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Yield attributes

The irrigation level during different growth stages gave significantly effect on number of kernels per ear in the two seasons (Table 6).I_{HHH} treatment produced significantly greater number of kernels per ear than I_{LLL} treatment in the two seasons. Number of kernels per ear produced by maize plants which received high soil moisture during the reproductive stage I VT-R3 (I_{HHL}, I_{LHH} and I_{LHL}) or during entire season (I_{HHH}) was practically the same. Number of kernels per ear was increased by increasing available soil moisture in root zone during entire season or during VT-R3 stage. This may be attributed to increase ear diameter and length. In this regard, Yılmaz *et al.* (2010) concluded that water stress at tasseling stages and milk stages decreased the kernel set on the ear. Aydinsakir *et al.* (2013) observed that the deficit in soil water content in flowering stage resulted in delayed silk emergence and their growth upsets, so anthesis–silking interval increased in water deficit treatments greatly. They add that delayed silk emergence caused non-simultaneous pollination and silking. Song–Feng *et al.* (1998) showed that water deficit led to slower pollen and filament development, reduced filament fertility and caused a reduction in grain number per ear. This result supported the works of Çakir (2004), Ge *et al.* (2012) and Kebede *et al.* (2014).

Data in Table 7 show that 100-grain weight was significantly heavier in all treatments receiving irrigation at 50% DAM during VT-R3 or R3-stage (I_{HHH}, I_{HHL}, I_{HLH}, I_{LHH} and I_{LHL}) than irrigation at 65% DAM during entire season in both seasons. Thus, sufficient soil moisture in the root zone through irrigation at 50% DAM during entire season or during reproductive stage increased the capacity of maize plants to accumulate dry matter through the increase in the area of photosynthesizing leaves which in turn resulted in more photo-synthetics available for filling grains. In this connection, Yılmaz *et al.* (2010) stated that kernel weight of full irrigation and irrigation until milk stage treatments was higher even than in the other treatments showed the determinative effect of water availability in soil during the period for the coming grain filling. Aydinsakir *et al.* (2013) reported that low level of available water cause reduction in the 1000 grain weight resulted in low transition of photosynthesis matter and assimilates to kernels. These results are in close agreement with those of Çakir (2004), Ge *et al.* (2012) and Kuşçu & Demir (2012).

Irrigation regime during different growth stages had a significant effect on grain weight per ear in the two seasons (Table 7). Plants irrigated at 50 % DAM during entire season produced the heaviest grain weight per ear, while those irrigated at 65 % DAM during entire season produced the lowest one in both seasons. No significant difference in grain weight per ear was evidenced among all treatments receiving irrigation at 50 % DAM during the reproductive stage I VT-R3 or entire season in both seasons. Such increase in grain weight per ear obtained from sufficient soil moisture in the root zone during entire season or during the reproductive stage I VT-R3 may be due to the considerable increase in dry matter accumulation, leaf area index, crop growth rate and net assimilation rate which reflected in the higher number of kernels per ear and kernel weight

and in turn increased grain weight per ear. Similar results were obtained by Borrás *et al*. (2003), Çakir (2004) and Kebede *et al.* (2014)

TABLE 7. Grain yield, grain weight/ear, shelling % and 100-grain weight of hybrid maize cv. SC10 as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.

Irrigation treatments	Growth stages			Grain weight (g/ear)		Shelling (%)		100-grain weight(g)		Grain yield (ton/ha)	
	S_1	S_2	S_3	2012	2013	2012	2013	2012	2013	2012	2013
I_{HHH}	H	H	H	249.0 a	283.1 a	80.38 a	81.92 a	43.91 a	46.33 a	10.14a	10.93a
I_{HHL}	H	H	L	239.3 a	270.8 ab	79.72 a	80.77 ab	42.97 ab	45.21 a	9.90a	10.58a
I_{HLH}	H	L	H	216.6 ab	251.3abc	78.86 ab	79.79 ab	43.41 ab	45.28 a	9.43a	10.14a
I_{HLL}	H	L	L	196.7 bc	240.1 bc	77.56 bc	79.68 ab	40.72 c	43.11 b	8.13bc	8.94 b
I_{LHH}	L	H	H	238.2 a	272.5 a	79.36 a	80.22 ab	43.62 ab	46.18 a	9.89a	10.58a
I_{LHL}	L	H	L	229.8 a	263.0abc	79.12 a	79.97 ab	42.56 b	44.8 ab	9.45a	10.35a
I_{LLH}	L	L	H	190.2 bc	233.2 c	77.51 bc	78.84 bc	42.83 ab	44.84 ab	8.65b	9.02 b
I_{LLL}	L	L	L	164.9 c	199.7 d	77.31 c	78.01 c	39.44 d	41.01 c	7.52c	7.93c
F test				**	*	**	*	*	**	**	**

S_1= Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages; S_2= Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stage]; S_3= Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].

H=irrigation at 50% depletion of the available soil moisture (DAM); **L**= irrigation at 65% DAM.

* and ** indicate P<0.05 and P<0.01. Means in each column designated by the same latter are not significantly different at 5% level using Duncan's Multiple Range Test.

Data in Table 7 show that irrigation treatments I_{HHH}, I_{HHL}, I_{HLH}, I_{LHH} and I_{LHL} though not significantly different, resulted in a substantial increase in shelling percentage compared with I_{LLL} treatment in the two seasons. Plants irrigated at 50 % DAM during entire season exhibited the highest shelling percentage, while those irrigated at 65 % DAM during entire season exhibited the lowest one. Such increase in shelling percentage obtained from sufficient soil moisture in the root zone at the mentioned stages may be attributed to improved plant growth and in turn increased grain filling and grain weight per ear. These results are in agreement with the findings of Abayomi *et al.* (2012), Khoshvaghti *et al.* (2013) and Zaki *et al.* (2014).

Grain yield

Data in Table 7 show that irrigation regime during different growth stages had significant effect on grain yield per hectare in both seasons. Plants irrigated at 50 % DAM during entire season (I_{HHH}) out yielded those irrigated at 65 % DAM (I_{LLL}) in grain yield per hectare in both seasons. Application of (L) level at S_1 and S_3 (I_{LHH} and I_{LHL}) did not cause significant yield reduction in the two seasons (Table 7). Plants receiving irrigation at 50% DAM during entire season (I_{HHH}) or during S_2 stage (I_{HHL}, I_{LHH} and I_{LHL}) practically produced the same grain yield and significantly surpassed those receiving irrigation at 65% DAM during these stages (I_{HLL}, I_{LLH}, I_{LLL}) in both seasons. The treatment receiving low irrigation level during entire season (I_{LLL}) recorded the lowest values of grain yield in the two seasons.

Figure 1 illustrated that irrigation at 65% instead of 50% DAM during any growth stage resulted in a decrease in grain yield than Irrigation at 50% DAM during entire season (I_{HHH}) in both seasons. The decrease in grain yield was ranged from 2.3 to 3.1% for I_{HHL}, 7 to 7.2% for I_{HLH}, 19.8 to 18.2% for I_{HLL}, 2.4 to 3.2% for I_{LHH}, 6.8 to 5.3% for I_{LHL}, 14.7 to 17.4% for I_{LLH} and 25.8 to 27.5% for I_{LLL} treatments in both seasons, respectively. Figure 1 also shows that irrigation at 65% DAM during entire season (I_{LLL}) recorded the highest reduction percentage in grain yield followed by I_{HLL} and I_{LLH} in both seasons. The increase in grain yield at high soil moisture applied during the entire season or from beginning tasseling to mid-milk stage may be attributed to better early growth, viz LAI, dry weight per plant, CGR, plant height, ear length and ear diameter which were reflected in the significantly higher values of yield components viz. number of kernel per ear, ear kernels weight and 100-grain weight and ultimately grain yield.
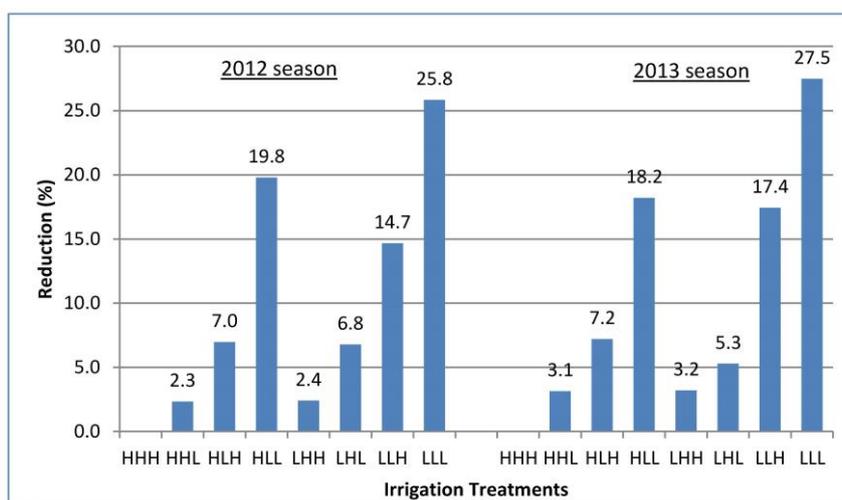

Fig. 1. Reduction percentage in grain yield due to application low irrigation regime (L) during different growth stages compared with application high irrigation regime (H) during entire seasons in 2012 and 2013 seasons.

In this connection, Yılmaz *et al.* (2010) found that stress conditions created at early vegetative and after milk stage did not cause significant yield decrease. They stated that when the water stress imposed at the tasseling (before and after tasseling), the yield decrease was 29.1% parallel with the results of irrigation water saving 16.0% based on averages of two years. Khalili *et al.* (2013)reported that water deficit during productivity stage can cause severe reduction in yield and yield components of corn cultivars. Aydinsakir *et al.* (2013) showed that corn can grow under water deficit (moderate level) without significant reduction in the amount of grain yield.

These results are in harmony with those of Farré & Faci(2009), Ge *et al.* (2012), Igbadun *et al.*(2008) and Khalili *et al.*(2013).

Some water relations

   Seasonal applied irrigation water and stored water

   Amount of applied irrigation water (AW) and stored water (SW) from sowing to harvest as affected by irrigation regime during different growth stages of maize are presented in Table 8. I_{HHH} treatment recorded the highest values of applied water 7286 and 7321 m^3/ hectare and stored water 5090 and 5148 m^3/hectare, while I_{LLL} treatment recorded the lowest values 6171 and 6198 m^3/ hectare and stored water 3990 and 4021 m^3/ hectare in the 2012 and 2013 seasons, respectively. Data indicated that amount of stored water was related with amount of applied water in both seasons. Such increase in the amount of applied water by increasing the level of irrigation water may be attributed to considerable increase in leaf area, which resulted in a greater transpiration and in turn water requirement.

TABLE8. Seasonal irrigation water applied (WA), water stored (WS) and water consumptive use (WCU) as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.

Irrigation treatments	Growth stages			WA (m^3/ha)		Saving water (m^3)		WS (m^3/ ha)		WCU (m^3/ ha)	
	S_1	S_2	S_3	2012	2013	2012	2013	2012	2013	2012	2013
I_{HHH}	H	H	H	7286	7321	-	-	5090	5148	4857	4860
I_{HHL}	H	H	L	6781	6802	505	519	4424	4633	4517	4538
I_{HLH}	H	L	H	6667	6714	619	607	4490	4543	4398	4448
I_{HLL}	H	L	L	6495	6514	790	807	4314	4336	4221	4240
I_{LHH}	L	H	H	6571	6593	714	729	4393	4417	4357	4369
I_{LHL}	L	H	L	6398	6424	888	898	4219	4248	4126	4152
I_{LLH}	L	L	H	6345	6362	940	960	4167	4190	4074	4095
I_{LLL}	L	L	L	6171	6198	1114	1124	3990	4021	3898	3926

S_1 = Vegetative stage, started from the third leaf (V3) to onset tasseling (VT) stages; S_2= Reproductive stage I started from VT to mid milk (R3) stages [including VT, silking (R1), blister (R2) and mid R3) stage]; S_3= Reproductive stage II started from mid R3 to physiological maturity (R6) [including dough (R4) and dent (R5) stages].
H=irrigation at 50% depletion of the available soil moisture (DAM); **L**= irrigation at 65% DAM.

   Data in Table 8 and Fig. 2 illustrated that Irrigation at 65% DAM instead of 50% DAM during any growth stage resulted in a substantially reduce in amount of applied water than irrigation at 50% DAM during entire season. The mentioned treatments saved from 505 to 1114 m^3 applied water in the first season and from 519 to 1124 m^3 in the second season than I_{HHH} treatment (Table 8). However, percentages of saving water obtained from low irrigation level during different growth stages were ranged from 11.3 to 25% in the first season and from 11.6 to 25.2% in the second season than high irrigation level (Fig. 2).

Although, the irrigation treatments I_{HHL}, I_{HLH}, I_{LHH} and I_{LHL} were equivalent to I_{HHH} in growth and grain yield, they were lower in amount of applied irrigation water. They saved at least 11.3, 13.6, 16 and 19.9 % applied water parallel with the yield decrease at the most 3.1, 7.2, 3.2 and 5.3% than I_{HHH} treatment, respectively. Yılmaz *et al.* (2010) observed that when the water stress imposed at the tasseling (before and after tasseling), the yield decrease was 29.1% parallel with the results of irrigation water saving 16.0% based on averages of two years.
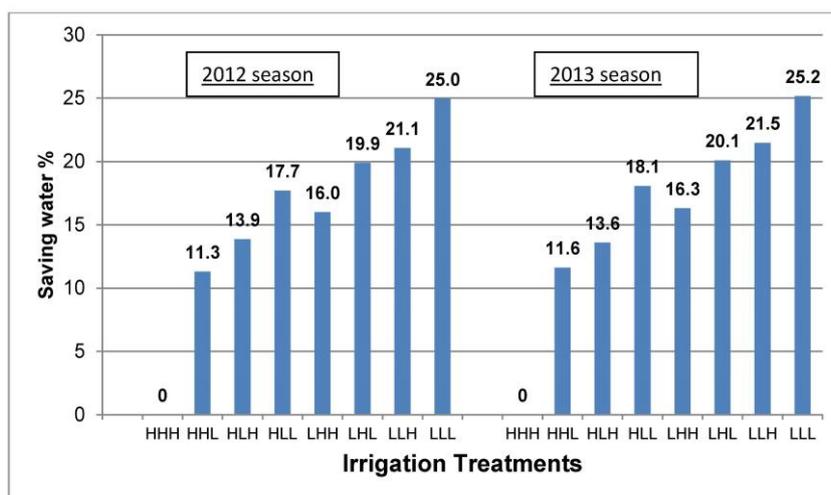
Fig. 2. Saving water percentage based on I_{HHH} as affected by irrigation regime during different growth stages in 2012 and 2013 seasons.

Seasonal actual water consumptive use

The quantities of water lost as evapotranspiration (seasonal water consumptive use) became greater by increasing the amount of applied water in both seasons (Table 8). Application of low irrigation level (L) during any growth stage (S_1, S_2 and S_3 stages) resulted in a decrease in values of seasonal water consumptive use (WCU) compared with application of high irrigation level (H) in the two seasons. I_{LLL} treatment recorded the lowest values of seasonal water consumptive use 3898 and 3926 m^3/ hectare, while I_{HHH} recorded the highest values 4857 and 4860 m^3/ hectare in the two seasons. Data indicated that seasonal water consumptive use was related positively with amount of applied water. In general, the treatment I_{HHH} gave the highest value of actual water consumptive use, while the lowest value was I_{LLL} treatment. High value of actual water consumptive use at I_{HHH} treatment can be attributed to the increase in evaporation at elevated available moisture; more supplying plants with sufficient moisture led to an increase in green cover and hence increase transpiration. These results agree with those of Aydinsakir *et al.* (2013), Igbadun *et al.*

(2008) and Pandey *et al.* (2000) who noticed that seasonal transpiration and evapotranspiration decreased with less seasonal water applied.

Water productivity

Water productivity (kg grain/m^3 water) is considered as an evaluation parameter of yield per unit of applied or consumed water. Data in Fig. 3 and 4 illustrated that irrigation at 65% DAM during two consecutive growth stages (I_{HLL}, I_{LLH} and I_{LLL}) decreased WP $_{water\ applied}$ and WP $_{WCU}$ compared with irrigation at 50% DAM during entire season (I_{HHH}) in the two seasons. However, irrigation at 50% DAM during the reproductive stage I VT-R3 (I_{HHL}, I_{LHH} and I_{LHL} treatments) and I_{HLH} increased this respect compared with I_{HHH} in both seasons. The I_{LHH} and I_{LHL} treatments recorded the highest values of water productivity, while I_{LLL} recorded the lowest values in both seasons.
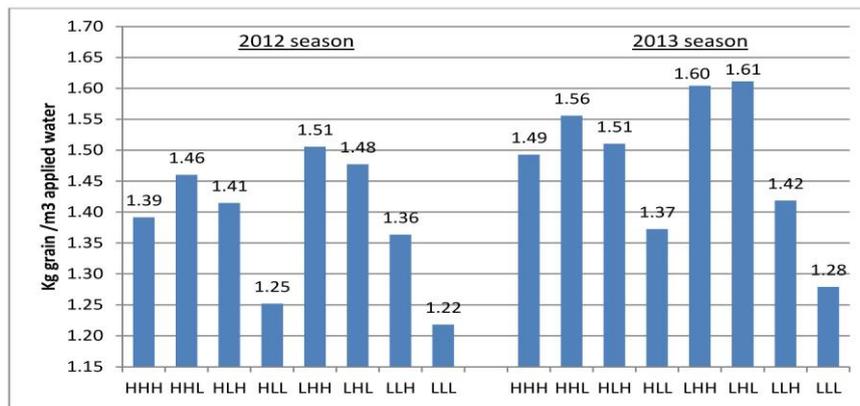

Fig. 3. Productivity of applied water as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.
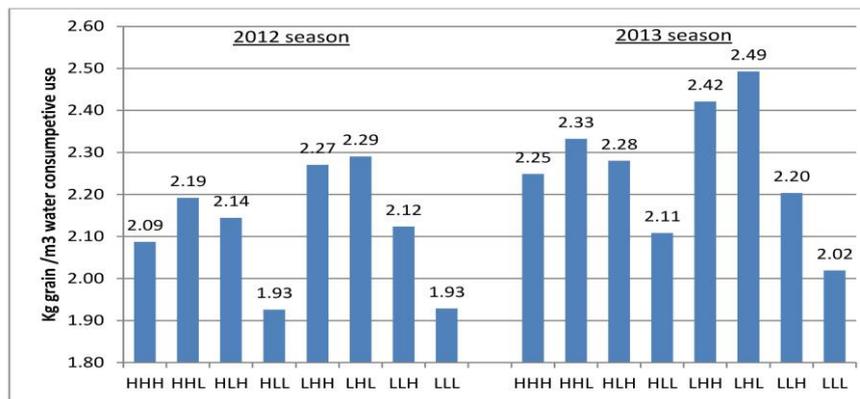

Fig. 4. Productivity of water consumptive use as affected by irrigation regime at different growth sages in 2012 and 2013 seasons.

Egypt. J. Agron . **38,** No. 3 (2016)

WP $_{water\ applied}$ was ranged from 1.51 to 1.60 kg grain/m^3 AW for I$_{LHH}$, from 1.48 to 1.61 kg grain/m^3 AW for I$_{LHL}$ and from 1.22 to 1.28 kg grain/m^3 AW for I$_{LLL}$ in the two seasons. WP $_{WCU}$ was ranged from 1.51 to 1.60 kg grain/m^3 WCU for I$_{LHH,}$ from 1.48 to 1.61 kg grain/m^3 WCU for I$_{LHL}$ and from 1.22 to 1.28 kg grain/m^3 WCU for I$_{LLL}$ in the two seasons. The increase in water productivity for I$_{LHH}$ and I$_{LHL}$ treatments may be due to the high grain yield and less amount of applied water and water consumptive use. The I$_{LHH}$ and I$_{LHL}$ treatments were statistically at par with the I$_{HHH}$ treatment in high grain yield and they were lower than them in amount of applied irrigation water and water consumptive use. Kebede *et al.* (2014) reported that the 50% of field capacity treatments were higher 100% and the 75% FC treatments at the V14, R1 and R3 stages. Aydinsakir *et al.* (2013) found that the highest water use efficiency obtained from 50 % water applied treatment. Yenesew &Tilahun (2009) reported that 75% deficit water treatment gave higher water use efficiency from 75% deficit treatment than stressing by 50% deficit. Djaman (2011) stated that 60 % of fully irrigated treatment resulted in the highest irrigation water use efficiency.

Crop coefficient (Kc)

Effect of crop characteristics, climatic conditions and irrigation frequency on crop water requirements is indicated by the crop coefficient (Kc) which represents the relationship between reference potential (ET$_0$) and actual crop evapotranspiration (ETA). Results of calculated values of crop coefficient (K) from the best irrigation treatment (I$_{LHL}$) are shown in Table 9.

TABLE 9. Computed empirical coefficient (Kc) of maize cv. SC 10 for the best treatment in both seasons.

Growth stage	2012 season			2013 season		
	Actual WCU (mm/day)	Penman monteith (ET$_0$ in mm/day)	Kc	Actual WCU (mm/day)	Penman monteith (ET$_0$inmm/day)	Kc
Emergence	3.60	7.17	0.50	1.46	4.06	0.36
Vegetative	3.88	6.44	0.60	3.18	6.81	0.47
VT-R3	3.97	6.26	0.63	4.19	6.49	0.65
R3-R5	2.85	5.20	0.55	3.73	6.02	0.62
R5- R6	1.57	3.15	0.50	4.11	7.83	0.52

VT= Tasseling, R3=Milk, R5= Dent and R6= maturity stages.

Figure 5 shows that Kc value increased gradually from emergence until the reproductive stage I from onset tasseling to med-milk stage (VT-R3) and then decreased in both seasons. The maximum Kc value was at VT-R3 stage (viz. tasseling, silking, blister and mid-milk stages). This was expected because of the fast elongation and the peak of dry matter accumulation occurred during this stage. The above mentioned stage is critical and has been shown to have the highest water requirement for maize. The high soil moisture level was adapted in the present study during this stage in which maize can be hurt the most when use exceeds supply.
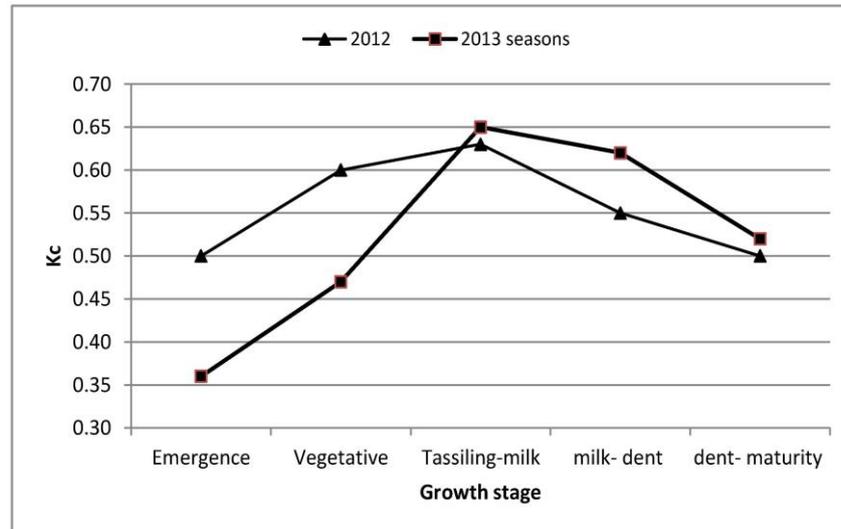
Fig.5. Computed empirical coefficient (Kc) of maize cv. SC 10 for the best treatment in both seasons.

The values of Kc for the best treatment (I_{LHL}) according the Penman Monteith equation were 050, 0.60, 0.63, 0.55 and 0.50 for the growth stages emergence, vegetative-tasseling, tasseling-milk, milk- dent and dent- maturity stages, respectively in the first season, while these values were 0.36, 0.47, 0.65, 0.62 and 0.52 in the second season. The maximum value throughout the two seasons was during from onset tasseling to mid milk stages.

At North Delta, Penman Monteith equation can be used in determining the actual consumptive use and the average of crop Coefficient (Kc) for the two seasons was found to be 0.43, 0.54, 0.64, 0.58 and 0.51 during emergence, vegetative-tasseling, tasseling-milk, milk- dent and dent- maturity stages, respectively. Gao *et al.* (2009) reported that crop Coefficient of maize varied at different growth stages, at initial, mid and late from 0.36-0.37, 1.18-1.19 to 0.22-0.28, respectively. Djaman (2011) found that the Kc values and their magnitude gradually decreased with decreasing irrigation amounts. These results agree with Jiang *et al.* (2014), Li *et al.* (2008) and Williams & Ayars (2005).

Conclusion

It can be concluded that irrigation at 65% DAM during vegetative stage followed 50% DAM during VT-R3 stage and 65% DAM during reminder season (I_{LHL}) was the best treatment which resulted in high grain yield with less amount of applied irrigation water and consumptive use in Kafr El-Shiekh Governorate.

Rreferences

Abayomi, Y., Awokola, C. and Lawal, Z. (2012) Comparative evaluation of water deficit tolerance capacity of extra-early and early maize genotypes under controlled conditions**.** *J. Agric. Sci*. **4**, 54.

Allen, R. G., Pereira, L. S., Raes, D. and Smith, M. (1998) Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56**.** *FAO, Rome*, **300**, D05109.

Aydinsakir, K., Erdal, S., Buyuktas, D., Bastug, R. and Toker, R. (2013) The influence of regular deficit irrigation applications on water use, yield, and quality components of two corn (*Zea mays* L.) genotypes**.***Agric. Water Manage.* **128**, 65-71.

Bahadori, A., Mobasser, H. R. and Ganjali, H. R. (2015) Influence of water stress and plant density on some characteristics in corn. *In* "Biological *Forum",* Vol. 7, pp. 673. Research Trend.

Bänziger, M., Edmeades, G. O., Beck, D. and Bellon, M. (2000) Breeding for drought and nitrogen stress tolerance in maize: From theory to practice. *In. Taller Internacional Sobre Bajo Fósforo en el Cultivo de Frijol*. 13-15 Nov 1995San José (Costa Rica)". CIMMYT, México, DF (México).

Black, C. A., Evans, D. and Dinauer, R. (1965) *Methods of Soil Analysis,* American Society of Agronomy Madison, WI.

Borrás, L., Westgate, M. and Otegui, M. (2003) Control of kernel weight and kernel water relations by post‐flowering source–sink ratio in maize. *Ann*. *Bot.* **91,** 857-867.

Çakir, R. (2004) Effect of water stress at different development stages on vegetative and reproductive growth of corn**.** *Field Crops Res.* **89**, 1-16.

Djaman, K. (2011) Crop evapotranspiration, crop coefficients, plant growth and yield parameters, and nutrient uptake dynamics of maize (*Zea mays* L.) under full and limited irrigation. *Ph.D. Thesis,* University of Nebraska-Lincoln,USA.

Duncan, D. B. (1955) Multiple range and multiple F tests**.** *Biometrics*, **11**, 1-42.

El-Bably, A. Z., Abd El-Hafez, S. A., Mahmoud, M. A. and Oud, S. A. H. (2015) A new conceptual framework for water conservation based on addressing water balance, crop rotation and economics**.** *Int. J. Water Res. Environ. Eng.* **4**, 120-127.

FAO (2014). FAOSTAT. http://fenix.fao.org/faostat/beta/en/#data/QC.

Farré, I. and Faci, J.M. (2009) Deficit irrigation in maize for reducing agricultural water use in a Mediterranean environment**.** *Agric. Water Manage.* **96**, 383-394.

Gao, Y., Duan, A., Sun, J., Li, F., Liu, Z., Liu, H. and Liu, Z. (2009) Crop coefficient and water-use efficiency of winter wheat/ spring maize strip intercropping**.** *Field Crops Res.* **111**, 65-73.

Ge, T., Sui, F., Bai, L., Tong, C. and Sun, N. (2012) Effects of water stress on growth, biomass partitioning, and water-use efficiency in summer maize (*Zea mays* L.) throughout the growth cycle.*Acta Physiol. Plant.* **34**, 1043-1053.

Ghooshchi, F., Seilsepour, M. and Jafari, P. (2008) Effects of water stress on yield and some agronomic traits of maize [SC 301]. *Am.-Eurasian J. Sustain. Agric.* **4**, 302-305.

Gomez, K. A. and Gomez, A. A. (1984) *Statistical Procedures for Agricultural Research,* John Wiley & Sons.

Hafez, E. and Gharib, H. (2016) Effect of exogenous application of ascorbic acid on physiological and biochemical characteristics of wheat under water stress. *Int. J. Plant Prod.* **10,** 4.

Igbadun, H. E., Salim, B. A., Tarimo, A. K. and Mahoo, H. F. (2008) Effects of deficit irrigation scheduling on yields and soil water balance of irrigated maize. *Irrigation Sci.* **27**, 11-23.

Israelsen, B. O. and Hansen, V. E. (1962) *Irrigation Principles and Practices",* John Wiley and Sons, Inc, New York, USA.

Jiang, X., Kang, S., Tong, L., Li, F., Li, D., Ding, R. and Qiu, R. (2014) Crop coefficient and evapotranspiration of grain maize modified by planting density in an arid region of northwest China. *Agric. Water Manage.* **142**, 135-143.

Kebede, H., Sui, R., Fisher, D. K., Reddy, K. N., Bellaloui, N. and Molin, W. T. (2014) Corn yield response to reduced water use at different growth stages. *Agric. Sci.* **5,** 1305.

Khalili, M., Naghavi, M. R., Aboughadareh, A. P. and Rad, H. N. (2013) Effects of drought stress on yield and yield components in maize cultivars (*Zea mays* L.).*Int. J. Agron. Plant Prod.* **4**, 809-812.

Khoshvaghti, H., Eskandari-Kordlar, M. and Lotfi, R. (2013) Responses of morphological characteristic and grain yield of maize cultivars to water stress at reproductive stage. *J. Biodivers. Environ. Sci.* **3**, 20-24.

Kramer, P. J. and Boyer, J. S. (1995) "*Water Relations of Plants and Soils",* Academic Press. San Diego. 495 p.

Kullberg, E. G. (2015) "*Evaluation of Stress Coefficient Methods to Estimate Crop Evapotranspiration",* Colorado State University,USA.

Kuşçu, H. and Demir, A. O. (2012) Responses of maize to full and limited irrigation at different plant growth stages. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, **26**.

Li, S., Kang, S., Li, F. and Zhang, L. (2008) Evapotranspiration and crop coefficient of spring maize with plastic mulch using eddy covariance in northwest China.*Agricultural Water Management*, **95**, 1214-1222.

Mansouri-Far, C., Sanavy, S.A.M.M. and Saberali, S. F. (2010) Maize yield response to deficit irrigation during low-sensitive growth stages and nitrogen rate under semi-arid climatic conditions. *Agric. Water Manage.* **97**, 12-22.

Moosavi, S. G. (2012) The effect of water deficit stress and nitrogen fertilizer levels on morphology traits, yield and leaf area index in maize**.** *Pak. J. Bot*. **44**, 1351-1355.

Mostafavi, K., Shoahosseini, M. and Geive, H. (2011) Multivariate analysis of variation among traits of corn hybrids traits under drought stress. *Int. J. Agri. Science*, **1**, 416-422.

MWRIE (2014) "*Water Scarcity in Egypt: The Urgent Need for Regional Cooperation among the Nile Basin Countries".* Ministry of Water Resources and Irrigation of Egypt.

Pandey, R., Maranville, J. and Admou, A. (2000) Deficit irrigation and nitrogen effects on maize in a Sahelian environment: I. Grain yield and yield components**.** *Agric. Water Manage.* **46**, 1-13.

Ritchie, S., Hanway, J. and Benson, G. (1993) How a corn plant develops. *Special Report* No: 48, Iowa State University.

Song–Feng, B., Dai Jun, Y., Zhang Lie, H. and Qing, Y. (1998) Effect of water stress on maize pollen vigor and filament fertility**.** *Acta Agron. Simca*, **24**, 368-373.

Udomprasert, N., Kijjanon, J., Chusri-iam, K. and Machuay, A. (2005) Effects of water deficit at tasseling on photosynthesis, development and yield of corn**.** *Kasetsart J. Nat. Sci*. **39**, 546-551.

Watson, D. J. (1952) The physiological basis of variation in yield**.** *Adv. Agron.* **4**, 101-145.

Williams, L. and Ayars, J. (2005) Grapevine water use and the crop coefficient are linear functions of the shaded area measured beneath the canopy**.** *Agric. For. Meteorol.* **132**, 201-211.

Yenesew, M. and Tilahun, K. (2009) Yield and water use efficiency of deficit-irrigated maize in a semi-arid region of Ethiopia**.** *African Journal of Food, Agriculture, Nutrition and Development*, **9**(8), 1635-1651.

Yılmaz, E., Akçay, S., Gürbüz, T., Dagdelen, N. and Sezgin, F. (2010) Effect of different water stress on the yield and yield components of second crop corn in semiarid climate**.** *Journal of Food, Agriculture & Environment*, **8**, 415-421.

Zaki, Nabila M., Ahmed, Amal G., Hassanein, M.S., Manal, F.M. and Tawfik, M.M. (2014) Yield and yield components of two maize hybrids as influenced by water deficit and amino cat fertilizer**.** *Middle East Journal of Applied Sciences,* **4**, 648-654.

Zarabi, M., Alahdadi, I., Akbari, G. A. and Akbari, G. A. (2011) A study on the effects of different biofertilizer combinations on yield, its components and growth indices of corn (*Zea mays* L.) under drought stress condition**.** *Afr. J. Agric. Res.* **6**, 681-685.

تأثير مستويات الري عند مراحل النمو المختلفة على النمو والمحصول فى الذرة الشامية

هانى صبحى غريب ، أحمد سعد الحناوى * **و محمد إبراهيم مليـحـة****

قسم المحاصيل ، *قسم الأراضى والمياه – كلية الزراعةـ جامعه كفر الشيخ -كفر الشيخ و**معهد بحوث إدارة المياه المركز القومى لبحوث المياه – القاهرةـ مصر.

تم زراعه الذرة الشامية صنف هجين فردى ١٠ فى تربه طينية بمنطقة الرى المطور بالوزارية – كفر الشيخ – مصر خلال موسمى ٢٠١٢ و ٢٠١٣ م لدراسة تأثير مستويات الري فى فترات النمو المختلفة على نمو ومحصول الذرة والعلاقات المائية للتربة. استخدمت معاملتى الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة (مستوى عالى، H) و الاخرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة (مستوى منخفض ، L) فى مراحل النمو المختلفة (مرحلة النمو الخضرى (S₁): تبدأ من الورقة الثالثة (V₃) لبداية تكوين النورة المذكرة (VT)، المرحلة الإنتاجية I (S₂): بعد بداية تكوين النورة المذكرة (VT) إلى النضج العجينى (R₃) و المرحلة الإنتاجية II (S₃): من بداية النضج العجينى (R₃) إلى النضج الفسيولوجى.

أعطت معاملة الرى IHHH (الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة (H) خلال مراحل النمو الثلاثة S₁، S₂ و S₃ و المعاملة IHHL (الرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة (L) في مرحلة النمو (S₃) و الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة (H) في مرحلتى النمو(S1 و S₂) أوالمعاملة ILHH (الرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة (L) في مرحلة النمو (S₁) و الرى عند استنفاذ ٥٠٪ من الماء الميسر فى التربة (H) في مرحلتى النمو(S₂ و S₃)أو المعاملة ILHL (الرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة (L) في مرحلة النمو (S₂) و الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة (H) في مرحلتى النمو(S₁ و S₃) زيادة معنوية فى دليل مساحة الأوراق و الوزن الجاف للنبات عند ٩٩ يوم من الزراعة ، معدل نمو المحصول فى الفترة من ٨١ – ٩٩ يوم من الزراعة ، طول الكوز، سمك الكوز ، عدد الحبوب/كوز ، وزن الحبوب/كوز ، وزن ال١٠٠ حبة ومحصول الحبوب مقارنة بمعاملة الرى ILLL (الرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة (L) خلال مراحل النمو الثلاثة(S₁ ، S₂ و S₃) فى كل من الموسمين. لا يوجد اختلافات معنوية فى محصول الحبوب بين معاملات الرى (IHHL, ILHH, ILHL, IHHH) فى كل من الموسمين . تعتبر الوفرة فى رطوبة التربة فى منطقة الجذور خلال مرحلة S₂ (تشمل تكوين النورة المذكرة ، التزهير ، العقد و الطور العجين) ضرورية للحصول على محصول حبوب عالى مقارب للمعاملة (IHHH).

أعطى الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة طوال الموسم (IHHH)أعلى قيمة لكمية الماء المضاف (٧٢٨٦ و ٧٣٢١ م³ / هكتار) ، بينما سجل الرى عند استنفاذ ٦٥ ٪ من الماء الميسر فى التربة طوال الموسم (ILLL) أقل قيمة (٦١٧١ و ٦١٩٨ م³ / هكتار) فى موسمى ٢٠١٢ و ٢٠١٣ على الترتيب. وجد أن معاملات الرى IHHL, ILHH, ILHL و التى تعرضت لمعاملة استنفاذ ٥٠ ٪ من الماء الميسر فى التربة فى فترة النمو S₂ مكافئه للمعاملة الرى عند استنفاذ ٥٠ ٪ من الماء الميسر فى التربة طوال مراحل النمو الثلاثة (IHHH)، إلا أنها أقل فى كمية الماء المضاف و الاستهلاك المائى ووفرت على

الاقل (١١,٣، ١٦ ، ١٩,٩ ٪ من كمية الماء المضاف مصاحبة بنقص فى المحصول قدرة (٣,١ ، ٣,٢ و ٥,٣ ٪) مقارنه بالمعاملة (I_{HHH}) على الترتيب. و ايضا زادت الانتاجية على اساس الماء المضاف و الانتاجية على اساس الاستهلاك المائى (كجم حبوب/م³ ماء) مقارنة بالمعاملة (I_{HHH}). كانت معادلة بنمان مونتث المستخدمة فى تقدير الاستهلاك المائى و متوسط كفاءة المحصول (K_c) فى كل من الموسمين ٠,٤٣ ، ٠,٥٤ ، ٠,٦٤ ، ٠,٥٨ ، ٠,٥٨ ، ٠,٥٨ فى فترة النمو و النمو الخضرى و تكوين النورة المذكرة إلى مرحلة النضج اللبنى ، الطور اللبنى إلى العجينى ، الطور العجينى إلى النضج الفسيولوجى على التوالى.

وعليه نوصى عندما تكون مياه الرى هى المحدد للزراعة فيجيب تطبيق معاملة الرى (I_{LHL}) لانها أعلى محصول حبوب مقارب للمعاملة (I_{HHH}) مع أقل كمية ماء مضاف و أقل استهلاك مائى وأعلى انتاجية للمياه والتي يمكن التوصية بها تحت ظروف الدراسة في محافظة كفر الشيخ ، فى شمال الدلتا ، مصر