World Journal of Agricultural Sciences 13 (5): 191-198, 2017
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2017.191.198

Optimum Irrigation Rate for Drip Irrigated Maize Grown In Semi-Arid Conditions of Upper Egypt

[1]Mamdouh A. Eissa, [2]Saudi A. Rekaby, [2]Sabry A. Hegab and [1]Hussein M. Ragheb

[1]Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut 71526, Egypt
[2]Departments of Soils and Water, Faculty of Agriculture, Al-Azhar University, Assiut 71524, Egypt

Abstract: Shortage of water in arid and semi-arid maize production systems increases the need of applying deficit irrigation. A two-year field study in the semi-arid region of Upper Egypt was carried out in a randomized complete block design (RCBD) during the summer seasons of 2014 and 2015. Maize plants were irrigated by 8276 or 6207 m^3 ha^{-1} (100 or 75% of water requirements, I_{100} and I_{75}). Uptake of N and K by maize irrigated by I_{100} increased by 11and 7% in the first season and by 13 and 15% in the second season compared to I_{75}. Increasing the irrigation level to 100% caused a 20 and 6% increase in the straw yield in the first and second season, respectively, also it caused a 20% increase in the biological yield in the first season. The grain yield of maize irrigated by I_{75} was higher by 5 and 10% in the first and second season, respectively, as compared to I_{100}. Water use efficiency (WUE) was higher by 41and 56% in the first and second season, respectively, in the case of I_{75} as compared to I_{100}. The data of the current study indicated that slightly water stress caused a slightly significant reduction in the straw and biological yield of maize and saved 2000 m^3 of water, moreover, it caused a slightly significant increase in the grain yield.

Key words:

INTRODUCTION

The main concern in arid and semi-arid regions is water availability and its efficient use [1]. In these areas, efficiency of irrigation has to increase to achieve sustainability [2]. Deficit irrigation is an optimization strategy that is utilized to reduce water use and increase water use efficiency (WUE) in many parts of the world [3]. It is well know that the water resources in Egypt are limited to the share of Egypt in the flow of the Nile River by 55.5 billion m^3, the deep groundwater in the deserts (mostly non-renewable) and a small amount of rainfall in the northern coastal area and Sinai. Meanwhile, water demand is continually increasing due to population growth, industrial development and the increase of living standards. Because of population growth, the per capita share of water has dropped dramatically to less than1000 (˜ 700) m^3/capita, which, by international standards, is considered the "water poverty limit". The value may even decrease to 584 m^3 /capita in the year 2025 [4]. Water is the main limiting factor on yield production in the hot and dry summer period of semiarid regions. When water resources are a limiting factor in yield production, irrigation programs need to be applied to enable maximum production per unit of irrigation water. Deficit irrigation is one way of maximizing water use efficiency for higher yields per unit of irrigation water applied [5]. Water scarcity in the next decades is a real threat to food production especially in arid and semi-arid areas where water is the limiting factor in the expansion of cultivated land. Therefore, water management that maximize yield per unit of water consumed by plant is highly desired. In Egypt, limitation of water resources coupled with high population forced to a great competition for water supply that makes conservation and efficient use of water obligatory [6]. This has stimulated the researchers to find new irrigation technologies, systems and irrigation strategies to improve water use efficiency. In modern irrigation systems, especially under arid or semi-arid conditions, water and nutrients are supplied simultaneously (fertigation). Under drip irrigation system water and nutrients have been used in highly efficient way.

Corresponding Author: Mamdouh A. Eissa, Department of Soils and Water, Faculty of Agriculture, Assiut University, Assiut 71526, Egypt.

Water stress (commonly known as drought) can be defined as the absence of adequate moisture necessary for normal plant grow and to complete the life cycle [7]. The lack of adequate moisture leading to water stress is common occurrence in rain fed areas, brought about by infrequent rains and poor irrigation [8]. Water deficits affect every aspect of plant growth, including the anatomy, morphology, physiology and biochemistry. In maize, the reduction in grain yield caused by drought ranges from 10 to 76% depending on the severity of the drought and the growth stage at which it occurs [9].

Maize is one of the most important cereal crops in the world. Moisture stress is an important factor affecting the growth of maize, especially in arid and semiarid regions [10]. Maize has been reported in the literature as having high irrigation requirements and sensitive to water stress [11]. In arid and semi-arid regions, the daily evapotranspiration rates of maize often exceed 10 mm day^{-1} for significant time periods [12]. Maize are crops with high water requirements, have the ability to tolerate a short period of drought. However, water stress influences various physiological and biochemical processes. This may inhibit plant growth, decrease developmental activities of the cells and tissues and cause a variety of morphological, physiological and biochemical modifications. In contrast to other stress factors, drought stress does not occur abruptly, but develops slowly and increases with time in intensity and cause damages [13]. Drought affects water and nutrient supply to the plants thus affecting adversely plant development and yield [14]. Water, being a universal solvent, is required for most of the metabolic activities of a plant and its shortage is expected to affect various physiological and biochemical processes in plants. Maize is one of the most important crops in the world and using drip irrigation in its production is commonly known. Irrigation and fertilization are crucial factors for successful establishment of annual food crops such as cereal crops [10]. Maize is a major cereal crop in Egypt due to its importance in human nutrition, animal and poultry where intervention in the industry dry feed rates of up to 70% and in the baking industry by 20% and also intervened in some industries such as extraction of glucose, fructose and oil.

The present research aims to determine the effect of deficit irrigation on: (1) plant growth, (2) N, P and K uptake, (3) yield and yield components and (4) water use efficiency of maize in semiarid conditions.

MATERIALS AND METHODS

Field Experiment: The present investigation was carried out at the Agricultural Experimental Station farm of the Faculty of Agriculture, Assiut University, Egypt, which is located around the point of 27°12 N latitude and 31° 09 E longitude and at 51 m altitude. The main physical and chemical properties are summarized in Table 1.

The experiment included two irrigation regimes (100 and 75% of water requirements). The experimental design was randomized complete block design (RCBD) with three replicates. The experimental site was irrigated using a drip irrigation system. Dripper laterals were installed 0.7 m apart and emitters were spaced 0.30 m apart with a flow rate of 2.1 L h^{-1}. Maize grains (*Zea mays* L., cv Single Hybrid 10) at rates of 24 kg ha^{-1} were sown on June 14th, 2014 and June 13th 2015 in the first and second season respectively. Grains were sown on one side of the dripper's jet. Two grains were drilled in holes 3-4 cm deep. After 15 days the plants were thinned at one plant per each. The approximate plant population was 48000 plants per ha. All the agriculture practices were applied at the recommendations set by the Ministry of Agriculture and Land Reclamation (Egypt). 396 kg urea (46%N) per hectare was applied with the irrigation water at five equal doses applied weekly, started after 15 days of sowing, 149 kg of super phosphate (15.5% P_2O_5) per hectare was added directly to the soil in one dose before planting. Potassium fertilizer at a rate of 120 kg potassium sulphate (50% K_2O) per hectare was added with the irrigation water in four equal portions (before sowing, 21, 35 and 50 days of sowing).

Calculation of Irrigation Water Requirements: The daily reference evapotranspiration (ET_o) was estimated using Penman–Monteith's modified equation [15]. The actual evapotranspiration (ET_c) was calculated according the equation ($ET_c = ET_o \times K_c$). K_c values used for maize were 0.60, 0.83, 1.20, 0.90 for growth stages initial, development, mid and end, respectively (Allen *et al*., 1998). Based on the climate data in Table 2, the ET_c values for maize were calculated. The estimated ET_o was 698 and 687 mm and the ET_c was 645 and 634 mm in 2014 and 2015 respectively. The total irrigation water requirement during the whole growth season was 8344 and 8209 m^3 ha^{-1} in the first and second season respectively (the application efficiency for drip irrigation (%) (Ea = 85) and the leaching fraction was considered as 10% of water requirement).

Table 1: Physical and chemical soil properties (0-30 and 30-60 cm)

Properties	0-30 cm	30-60 cm
Sand (%)	24.1	24.3
Silt (%)	62.4	62.5
Clay (%)	13.5	13.2
Texture	Si. L	Si. L
Field capacity (v%)	42.7	42.5
Witling point (v%)	21.1	20.1
$CaCO_3$ (%)	5.42	5.08
pH (1:2.5 suspension)	7.54	7.78
EC_e dS m^{-1}	0.99	0.95
Organic matter (g kg^{-1})	2.41	2.25
Total nitrogen (mg kg^{-1})	560	520
Available nitrogen (mg kg^{-1})	67.2	62.4
Available Olsen P (mg kg^{-1})	11.78	11.32
Available-K (mg kg^{-1})	258.1	477.4

Each value represents a mean of three replicates

Table 2: Average monthly maximum (T_{max}) and minimum (T_{min}) temperature, relative humidity (RH), wind speed (WS) and reference evapotranspiration (ET_o) during 2014 and 2015 growing seasons

Month	T_{max}	T_{min}	RH (%)	WS (km day^{-1})	ET_o (mm)
June, 2014	37.8	22.3	33.2	148.8	7.54
July, 2014	38.3	23.6	32.0	153.6	7.66
August, 2014	38.4	23.9	33.8	172.8	7.67
September, 2014	35.8	22.1	33.6	189.6	6.87
October, 2014	31.3	16.9	36.7	117.6	4.44
June, 2015	36.6	21.3	37.4	156.3	7.43
July, 2015	38.8	22.8	35.9	98.4	6.74
August, 2015	40.3	24.8	38.6	100.8	6.71
September, 2015	38.5	23.8	38.5	175.2	6.93
October, 2015	33.0	19.5	51.3	195.6	5.35

Rainfall was 0 for the two growth season. Data were obtained from Assuit weather station (Central Laboratory for Agricultural Climate)

The irrigation treatments started after 20 days of transplanting. During the first 20 days (initial stage), the maize plants were irrigated according to the calculated irrigation requirements, while in other stages (development, mid and end) the plants irrigated by 100 or 75% of water requirements. Water use efficiency (WUE) was calculated using the equation (WUE = GY / ET_c), where GY equals grain yield, ET_c equals seasonal actual evapotranspiration (mm). Irrigation water use efficiency (IWUE) was estimated using the formula (IWUE = GY / IW), where IW equals seasonal crop water applied (mm).

Collection of Plant Samples: Composite plant samples, each consists of three plants, were taken from each experimental unit after 60 days of sowing. Plant height and fresh weights were recorded. These samples were cleaned, washed with tap and distilled water, air dried, then dried in oven at 70 °C until constant weight, ground and stored for chemical analysis. Maize plants were harvested on October 7th, 2014 and October 8th, 2015 in first and second seasons respectively and the grain and total yield were recorded. Also, weights of ears, weight of grain per ear and seed index (100 seeds) were recorded grain and straw samples from each experimental unit were taken.

Soil and Plant Analysis: Composite soil samples (0-30 and 30-60 cm) were collected before cultivation. Air-dried, crushed and sieved to pass through a 2-mm. Physical and chemical properties of the soil were determined according to Burt [16]. The soil pH was measured in 1:2.5 soil to water suspension using a digital pH meter. The electrical conductivity (EC) was estimated using the salt bridge method [16]. Available soil nitrogen was extracted by 2 M potassium chloride and then nitrogen in the extract was determined using micro-kjeldahl method Burt (2004). Available soil phosphorus was extracted by 0.5 M sodium bicarbonate solution at pH 8.5 according to Olsen method [16] and phosphorus was determined by spectrophotometer. Available potassium was extracted by ammonium acetate method and was measured by flame photometry [16]. Plant samples were digested in H_2SO_4 and H_2O_2 as described by Parkinson and Allen [17] then were analyzed for N, P and K as described by Burt [16].

Statistical Analysis: Data obtained in each season were statistically analyzed. SPSS statistical computer program was used. Mean values were compared for each other using Duncan's test at $P<0.05$.

RESULTS AND DISCUSSION

Effect of Irrigation Rate on the Growth of Drip Irrigated Maize: The data in Fig. 1, 2 and 3 show the effect of the irrigation levels on the growth of 60 days-old maize. The irrigation of drip irrigated plants by I_{100} significantly ($P<0.05$) increased the plant height and fresh and dry weights by 5, 12 and 3% in the first season and by 6, 11 and 8% in the second season compared to I_{75}. It is clear that all the measured growth characters negatively affected by the lower water supply treatment as compared with the normal water supply treatment in both seasons. These results are in agreement with those obtained by [18] who concluded that yield and its attributes of maize plants were gradually increased as a result of increasing in the availability of soil moisture content. The availability of water is an important factor in the growth of maize plants. Maize is one of the most efficient field crops in producing higher dry matter per unit quantity of water [19]. [20] reported that growth of maize is highly related to irrigation depth and it increases with increasing the irrigation level. These results are in harmony with those obtained by [21].

Effect of Irrigation Rate on the N, P and K Uptake by Drip Irrigated Maize: Nitrogen (N), phosphorus (P) and potassium (K) uptake by 60 days-old maize affected significantly ($P<0.05$) by the irrigation levels as shown in Table 3. Uptake of N and K by maize irrigated by I_{100} increased by 11 and 16% in the first season and by 13 and 15% in the second season compared to that irrigated by I_{75}. The current study clearly showed that water stress reduced the concentrations and uptake of N, P and K by drip irrigated maize. From the previous results it could be mentioned that the increase of N, P and K% in maize plants may be attributed to increasing of soil moisture. As soil moisture content increased solubility and mobility of N, P and K are increased [22, 23]. Deficit irrigation had a negative effect on N, P, and K concentrations in the shoots of maize plants. As a result of vegetative growth reduction, the absorption of nutrient elements could be decreased [24]. Similar results were obtained by Silber *et al*. [25].

Effect of Irrigation Rate on Ears Weight, Grains Weight per Ear and Seed Index of Drip Irrigated Maize: The data in Table 4 show the ears weight (EW), grains weight per ear (GWE) and seed index (SI) of drip irrigated maize as affected by the irrigation treatments. In general the irrigation treatments have significant effects in the mentioned parameters. The low level of irrigation (I_{75}) caused a 9 and 5 increases in the ears weight (EW), grains weight per ear (GWE) in the first season and 7 and 10% in the second season compared to the high level of irrigation (I_{100}). Also the low level of irrigation (I_{75}) caused 8 and 10% decrease in the seed index (SI) in the first and the second season compared to the high level of irrigation (I_{100}). The current study indicated that water stress increased the ears weight (EW) and grains weight per ear

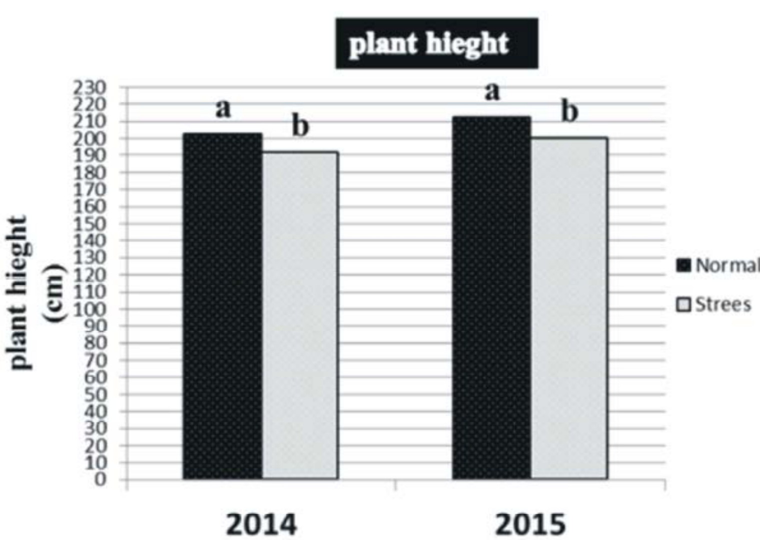

Fig. 1: Plant height of 60 days-old maize (cm) as affected by irrigation rates

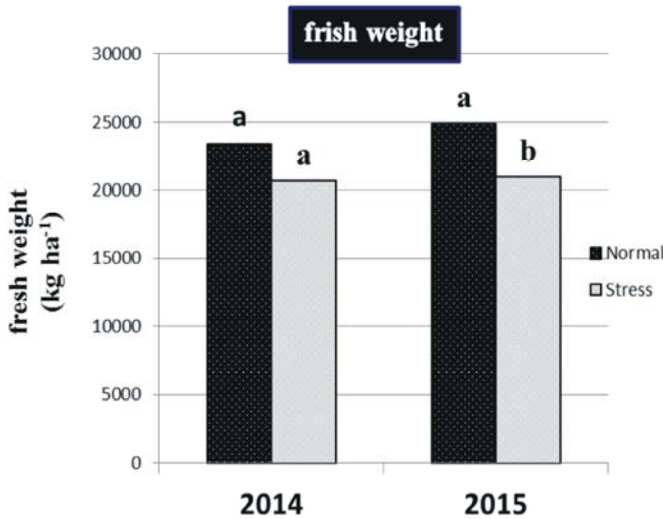

Fig. 2: Fresh weight (kg/ha) of 60 days-old maize as affected by irrigation rate

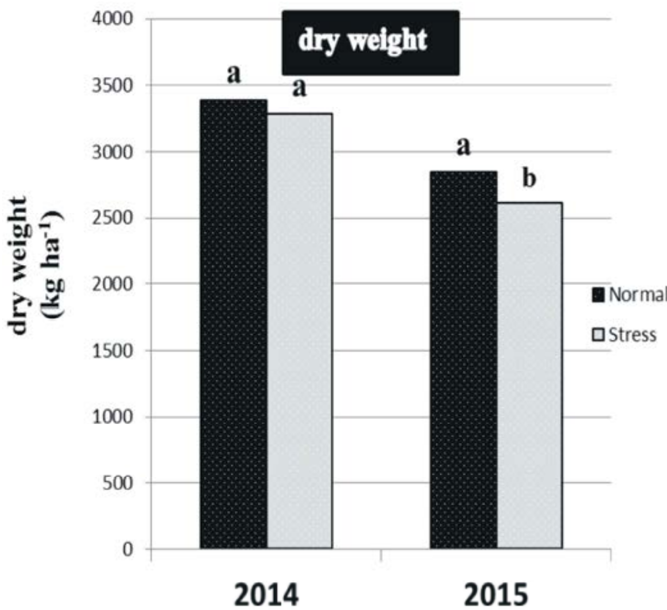

Fig. 3: Dry weight (kg/ha) of 60 days-old maize as affected by irrigation rate

Table 3: N, P and K uptake (kg ha^{-1}) by 60 days-old maize as affected by irrigation rates

	2014			2015		
Irrigation level	N	P	K	N	P	K
I_{100}	86.16^{a}	18.13^{a}	75.99^{a}	66.02^{a}	15.64^{a}	66.01^{a}
I_{75}	77.48^{b}	17.01^{a}	65.40^{b}	58.48^{b}	15.61^{a}	57.14^{b}

Means denoted by the same letter indicate no significant difference according to Duncan's test at P<0.05

Table 4: Ears weight (EW), grains weight (GWE) per ear and seed index (SI) (g) of maize as affected by irrigation rates.

	2014			2015		
Irrigation level	EW	GWE	SI	EW	GWE	SI
I_{100}	106.86^{b}	85.14^{a}	28.77^{a}	104.87^{b}	72.00^{b}	27.97^{a}
I_{75}	116.15^{a}	89.48^{a}	26.27^{b}	112.42^{a}	79.46^{a}	25.23^{b}

Means denoted by the same letter indicate no significant difference according to Duncan's test at P<0.05.

Table 5: Grain (GY) straw (SY) and biological yield (BY) (kg ha^{-1}) of maize as affected by irrigation rates.

	2014			2015		
Irrigation level	GY	SY	BY	GY	SY	BY
I_{100}	8004[a]	25108[a]	33112[a]	6769[a]	23127[a]	29896[a]
I_{75}	8411[a]	21366[b]	27444[b]	7453[a]	21740[a]	29193[a]

Means denoted by the same letter indicate no significant difference according to Duncan's test at $P<0.05$

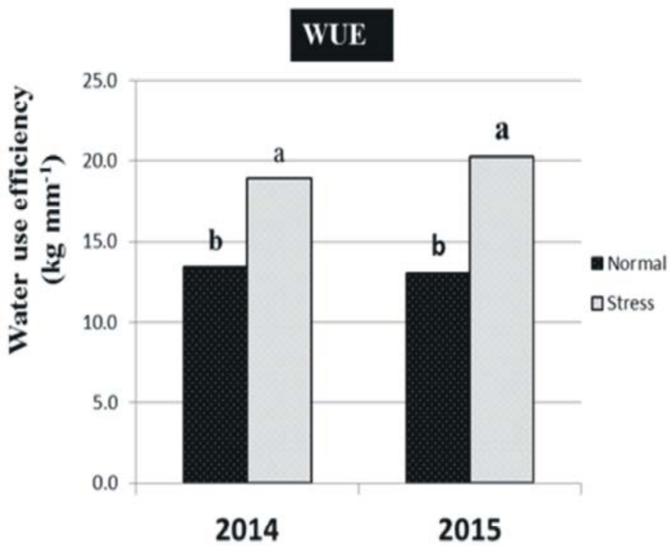

Fig. 4: Water use efficiency (WUE) (kg grain yield mm^{-1} of water) of maize as affected by irrigation rates

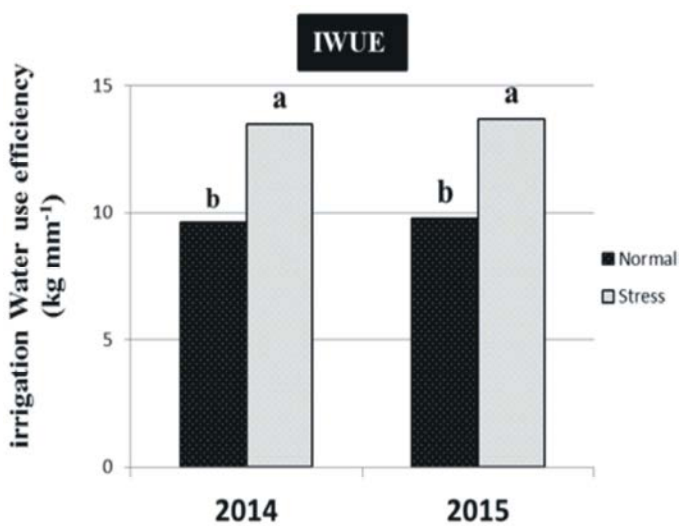

Fig. 5: Irrigation water use efficiency (IWUE) (kg grain yield mm^{-1} of water) of maize as affected by irrigation rates

(GWE) of drip irrigated maize. Our results were in agreement with the results of Mansouri *et al*. [26]. They reported that when the amount of water decreased, the seed index was decreased. Also, Ogretir [27] reported that the application of deficit irrigation on maize at the flowering period decreased the seed index.

Effect of Irrigation Rate on Yield and Yield Components of Drip Irrigated Maize: The data in Table 5 show the effect of irrigation treatments on the yield of drip irrigated maize. Irrigation treatments did not have any significant effects on the biological yield of maize in the two seasons. The irrigation treatments affected significantly on the grain and straw yield in the first season, but did not have any significant effects on the second season. However, the grain yield of maize irrigated by I_{75} was higher by 5 and 10% in the first and second season, respectively, compared to I_{100}. Increasing the irrigation level to 100% of water requirements caused a 20 and 6% increase in the straw yield in the first and second season, respectively, also it caused a 20% increase in the biological yield in the first season.

The data of the current study indicated that water stress caused a slightly reduction in the straw and biological yield of maize, on the other hand it caused a slightly increase in the grain yield. These results are in agreement with those obtained by [28] who studied the effect of irrigation treatments (irrigation after the depletion of 50 and 80% of available soil water) and they found that increasing irrigation level increased the plant highest and shoot dry mater biomass by 31 and 73%, respectively. Increasing the plant highest and dry mater biomass will increase the straw yield rather than grain yield. Our findings are in agreement with [29].

Effect of Irrigation Rate on Water Use Efficiency of Drip Irrigated Maize: The data in Fig. 4 and 5 show the water use efficiency (WUE) and irrigation water use efficiency (IWUE) of maize as affected by the different irrigation levels. Irrigation treatments affected significantly in the WUE and IWUE in the two growth seasons. WUE was higher by 41and 56% in the first and second season, respectively, in the case of I_{75} compared to I_{100}. IWUE of the wheat plants irrigated by I_{75} was higher by 41 and 40% in the first and second season, respectively, compared to I_{100}. Under water stress water was used efficiently more than normal irrigation. The higher values of water use efficiency observed under water stress treatment as compared to normal irrigation was mainly due to less water applied for these treatments and the high obtained grain yield. These results are in agreement with those of [12]. [30] reported that it is feasible to reduce irrigation amount in a certain growing stage of maize to maximize the irrigation water productivity. Deficit irrigation is one of the most important ways of maximizing water use efficiency [5].

CONCLUSIONS

A field study for two years was conducted to evaluate the response of drip irrigated maize to water stress. Increasing the irrigation water to 100% of water requirement increased the plant growth, nutrients uptake and biological yield of maize. The grain yield of maize irrigated by 75% of water requirements was higher by 5-10% than that received 100% of water requirements. Irrigation the drip irrigated maize by 100% of water requirements increased the vegetative growth and this increased the straw and lead to a slightly reduction in the grain yield. Under drip irrigation system maize can be irrigated by only 75% of water requirements without any loss in the grain yield.

REFERENCES

1. Tavakkoli, A.R. and T.Y. Oweis, 2004. The role of supplemental irrigation and nitrogen in producing bread wheat in the highlands of Iran. Agr Water Manag., 65: 225-236. doi:10.1016/j. agwat.2003.09.001.
2. Debaeke, P. and A. Aboudrare, 2004. Adaptation of crop management to water-limited environments. Eur J Agron., 21: 433-446. doi:10.1016/j.eja.2004.07.006.
3. Sepaskhah, A.R., A.R. Tavakkoli and S.F. Mousavi, 2007. Principles and applications of deficit irrigation. Iran: National Committee of Irrigation and Drainage. In Persian.
4. Abd El-Rahman, G., 2009. Water Use Efficiency of Wheat under Drip Irrigation Systems at Al-Maghara Area, North Sinai, Egypt. American-Eurasian J. Agric. & Environ. Sci., 5(5): 664-670.
5. Bekele, S. and K. Tilahun, 2007. Regulated deficit irrigation scheduling of onion in a semi-arid region of Ethiopia. Agric. Water Manage., 98(1-2): 148-152.
6. Gaber, A.M., 2000. Water consumptive, water use efficiency and production of some wheat varieties. Egypt, J. Soil Sci., 40(4): 545-556.
7. Zhu, J.K., 2002. Salt and drought stress signal transduction in plants, Annu. Rev. Plant Biol., 53: 247-273.
8. Wang, F.Z., Q.B. Wang, S.Y. Kwon, S.S. Kwak and W.A. Su, 2005. Enhanced drought tolerance of transgenic rice plants expressing a pea manganese superoxide dismutase, J. Plant Physiol., 162: 465-472.
9. Bolaoos, J., G.O. Edmeades and L. Martinetz, 1993. Eight cycles of selection for drought tolerance in lowland tropical maize. III. Response in drought adaptive physiological and morphological traits. Field Crops Res., 31: 269-86.
10. Eissa, M.A., M. Nafady; H. Ragheb and K. Attia, 2013. Effect of Soil Moisture and Forms of Phosphorus Fertilizers on Corn Production under Sandy Calcareous Soil. World Applied Sciences Journal, 26(4): 540-547 ISSN 1818-4952.

11. Stone, P.J., D.R. Wilson, J.B. Reid and G.N. Gillespie, 2001. Water deficit effects on sweet maize: I. Water use, radiation use efficiency, growth and yield. Aust. J. Agric. Res., 52: 103-113.
12. Howell, T.A., A. Yazar, A. D. Schneider, D. A. Dusek and K.S. Copeland, 1995. Yield and water use efficiency of maize in response to LEPA irrigation. Trans. ASAE, 38: 1737-1747.
13. Larcher, W., 2003.Physiological Plant Ecology. Berlin: Springer-Verlag.
14. Erdem, T., L. Delibas and A.H. Orta, 2001. Water-use characteristics of sunflower (*Helianthus annuus* L.) under deficit irrigation. Pakistan Journal of Biological Sciences, 4: 766-769.
15. Allen, G.R., L.S. Pereira, D. Raesand M. Smith, 1998. Crop evapotranspiration guidelines for competing cropwater requirements. FAO. Irrigation and drainage paper 56. Rome, Italy.
16. Burt, R., 2004. Soil survey laboratory methods manual. Soil Survey Investigations Report No. 42, Version 4.0, Natural Resources Conservation Service, United States Department of Agriculture.
17. Parkinson, J.A. and S.E. Allen, 1975. A Wet Oxidation Procedure Suitable for the Determination of Nitrogen and Mineral Nutrients in Biological Materials. Communications in Soil Science and Plant Analysis, 6: 1-11.
18. Omran, W.M., 2005. Maize yield response to available soil moisture. Monofiya J. Agric. Res., 30(4): 1257-1268.
19. Megyes, A., J. Nagy, T. Rátonyi and L. Huzsvai, 2005. Irrigation of maize (*Zea mays* L.) in relation to fertilization in a long-term field experiment. Acta Agron. Hungaria, 53(1): 41-46.
20. Meleha, M.I., 2006. Water management of maize crop on North Delta. J. Agric. Sci. Mansoura Univ., 31(2): 1185-1199.
21. Kara, T. and C. Biber, 2008. Irrigation frequencies and corn (Zea mays L.) yield relation in Northern Turkey. Pak. J. Sci., 11(1): 123-126.
22. Othman-Sanaa, A., A.M.M. Shehata and I.M. El-Naggar, 2005. Effect of rice straw compost and N-fertilization on maize production and some soil physical properties. Minufiya J. Agric. Res., 30(6): 1853-1863.
23. Ibrahim, S.A. and H. Kandil, 2007. Growth, Yield and Chemical Constituents of corn (*Zea maize* L.) as affected by nitrogen and phosphors fertilization under different irrigation intervals. Journal of Applied Sciences Research, 3(10): 1112-1120.
24. Pascale, S.D., R. Paradiso and G. Barbieri, 2001. Recovery of physiological parameters in Gladiolus under water stress. Colture Protette, 30(7): 65- 69.
25. Silber, A., G. Xu and R. Wallach, 2003. High irrigation frequency: the effect on plant growth and on uptake of water and nutrients. Acta Hort. (ISHS), 627: 89-96.
26. Mansouri-Far, C.S.A., M.M. Sanavy and S.F. Saberali, 2010. Maize yield response to deficit irrigation during low sensitive growth stages and nitrogen rate under semi-arid climatic conditions. Agricultural Water Management, 97(1): 12-22.
27. Ogretir, K., 1993. The water-yield relationships of corn in Eskişehir conditions.PhD thesis, Irrigation and Agricultural Structures, Graduate School of Natural and Applied Sciences.Cukurova University, Adana.
28. Hammad, S.A.R. and O.A.M. Ali, 2014. Physiological and biochemical studies on drought tolerance of wheat plants by application of amino acids and yeast extract. Ann. Agric. Sci., 59(1):133-145.
29. Zhang, H. and T. Oweis, 1999. Water–yield relations and optimal irrigation scheduling of wheat in the Mediterranean region Agric. Water Manage., 38: 195-211.
30. Zhang, Y., E. Kendy, Y. Qiang, L. Changming, S. Yanjun and S. Hongyong, 2004. Effect of soil water deficit on evapotranspiration, crop yield and water use efficiency in the north China plain. Agric. Water Mgmt., 64(1): 107-122.