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Effect of Moisture Depletion Rates and Irrigated Zone Depth on Water Requirement Growth and Yield of Corn *Zea mays* L.

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Abstract: Implemented a field experiment to grow the corn crop *Zea mays* L. of the Autumn season 2016. The experiment, located 15 km South-West of Baghdad on the line along the 33°70'84" North and longitude 44°18' 75" East, Yusufiyah area, according to design were arranged in a split-plot design with three replications which included major treatment proportions of moisture depletion as added irrigation water after depleting 60, 75, 90% of available water to plant and included secondary plots the depth of the irrigated zone is D1 (0-45 cm) from the beginning of planting to harvest and second depth D2 (0-15 cm) from agriculture to the beginning of the vegetative growth stage, then increase depth of irrigated zone (0-30 cm) to the beginning of flowering, then increase (0-45 cm) to the end of physiological maturity. This experiment is designed to study the effect of the proportions of moisture depletion and the depth of irrigated zone on the plant growth of sorghum and estimate the water consumption of the crop under conditions of Iraq center given I1D1 treatment the highest value of actual Evapotranspiration (ETa) reached to 624 mm. While given I1D2 treatment the highest of water consumption for the second depth reached 567 mm. Calculate reference evapotranspiration by the Penman-Monteith modified equation ant its value 612 mm. Calculate the crop coefficient (K_c), field Water use Efficiency (WUE_f) and crop Water Use Efficiency (WUE_c) I2D2 treatment gave the highest value of WUE_c WUE_f reached to (1.03, 1.06) kg of grain.m^{-3}, respectively while the I3D2 treatment given lower value to WUE_c WUE_f reached to (0.82, 0.86) kg of grain.m^{-3}, respectively has been studying factors of growth and yield of plant (plant height, leaf area, leaf area index, yield of grain, 500-grain weight).

Key words: Moisture depletion, water requirement growth, WUEc, WUE_f, growth, consumption

INTRODUCTION

Zea mays L. is regarded one of the most important cereal crops in Iraq where it has been cultivated in large areas because of its importance and its high production capacity. It comes after wheat and rice in terms of cultivated area and production. The total cultivated area of this crop over the world during 2005-2006 was approximately 14.756 mln.ha with a total production of 70.120 mln.ton and an average yield of 4752 kg.grains.ha^{-1} (Akbar *et al*., 2008). In Iraq, the cultivated area of the crop during the same period was about 155, 100 ha. and a total production of 384, 500 tons with an average yield of 2478.8 kg.ha^{-1} (Anonymous, 2006). Field irrigation losses or so called additive losses, represent the largest part of surface irrigation losses. In addition, the irrigation efficiency of Arab countries is estimated to be about 40-50% which is about 60% of the total losses of surface irrigation. For that it is considered the weakest point in the surface irrigation circle and therefore, great efforts are needed to reduce these losses (AOAD., 2002).

One of these losses is the leakage to depths below the root area. Therefore, the recent trends in irrigation management are to moisten the root system by adding water locally at the roots without full moistening of the root system or partial moistening of the root system. It is here necessary to take into account the stages of the plant growth and avoiding exposing the sensitive stages to water deficit (McCarthy *et al*., 2002).

Therefore, determining the depth of an irrigated area which depends on the effective depth of the root area according to the stages of growth and development of the crop is an important mechanism in reducing the amount of water to be added. Thus, reducing the water to be used in irrigation will introduce additional areas for agriculture. The irrigation process is sufficient when we maintain water available within the boundaries of the root area after

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determining critical stress levels that do not cause economic loss of the crop. These levels vary by crop type.

MATERIALS AND METHODS

Agricultural operations and cultivation of *Zea mays* L. crop: The soil was plowed by a moldboard plow and was then softened by using disk harrows. The field was divided into plots of 3×3 m leaving a separation of 2 m and between each two blocks and a separation of 1.5 m between each two plots in order to control the horizontal movement of water between plots.

On 16/7/2016, during Autumn season, *Zea mays* L. seeds were planted in the form of rows in the plots, the distance between each two rows was 0.75 m and the distance between each two hills was 0.25 m to get a plant density of 53333 plants ha^{-1} (Younis, 1993).

About 4-5 seeds were put in each hill with a depth of 0.03-0.05 m. The plants then were diluted to be one plant per hill after 2 weeks from germination.

A diazinon herbicide (10% effective ingredient and 6 $kg.ha^{-1}$) was used in the heart of the plant in two batches. The first one was after 20 days from germination and the second was after 15 days from the first batch to control the Sesamiacretica lea (Anonymous 2006).

However, fertilizers were added in accordance with the fertilizer recommendation of *Sorghum bicolor* L. (Moench) (Naimi, 1999). Phosphate fertilizer was added in the form of TSP (46% P205) for all treatments and at a rate of 89 kg P. ha^{-1} when planting began. Nitrogen fertilizer on the other hand was added in an urea form (46% N) for all treatments with a total of 320 kg $N.ha^{-1}$ in two batches, the first batch after 25 days and the second batch after 60 days from planting.

At the beginning of anthesis stage, potassium fertilizer was also added in K_2SO_4 potassium sulfate form (26% K_2O) and at a rate of 83 kg $K.ha^{-1}$ within three batches according to different stages of growth. The process of planting new seeds instead of the ones that failed to grow was performed 2 weeks after the planting. Additionally, weeding process was carried out manually during the whole growth season. Finally, harvest was carried out on 10/11/2016.

Laboratory measurements of soil: Random samples were taken from field soil before planting the crop from three different sites with a depth of 0-0.3 m to determine the primary physical and chemical properties of the soil as shown in Table 1.

Experiment design: The Random Complete Block Design (RCBD) with three replicates was used in accordance with the plots order. The main plots included the rates of moisture depletion. Irrigation water was added after depleting 60, 75 and 90% of the soil conservation capacity to the ready water. Likewise, the secondary plots included the depth of the irrigated area: the first treatment (0-0.45 m) from the beginning of planting until the harvest, the second treatment (0-0.15 m) during the emergence stage (0-0.30 m) during the vegetative growth stage and (0-0.45 m) during the anthesis and maturity stages.

Table 1: Some chemical and physical soil properties

Soil depth/unit	Properties
30_0 (cm)	
3.2 ($ds.m^{-1}$)	EC
7.6	pH
120	
	Sand
620 ($g.kg^{-1}$)	Silt
260	Clay
SiL	Texture
23.31($cmole.kg^{-1}$)	CEC
28.0 ($g.kg^{-1}$)	$CaCO_3$
16.15	
	Ca
7.51	Mg
12.88	Na
1.63 ($Mleq.L^{-1}$)	K
Nill	CO_3
1.95	HCO_3
20.22	CL

Experiment treatments: The first factor: the depth of the irrigated area (D). Irrigation was carried out after the estimated percentage of the soil conservation capacity was depleted at two levels of irrigation depth.

First treatment (D1): The irrigation is carried out to a depth (0-45 m.) throughout the growing season and for all the growth stages.

Second treatment (D2): Irrigation was carried out to depth (0-0.15) during the emergence stage, then to depth (0-0.30 m) during the vegetative growth stage and then to depth (0-0.45 m) during the stages of anthesis and the grain growth until the harvest.

The second factor: The depletion rate of the ready water (I).

First treatment (I1): Irrigation when the depletion rate is 60% of the ready water.

Second treatment (I2): Irrigation when the depletion rate is 75% of the ready water.

Treatment III (I3): Irrigation when the depletion rate is 90% of the ready water. Irrigation was carried out using water from Tigris River whose electrical conductivity was (1.37) $ds.m^{-1}$. Irrigation dates for each treatment varied according to the depletion rates of soil conservation capacity of the ready water and irrigation depth. Soil conservation capacity to ready water was determined on the basis of the difference between the plant conservation capacity of ready water at the field capacity and at the permanent wilting point.

Measurements of the water content of the soil were carried out by the Gravimetric method on the entire irrigation depth using a Mini-Auger sampler with a diameter of 0.02 m and a height of 1 m. The moisture content of the soil samples was estimated by drying the samples in a microwave oven for 15 min after the drying period. The microwave oven was calibrated with an electric oven according to the method suggested by Zein (2002). The samples were periodically taken throughout irrigations until reaching the water content which was achieved at the required percentage of depletion to conduct the next irrigation except for the germination irrigation which was calculated on the basis of the primary moisture content to deliver the moisture to the field capacity. The amount of the added irrigation water of each plot was calculated according to the equation mentioned by Kovda *et al*. (1973):

$$d = (\theta_{Fc} - \theta_{bi})D \quad (1)$$

Where:
d = Depth of added water (cm)
θ = Fc volumetric humidity at field capacity

Volumetric humidity before irrigation and after draining 60, 75, 90% of the water θ_{bi} ready deep of soil (m) D. The amount of water to be added to the experimental units was calculated on the basis of moistening the soil layer from 0-0.45 m for the period from the beginning of planting until the harvest (the first treatment). The moistening calculations in the second treatment were (0-0.15 m) (0-0.30 m) during the vegetative growth stage and (0-0.45 m) for the period from the beginning of the anthesis stage until the harvest. The growth stages of the plant were determined by Doorenbos and Pruitt. The growth periods were (20 days) for emergence stage, (30 days) for vegetative growth stage (40 days) for anthesis stage and (30 days) for grains maturity stage. Thus, the total peroid of the growth season was (120 days). Plastic pipes connected to a water-feeder (diesel pump) strapped to a water tank which received water from Tigris River. A water meter was connected to measure the amount of water to be added to each experimental unit. The water was distributed homogenously to reach moisture content at field capacity.

Calculation of water requirements: Equation of water balance and calculation of actual water requirement (ETa) the water balance equation was used as a direct method in calculating the actual water consumption of the crop and according to the following Eq. 2 (Allen *et al*., 2006):

$$(I+P+C)-(ETa+D+R) = \pm\Delta S \quad (2)$$

Where:
I = Irrigation water added (mm)
P = Rain (mm)
C = Height of water with capillary properties (mm)
ETa = Actual Evaporation-Transpiration (mm)
D = Deep Duck (mm)
R = Surface Runoff (mm)
ΔS = Stocks of Soil moisture at the beginning and end of the season

IF, R = 0 (because the ground is level and surface runoff is almost non-existent). C = 0 (because ground water is deeper than 2.5 m). D = 0 (because irrigation is limited to the attenuation ratios of the prepared water and to a certain depth of the soil layer). Therefore, the equation becomes as follows:

$$I+P = ETa \pm \Delta S \quad (3)$$

The modified Benman-Monteth equation for the Evapotranspiration calculation (ETo). The FAO Penman-Monteith equation (Allen *et al*., 2006) is based on the measurement of Evapotranspiration (ETo) based on the Cropwat (Smith, 1992) program. Using the climatic information for the Autumn season 2016 from the air station of the pilot station of the ministry of water resources:

$$ETo = \frac{\left[0.408\times(Rn-G) + \gamma\left[\frac{900}{T+273}U_2(ea-ed)\right]\right]}{\Delta+\gamma(1+0.34U_2)} \quad (4)$$

Where:
ETo = Evapotranspiration-nectar of yield ($mm.day^{-1}$
R_n = Pure radiation (mJ^2 m day^{-1})
G = Soil heat flow (mG^2 m-day^{-1})
T = Average temperature (m 0)
U_2 = Wind speed measured at 2 m height (mtha)
ea = Saturated steam pressure (kPa)
ed = True vapor pressure (kPa)
Δ = Slope of steam pressure curve (kPa)
γ = Humidity constant (kPa) 900 = Conversion factor crop coefficient

The yield coefficient K_c was calculated according to the following equation:

$$K_c = \frac{ETa}{ETc} \quad (5)$$

Where:

Eta = Actual Evaporation-Transpiration (mm)
Eto = Evaporation-nectar reference (mm)
K_c = Crop coefficient (without units)

WUE (Water Use Efficiency): Field Water use Efficiency (WUE_f) was calculated by Eq. 6:

$$WUE_f = GY/WA \quad (6)$$

Where:

WUE_f = Field Water Use Efficiency (kg, m^3)
GY = Total grain yield (kg-ha^{-1})
WA = Irrigation Water Actually added to the field (m^3 ha^{-1}

Water Use Efficiency (WUE_c) was calculated according to the Eq. 7:

$$WUE_c = GY/ETa \quad (7)$$

Where:

WUE_c = Potable Water Use Efficiency (kg, m^3)
GY = Total grain yield (kg. ha^{-1})
ETa = Evaporation-Transpiration of the seasonal effect of a unit area (m^3 ha^{-1})

RESULTS AND DISCUSSION

Water requirements of crop

Total water consumption: Figure 1 showed the effect of moisture depletion and the depth of the irrigated area on the water consumption of *Zea mays* L. for the Autumn season of 2016. The results showed that treatment I1 showed that the highest water consumption (ETa) was 619 and 574 mm.season^{-1} for the depth D1 and D2, respectively. Differently in treatment I2, water consumption values were 517 and 481 mm. season^{-1} for the depth D1 and 2, respectively and in treatment I3, the water consumption values were the lowest, 425, 395 mm. season^{-1} for the depth D1 and D2, respectively.

Table 2 showed the number of irrigations, the depth of the added water and the contribution of rainfall. But the contribution of groundwater has been neglected because it is at a level far away from the effect of the actual evapotranspiration. Accordingly the water balance equation terms have been depended upon in the calculation of the actual evapotranspiration for each treatment. The Irrigation treatment when depleting 60% of the soil conservation capacity of the ready water, showed the highest water consumption compared to the irrigation treatments when depleting 75 and 90% of the soil conservation capacity of the ready water. This is because the relationship between the rate of moisture depletion and water consumption is inverse. Hence, increasing moisture depletion ratios led to make the soil moisture content close to the permanent wilting point. At low depletion rates, the moisture content is close to the field capacity. Intervals between irrigations become close, leading to increasing the water consumption by increasing the soil moisture content because of increasing evapotranspiration. The results showed that the depth D1 was the highest water consumption compared to the depth D2 and all the treatments 11-I3 in order to reduce the amount of irrigation water to be added during the stages of emergence and vegetative growth. The possibility of saving 17 and 31% of the added water in depth D1 at treatments I2 and I3 compared to the treatment I1. At depth D2, 16 and 31% of the added water was saved at treatments I2 and I3, respectively, compared to treatment I1 at the same depth of irrigation.

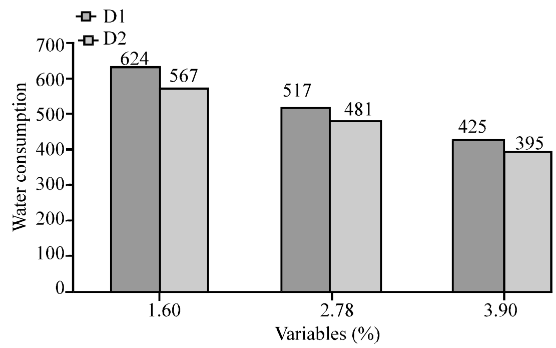

Fig. 1: Actual cumulative water consumption of different treatments (mm)

Table 2 the depth of the added water and the total water consumption and the saving ratios in the irrigation water of the white maize crop for the different treatments.The values of water consumption for the study treatments were within the value ranges mentioned in publications of FAO (2012), ranging from 450-750 mm. season^{-1} of the plant, except for treatment I3 which was less than the mentioned values due to the severe moisture stress experienced by the plants which in turn negatively affected the yield.

When comparing the values of water consumption for the comparison treatment in this experiment with the values obtained in other experiments in central Iraq, it was noted that it aws less than what had been recorded

Table 2: The depth of the added water and the total water consumption and the saving ratios in the irrigation water of the white maize crop for the different treatments

Irrigation water supply (%)	Evaporation-total actual transpiration (mm^{-1})	Difference in primary water content stock between irrigation ΔS (mm)	Contribution of rain water	Depth of irrigation water added	Number of irrigation	Depth of irrigated area (cm) (D)	Drainage ratios of ready-made water (%) (1)
0	619	36	13.5	642	20	D1	60 (11)
0	574	25	13.5	589	28	D2	
17	517	27	13.5	530	12	D1	75 (12)
16	481	19	13.5	488	17	D2	
31	425	22	13.5	434	8	D1	90 (43)
31	395	30	13.5	412	11	D2	

Table 3: Actual water consumption during different growth stages (mm)

Treatment (1)	Actual water consumption (ETa) mm. season-1	Actual water consumption during different growth stages (mm)			
		Maturity stages	Anthesis stage	Vegetative growth stage	Emergence stage
I1D1	619	62	215	210	132
I1D2	574	65	229	173	107
I2D1	517	68	176	169	104
I2D2	481	61	168	164	88
I3D1	425	62	147	133	83
I3D2	395	58	154	119	64

(Abdel-Motagally, 2010; Ismail, 1984; Abdulhasan, 2007), reaching 839, 840, 727 and 729 mm.season^{-1}, respectively. While the values of water consumption for the treatment of full irrigation is similar to that obtained reaching 577 and 605 mm.season^{-1}, respectively.

Water consumption during different stages of growth: Table 3 showed that the amount of water consumed for various treatments was based on the growth stage and the environmental conditions prevailing during the growth season. The actual water consumption of the plant (ETa) was increased by increasing the age of the plant at all the irrigation treatments. It reached its highest value during the anthesis stage then decreased during the maturity and harvest stages

The reason for the increase in evapotranspiration during the anthesis stage is due to increasing the depth of the irrigated area. In treatment D2, absorption of water and nutrients was increased because the time consumed during anthesis stage is longer than that of other stages and the leaf area of the plants reached its maximum. In addition to that water lost by plants was increased as well through the transpiration reaching the highest rate during the anthesis stage at all treatments. Water consumption values decreased after the anthesis stage for many reasons such as the plant's need for water reduced due to the com pletion of plant growth, the decrease in temperature, the increase in relative humidity and the number of the solar luminosity hours decreased that helped to reduce the evaporation rates of the soil and allow the soil to dry after the last irrigation. Consequently, the decrease in crop requirement for the water resulted in a decrease in soil moisture depletion and then spacing the irrigation intervals and reducing the actual evapotranspiration. This is consistent with (Stichler and Fipps, 2003; (McWilliams, 2003) who showed that the maximum water requirement of the plant occurred from the booting stage until the end of the anthesis stage. After that the daily requirement for water began gradually to decrease during the grain filling stage.

It was noticed that the evapotranspiration of the daily activity was greater in the emergence stage than in the rest of the growth stages because the coverage degree to the soil surface by the plant's leafs and the coverage of the leafs to each other were very small compared to the coverage degree in the rest of the stages. Moreover, the high rate of temperature, wind speed and solar luminosity with a low relative humidity in this period have helped in increasing the evapotranspiration. However, the length of the anthesis stage had a significant effect on increasing the water consumption during this stage compared to the rest of the growth stages.

Crop coefficient (K_c): The crop coefficient of *Sorghum bicolor* L. (Moench) was calculated by using Eq. 5. The values of the reference evapotranspiration (ETo) were calculated by using the modified Panamantometh equation (FAO., 1992) which is calculated by Cropwat program (Smith, 1992). Furthermore, the actual cumulative evaporation (ETa) was calculated by the water balance equation. In like manner, Fig. 2 showed the variation in crop coefficient values during the growth season of the different treatments at different stages of growth. The values of the crop coefficient was observed to be increased in line with the progressing of growth stages until the anthesis stages. Contrarily, the crop coefficient values decreased in the last stages of the crop life cycle

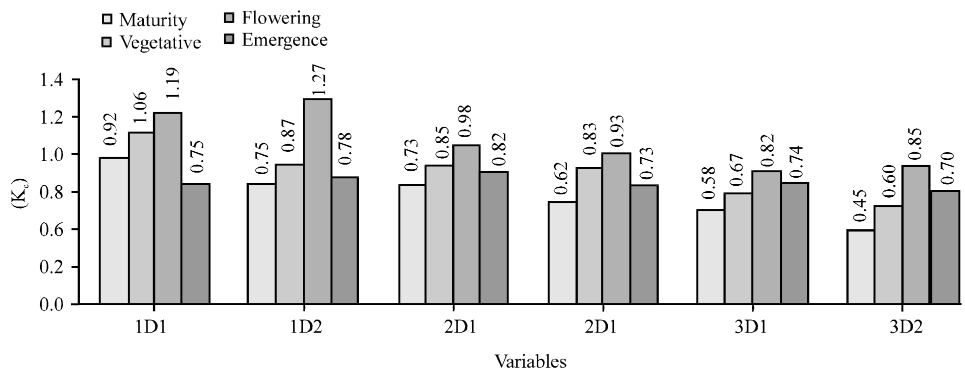

Fig. 2: The crop coefficient (K_c) for different treatments during the growth stages

due to the low actual evapotranspiration that was resulting from low temperatures and high relative humidity as well as the completion of plant growth and the maturity of the crop. These findings were in agreement with Odhiambo and Irmak (2012), Piccinni *et al.* (2009) and FAO (2012).

It is possible to observe from (Fig. 2) that the values of the crop coefficient are decreased by decreasing the quantities of irrigation water the growth stages of different treatments because of a linear relationship between the actual evapotranspiration and the crop coefficient. It can also be noted that there is a relative increase in the value of the crop coefficient at the emergence stage compared to the values indicated by (FAO, 1992). If the area is all wet as in the case of irrigation, the value of the crop coefficient starts with a large increase due to the increase in the surface of the moistening soil, resulting in an increased evaporation from the soil surface and consequently increasing the actual water consumption which in turn led to increase the value of the crop coefficient (Xie *et al.*, 2012). In opposite direction, the coefficient value of the plants started small if the soil was wet in part. These results were in line with (Smith *et al.*, 1996) who stated that the crop coefficient can be affected during the first stage of the growth by the irrigation method used in the process. Nonetheless, it was found that the value of the crop coefficient started large when the area was all wet as in sprinkler irrigation. But If the soil was partially wet as in the dripping irrigation, the value of the plant started small.

Field and crop water use efficiency: Table 4 and 5 show the efficiency of field and crop water use that is calculated from Eq. 6 and 7 during the growth stages of *Sorghum bicolor* L. (Moench). Because of the effect of moisture depletion and the depth of the irrigated area, the values of the efficiency of field and crop water use became close.

Table 4: Rate of wet attrition rates and the depth of the irrigated area and their overlap

	Depth of irrigated area (D)		
Moisture attenuation ratios (1) (%)	D2	D1	Average
60 (I1)	1.01	1.00	1.02
75 (I2)	1.03	1.02	1.06
90 (I3)	0.82	0.98	0.94
LSD 5	ns		ns
Average	0.99	1.01	
LSD 5			ns

Table 5: Effect of moisture attenuation ratios and the depth of the irrigated area and their overlap in the efficiency of the use of crop water (kg of grain m^3)

	Depth of irrigated area (D)		
Moisture attenuation ratios (1) (%)	D2	D1	Average
60 (11)	1.05	1.02	1.05
75 (12)	1.06	1.05	1.08
90 (13)	0.86	1.01	0.97
LSD 5	ns		ns
Average	1.03	1.04	
LSD 5			ns

This is due to the fact that the amount of water added to the field is close to the amount of actual water consumption ETa for the crop at all the experiment treatments. Water addition has adopted specific moisture depletion ratios. The depth of irrigation was determined according to the stage of plant growth which allowed to control the quantities of the added water and not letting irrigation go into deeply penetration. It can be observed that the potential contribution of ground water to actual evapotranspiration was not possible because it was far from effecting the water consumption.

The results in Table 4 and 5 showed that the factors of moisture depletion and the depth of the irrigated area had no significant effect on the efficiency of field and crop water use nor did the interference have a significant effect on the efficiency of field and crop water use. This can be attributed to the reduction of the cereal yield in a linear and significant manner with decreasing the irrigation water quantities at all the treatments. Hence, the values of the efficiency of field and crop water use became close.

Treatment I2 gave the highest average, reaching (1.06-1.03) kg grain.m^{-3} for the efficient of field and crop water use, respectively. The increase in the efficiency values of field and crop water use at the depletion rate of 75% compared to the depletion rate of 60% can be attributed to decreasing the amount of the added irrigation water and the actual evapotranspiration. As the decrease in the amount of used water with reference to the cereal yield led to a rise in water use efficiency. This was consistent with Hadi *et al.* (2010) and Abdulhasan (2007).

While treatment I3 gave a lower average of this property, reaching (0.82-0.86) kg grain.m^{-3} for both field and crop water-use efficiency, respectively. As a consequence, reducing the frequency of irrigation at high depletion rates increased the time between the irrigations which led to the full depletion of soil moisture. This caused the plant to be exposed to acute water stress which in turn was reflected in the processes of expansion and division of cells. Accordingly processes of stem elongation and leaf expansion were reduced. Therefore, the area of carbonation, leaf area, leaf efficiency as well as the ability of the plant to transfer the products of carbonation between its parts were decreased. It can be observed that the decrease in cereal yield was in a linear relationship with the decrease in irrigation water quantities at different treatments which caused a decrease in the efficiency of water use as result. Such findings conformed with (Saeed and EL-Nadi, 1998).

As shown in Table 4 and 5, the depth of the irrigated area had no effect on the efficiency of field and crop water use. The convergence of the efficiency values of field water use for both D1 and 2 were 1.01 - 0.99 kg grain. M^{-3}, respectively. There was also a convergence in the values of the efficiency of crop water use for both D1 and 2 were (1.04-1.03) kg.grains.m^{-3}, respectively. This can be attributed to the absence of significant differences in grain yield for the both depths of the irrigated area, despite the different quantities of added water and the actual evapotranspiration.

This method is one of the factors of irrigation management of the crop which ensures a good grain yield in the unit area as well as saving water quantities to enable us to cultivate additional areas.

Concerning the effect of the interference between moisture depletion and irrigated area depth on the efficiency of field water use the highest value was (1.03) kg grain.m^{-3} at treatment I2 D2 where it gave the highest productivity of the water unit. While the lowest value was (0.82) kg grains.m^{-3} at treatment I3D2 due to the significant decrease in the cereal yield value compared to the rest of treatments. This was consistent with what Ottman (2010) have found. It was found that the highest value of field and crop water use efficiency of *Sorghum bicolor* L. (Moench) was at 75% of the full irrigation treatment while the lowest value was at 25% of the full irrigation treatment.

CONCLUSION

The effect of interference on the efficiency of crop water use was similar to that of field water use. Yet, the highest value was 1.06 kg grains.m^{-3} at treatment I2D2. The reason for that was the absence of significant differences in the cereal yield in this treatment compared to treatment I2D1, despite the decrease in the actual evapotranspiration of treatment T2D2 compared with I2D1 which indicated a high efficiency in the use of crop water. These findings were similar to what have been reached by Abdel-Motagally (2010). The lowest value for crop water use efficiency was (0.86) kg grains. m^{-3} at treatment I3D2. Such decrease was because of the large decrease in the yield by (44%) which in turn reduced the efficiency of crop water use.

REFERENCES

AOAD., 2002. Study of ways of developing surface irrigation and drainage in the Arab countries. Arab Organization for Agricultural Development, Khartoum, Acronym.

Abdel-Motagally, F.M.F., 2010. Evaluation of water use efficiency under different water regimes in grain sorghum (*Sorghum bicolor* L. Monech). World J. Agric. Sci., 6: 499-505.

Abdulhasan, A.S., 2007. Response of two types of *Sorghum bicolor* (L.) Moench for water stress under field conditions. Ph.D Thesis, Department of Field Crops Science, University of Baghdad, Baghdad, Iraq.

Akbar, M., M.S. Shakoor, A. Hussain and M. Sarwar, 2008. Evaluation of maize 3-way crosses through genetic variability, broad sense heritability, characters association and path analysis. J. Agric. Res., 46: 39-45.

Allen, R.G., S. Luis, Pereira and M. Smith, 2006. Irrigation and drainage paper No. 56: Crop evapotranspiration (Guidelines for computing crop water requirements). Food and Agriculture Organization, Rome, Italy.

Anoymous, 2006. Guidelines for the cultivation and production of white maize general authority for extension and agricultural cooperation. White Corn Research Development Project, Ministry of Agriculture, New Delhi, India.

FAO., 1992. The use of saline water for crop production irrigation and drainage paper 47. Food and Agriculture organization, Rome Italy.

FAO., 2012. Crop yield response to water irrigation and drainage paper 66. Food and Agriculture organization of United Nations, Rome, Italy.

Hadi, A., M. Karim and R.K. Shati, 2010. Role of irrigation depth and frequency in growth and yield of maize: Water use effeciency, grain yield and its components. Iraqi J. Agric. Scis., 41: 40-47.

Ismail, H.N., 1984. Lecture on water consumption in the Arab world, water needs course for irrigation projects. Master Thesis, University of Baghdad, Baghdad, Iraq.

Kovda, V.A., C.V. Berg and R.M. Hangun, 1973. Irrigation, drainage and salinity. Food and Agriculture Organization, Rome, Italy.

McCarthy, M.G., B.R. Loveys, P.R. Dry and M. Stoll, 2002. Regulated Deficit Irrigation and Partial Rootzone Drying as Irrigation Management Techniques for Grapevines. In: Deficit Irrigation Practices, FAO (Eds.). Food and Agriculture Organization, Rome, Italy, ISBN-13: 9789251047682, pp: 79-87.

McWilliams, D., 2003. Drought strategies for corn and grain sorghum. New Mexico State University, Las Cruces, New Mexico.

Naimi, S.N.A., 1999. Fertilizers and soil fertility. Ministry of Higher Education and Scientific Research, University of Al Mosul, Mosul, Iraq.

Odhiambo, L.O. and S. Irmak, 2012. Evaluation of the impact of surface residue cover on single and dual crop coefficient for estimating soybean actual evapotranspiration. Agric. Water Manage., 104: 221-234.

Ottman, M.J., 2010. Water use efficiency of forage sorghum grown with sub-optimal irrigation, 2009-2010 forage and grain report. Master Thesis, University of Arizona, Tucson, Arizona.

Piccinni, G., J. Ko, T. Marek and T. Howell, 2009. Determination of growth-stage-specific crop coefficients (KC) of maize and sorghum. Agric. Water Manage., 96: 1698-1704.

Saeed, I.A.M. and A.H. El-Nadi, 1998. Forage sorghum yield and water use efficiency under variable irrigation. Irrig. Sci., 18: 67-71.

Smith, M., R.G. Allen and L.S. Pereira, 1996. The revision of the FAO-24 guidelines for predicting crop water requirements. Proceedings of the ASAE International Conference on Evapotranspiration and Irrigation Scheduling, November 3-6, 1996, Henry B. Gonzalez Convention Center, San Antonio, Texas, pp: 1166-1166.

Smith, M.A., 1992. Senior irrigation management officer water resources. Food and Agriculture Organization, Rome, Italy.

Stichler, C. and G. Fipps, 2003. Irrigating sorghum in South and South Central Texas. Texas FARMER. Collect., 1: 1-6.

Xie, K., X.X. Wang, R. Zhang, X. Gong and S. Zhang *et al.*, 2012. Partial root-zone drying irrigation and water utilization efficiency by the potato crop in semi-arid regions in China. Sci. Hortic., 134: 20-25.

Younis, A.A., 1993. Production and Improvement of Field Crops. University of Baghdad, Baghdad, Iraq,.

Zein, A.K., 2002. Rapid determination of soil moisture content by the microwave oven drying method. Sudan Eng. Soc. J., 48: 43-54.