Available online at www.scholarsresearchlibrary.com

Scholars Research Library

***J. Nat. Prod. Plant Resour*., 2013, 3 (1):78-87**
(http://scholarsresearchlibrary.com/archive.html)

ISSN : 2231 – 3184
CODEN (USA): JNPPB7

Yield and Water Use Efficiency of a Durum Wheat (Triticum Durum Desf.) Cultivar Under the Influence of Various Irrigation Levels in a Mediterranean Climate

Sami Bhouri Khila[1], Boutheina Douh[1], Amel Mguidiche[1], Françoise Ruget[2], Mohsen Mansour[3], Abdelhamid Boujelben[1]

[1]Higher Agronomic Institute of Chott Mariem. BP 47, 4042 Chott Mariem, Sousse, Tunisia
[2]UMR EMMAH : Modelling Agricultural and Hydrological Systems in the Mediterranean environment. Domaine Saint Paul, Site Agroparc- 84914 Avignon cedex 9- France
[3]Regional Research Center in Horticulture and Organic Farming, BP.57, 4042, Chott Mariem, Sousse, Tunisia

---

ABSTRACT

The present work analyzes the effects of different water application levels on agronomic parameters and water use efficiency of a durum wheat (Triticum durum Desf. Var. Karim.) cultivar under the Mediterranean climatic conditions in central Tunisia. The objective of this work was to identify an appropriate irrigation strategy associated with high crop water use efficiency. Field experiment was conducted at the Higher Institute of Agronomy of Chott Meriem during the growing season 2011-2012. The irrigation strategy consisted in maintaining fixed the irrigation intervals and changing the volumes of water applied as a percentage of the crop water requirements. The effects of three irrigation treatments were investigated. The irrigation treatments were full irrigation (T1) corresponding to 100% of predetermined irrigation water levels, (T2) 75% of full irrigation and (T3) 50% of full irrigation. Results concerning water use efficiency revealed that T1 and T3, with respectively 1.72 and 1.6 kg/m^3, were classified in the same group. T2, with 1.43 kg/m^3, resulted in lowest water use efficiency. Comparing the effects of water supply on yield components, the best results were registered for T1 while the lowest yield components were obtained for T3. LAI from T1 was significantly higher than in the other treatments. According to the study results, each increase in irrigation regime increased days to maturity. The results achieved in this study showed that irrigating winter wheat with continuously providing only 50% of the crop water requirements in semi arid climate in Tunisia could result in high efficient irrigation water use.

Key-words: Durum wheat, irrigation, yield, water use efficiency

---

INTRODUCTION

Irrigated agriculture in Tunisia, with a potentially irrigable area of 460,000 ha, has been developed to help farmers cope with irregular rainfall but also to the intensification of production and the adjustment of yields, which reduces the dependency of farm incomes to climate factors [1]. Cereals occupy 14% of irrigated areas in Tunisia and contribute to 25% of national cereal production [1]. Areas which have received supplemental irrigation have evolved from 94,000 hectares in 2009 to 120,000 hectares in 2011. In Tunisia, cereal yields are subject to significant fluctuation, given the interannual variability of rainfall, in addition to seasonal moisture deficits that may prevail, even during a wet year [2]. Tunisia imports annually more than 10 million quintals to meet its needs in cereals of which 900,000 tonnes of wheat. In Tunisia, considerable efforts are made to promote the irrigated sector; results still remain below potential and performance expectations. The results obtained in terms of yields of irrigated cereals show that there has been no great improvement in performance. Indeed, it is always of supplementary irrigation where farmers irrigate their crops in case of urgent needs [1]. Conducting irrigated cereals require further development, especially under conditions of climate change and droughts that have become increasingly frequent [3].Obtaining high yields of cereals require, in addition to chemical treatments, irrigation and use of mineral fertilizers [4] [5] [6] [7].

Faced with demographic change, the fragility of the agricultural sector and the scarcity of water resources, it is clear that the challenge is the increase in grain yields, to ensure food security, while ensuring a water security [8]. Thus, we should focus on maximizing the efficiency of water use in environments with limited water resources [9]. In the arid and semiarid zones, shortage of water is ever one of the main limitations for agricultural development and therefore promotion of Water Use Efficiency (WUE) in these zones is very important [10]. The improvement of WUE in the Mediterranean region is an imperative imposed by the critical situation of water resources present in the region as well as by the demographical increment [11]. Increasing the productivity of irrigation water in agriculture is a way to address water scarcity issue [12]. Improving efficiency at the plot scale would release additional volumes of water [13] and the water saved can be used to irrigate a larger area or for purposes of irrigation the next agricultural season especially in times of shortage [14]. It has been shown that the variability observed in determining water use efficiency, may be attributed to the mineral and water regime applied [15] [16] [17] [18] [19]. The scientific contribution of this work is to identify an irrigation regime to improve water use efficiency of durum wheat in Mediterranean climatic conditions of Tunisia.

MATERIALS AND METHODS

Experimental site

Field studies aiming at examining the response of durum wheat (Triticum durum Desf. Var. Karim.) to different irrigation levels were conducted from December 2011 to May 2012 at the Higher Agronomic Institute of Chott Mariem-Sousse. (Latitude 35°55N, altitude 15 m).

In the study area, the climate is typically Mediterranean with hot-dry summers and mild-rainy winters. According to long term weather data (1973-2006), maximum monthly temperatures range between 16 and 31 °C and minimum monthly temperature vary from 7 to 21 °C. Mean relative humidity vary from 69% to 71%. Monthly rainfall ranges between 2 and 58 mm (figure 1).

The rainfall distribution over the growing period of durum wheat in the study area is 23% rainfall during seedling and emergence, 38% during tillering and stem elongation, and 39% from heading to maturity.

Table.1. Long term mean (1973- 2006) meteorological data in the study area (source: National Meteorological Institute of Tunisia)

	Average of Temperature (°C)		wind speed (m s^{-1})	mean relative humidity (%)
	maximum	minimum		
January	16.96	7.29	1.24	69.32
February	17.78	7.42	1.30	69.14
March	18.99	8.93	1.36	69.29
April	20.73	10.76	1.45	65.61
May	23.89	13.97	1.38	71.35
June	27.62	17.42	1.35	69.54
July	30.92	19.91	1.30	67.78
August	31.58	20.94	1.29	69.00
September	29.55	19.58	1.29	68.54
October	26.11	16.34	1.12	70.29
November	21.48	11.81	1.10	68.99
December	18.49	8.41	1.15	68.54

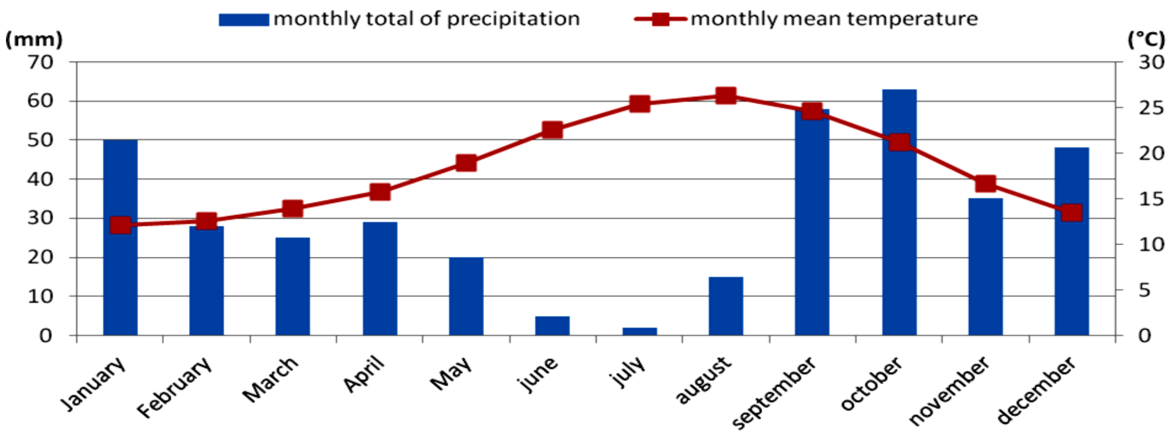

Fig.1 Long term mean monthly rainfall distribution and mean air temperature in the study area.

Experimental design and agriculture practices

Durum wheat was sown by 1 December 2012 with row spacing of 25 cm. The seed rate was 100 kg ha^{-1} according to the standard practices in the study area. Harvesting was done on the first half of May. Before sowing, the land was cleared of vegetation which was basically old plant residues. The soil was carefully leveled to ensure even distribution of water. At planting, water was distributed in the field uniformly to ensure germination. In this experimental work, irrigations were made with a 12 liters watering can. Irrigation treatments were carried out in experimental plots designed as 1.5 m wide, 2.5 m long and a total area of 3.75 m^2. A buffer zone of 1 m spacing was provided between plots. The experiment was laid out in a randomized complete block design with three replicants, in which irrigation was carried out in three levels. All treatment plots received the same amount of total fertilizer. Ammonitrate 33,5% was applied to the experimental plots at a rate of 75 kg/ha on 01/02/2012, 75 kg/ha on 09/03/2012, 50 kg/ha on 23/03/2012 and 100 kg/ha on 28/03/2012.

To identify some of the physical properties of the soil, representative composite soil samples were collected from the experimental site 30 days prior to planting from depths of 0–30 cm, 30–90 cm and 90–120 cm. Analysis revealed that the total soil available water, calculated between field capacity and wilting point for an assumed wheat root extracting depth of 1 m, is 107 mm.

Table 2. Measured soil's parameters.

layer		0 - 30 cm	30 - 90 cm	90 - 120 cm
soil class				
texture analysis	% sand	81.83	73	89.3
	% silt	5.36	8.2	2.1
	% clay	11.5	16.03	6.36
water content	Hcc%	18.7	19.8	8.58
	Hpfp %	7.56	8.52	4.52
bulk density (g/cm^3)		1.5	1.47	1.58

Experimental plots were irrigated with different amounts of water according to predetermined irrigation water levels. Fully irrigated treatment (T1) received sufficient irrigation to meet crop evapotranspiration. Deficit irrigation treatments (T2 and T3) received 50% and 75% of the fully irrigated amount on the same days. Irrigations occurred when 30 to 50 percent of the soil water reservoir has been depleted by wheat evapotranspiration. This depletion is important for conducting plants in T1 because it ensures that the available soil water can be utilized easily by the crop before the next irrigation [20]. Experiences were carried out under a rainout shelter to enable the control of applied water and to ensure difference between irrigation treatments. In the irrigation experiment, reference evapotranspiration (ETP) was calculated on a daily basis by means of Penman Monteith's semi-empirical model [20], using 30 year daily weather data collected from the meteorological station of the Regional Research Center in Horticulture and Organic Farming (CRRHAB), located near the trials. These data was entered in Cropwat program [21] to estimate crop evapotranspiration for daily time step by using reference evapotranspiration combined with a wheat crop coefficient (Kc) following the FAO-56 method given in [20]. The program also allowed determining irrigation frequency.

Observation and Data Collection

Meteorological data concerning air temperature, relative humidity, wind speed rainfall, and solar radiation were collected during the experiment from CRRHAB weather station. The plant growth parameters were observed throughout the study. For this purpose, three plants in each replication plot at about 15 to 20 days intervals were randomly selected representing all the characteristics of its treatment. The plants were cut at ground level and measurements of leaf number, leaf area and dry matter were carried out on these selected plants and average values were calculated for each treatment. The dry-weight of the plant parts was determined by oven-drying samples at 70°C until constant weight was achieved. Plant weights were determined by weighting above ground of the plants using a 0.01 g sensitive digital balance The measurements of the leaf area are achieved with the help of an analogical area meter (model LI-3100C Area Meter, LI-COR, Nebraska USA). Then Leaf Area Index (LAI) was calculated. In addition, yield components were evaluated at physiological maturity. Ten spike heads randomly selected from each plot at harvest were used for recording the number of grains per spike head. Grain samples from each net plot produce was drawn for recording 1000-grain weight. In addition, the total biomass yield for each net plot was recorded at harvest.

To evaluate crop water use efficiency, we employed the indicator "irrigation water use efficiency" (IWUE) obtained from the following ratio [22] [23].

$$IWUE = \frac{Y_g}{I_r} \qquad (1)$$

Where IWUE= irrigation water use efficiency (kg m^{-3}), I_r= The seasonal irrigation volume (m^3), Yg= The grain yield (kg)

This definition integrates the agronomic aspects as well as the practice of irrigation. Several researchers [24] [25] [26] [27] consider this definition particularly suited to identify the appropriate irrigation strategy.

Collected data in this study were analyzed and examined statistically using analysis of variance (ANOVA) from the Statistical Analysis System (SPSS 17.0 for Windows) appropriate for a randomized complete block design. Means were compared by the Duncan Test at the 5% level of significance. The mean values of each treatment are designated by letters (a, b, c) which represent the significance degree of the difference between the means. The letter "a" means the highest average, "b" is the one between "a" and "c". Means represented by two letters in common indicate that the difference is not significant or weakly significant.

RESULTS AND DISCUSSION

Weather data and irrigation

The average values of meteorological data (wind speed, relative humidity and air temperature) recorded during the experimental period are shown in table 3. The mean temperatures ranged between 10,2 and 23,8 °C, mean relative humidity varied from 62 to 85% and wind speed varied from 1,15 to 1,45 ms^{-1}. Crop evapotranspiration (figure 2) was estimated by using reference evapotranspiration combined with a wheat crop coefficient (Kc) following the FAO-56 method given in [20].

Table 3. Measured average values of weather parameters over the experimental period

		December	January	February	March	April	May
climatic parameters	minimum temperature (°C)	9.54	7.80	4.58	10.09	12.96	14.44
	maximum temperature (°C)	20.04	17.94	15.83	20.38	25.16	33.16
	mean temperature (°C)	14.79	12.87	10.20	15.23	19.06	23.80
	relative Humidity (%)	83.46	83.21	82.77	84.93	81.31	62.40
	wind speed (m s^{-1})	0.62	0.91	1.03	1.17	1.00	1.25
	radiation (MJ m^{-2} day^{-1})	4.00	4.16	5.54	7.02	8.10	9.73

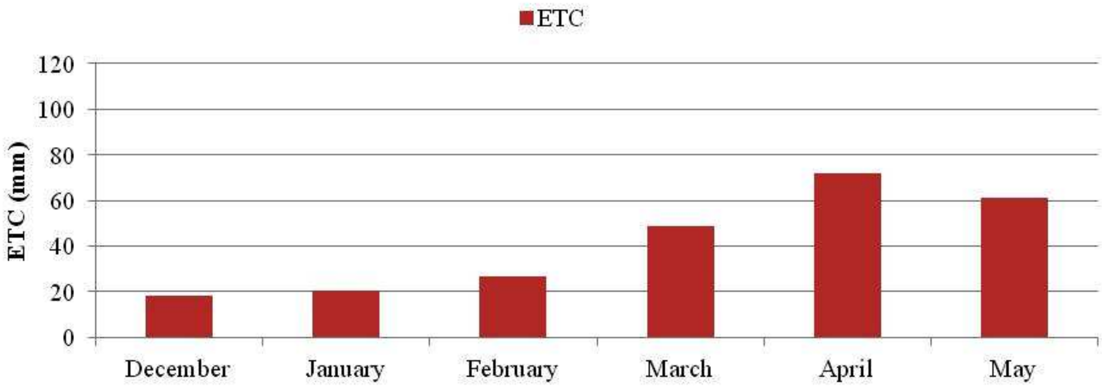

Fig 2. Monthly crop evapotranspiration over the growing period of Durum Wheat in the study area.

Irrigation treatments were initiated on 14/12/2012 (14 days after seeding). Prior to that date, all the treatments were given uniform irrigation to ensure germination. The water applied to T1 treatment was about 403 mm. The average amount applied to T2 was about 316 mm. The irrigation amount for T3 treatment was about 225 mm.

Table 4. Irrigation dates and depths.

date	growth stage	Irrigation (mm)		
		T1	T2	T3
December	emergence	92	81.5	69.5
January	tillering	31.5	24	15.75
February	stem elongation	54.14	40.60	27.07
March	heading	56.07	42.05	28.04
April	dough stage	112.70	84.52	56.35
May	maturity	57.38	43.04	28.69

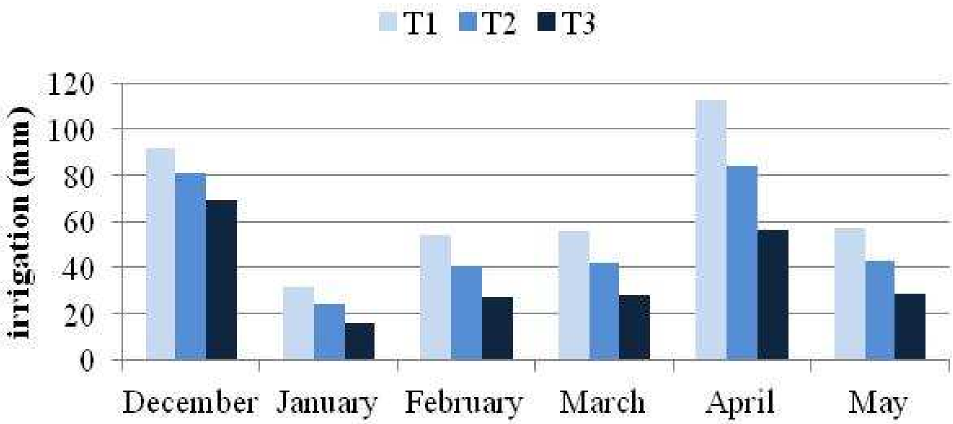

Fig 3. Monthly irrigation amount for different treatments.

Agronomic parameters

The irrigation treatment significantly influenced all measured traits including leaf area, dry matter per plant, number of spikes per plant, number of grain per spike, 1000 grain weight, grain yield and aerial dry matter.

Leaf area index

Changes in leaf area index (LAI) from seedling stage for different irrigation treatments are presented in figure 5. During seedling period, the LAI values for all treatments were small, and began to increase at leaf development stage. When near the heading stage, the LAI values of different treatments reached their maximum, and then decreased at the end of experiments. This result is consistent with the findings given by [28]. The trend of LAI over the growth period suggested that increasing irrigation amount led to an increase in LAI values. Differences among treatments began to be notable from heading stage, this could be attributed to progressive water stress imposed during vegetative stage. Figure 5 shows that drought imposed on the crop throughout the growing season (in T2 and T3) reduced LAI significantly as compared to that of the fully irrigated plants. Lowest LAI was obtained in less irrigated treatment (T3), this corroborate the findings of [29]. Highest results had been recorded in the case of T1 treatment with an average of 7,29 , whereas LAI didn't exceed 5,8 and 4,9 respectively in T2 and T3. That result shows the effect of a better water availability of the soil for the crop LAI.

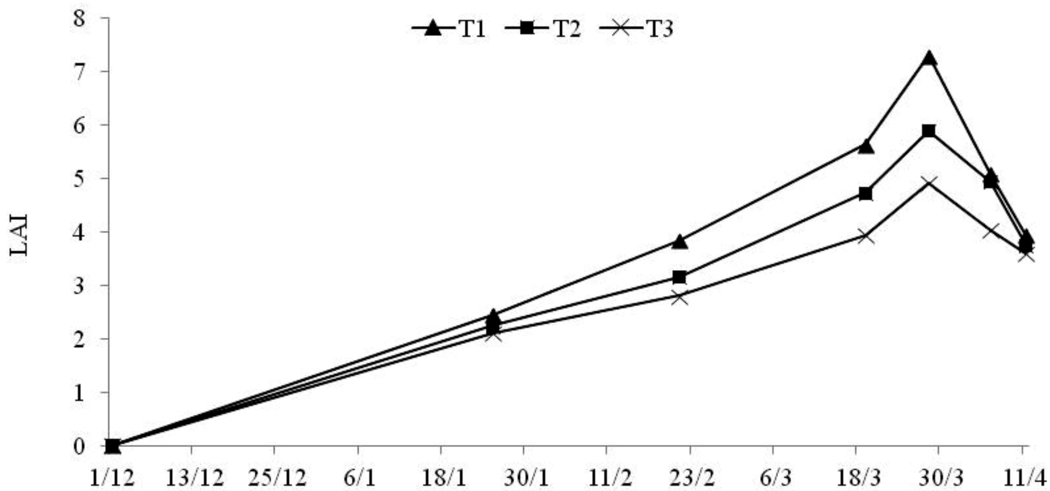

Fig 4. Leaf area index development during the growing period in different irrigation treatments.

Dry matter per plant

Figure 5 indicates the dry mass accumulation versus time relation. At first, the dry mass for each treatment accumulated slowly, and began to increase rapidly from 23/02/2012. From 05/04/2012, the dry mass accumulated slowly again. The highest dry matter per plant was produced at full irrigation treatment with a mean of 15,44 g per plant. With application of deficit irrigation it was found that the biomass decreased by 12% at T2 treatment and by 20 % at T3 treatment. The present finding showed that dry matter accumulation was consistently greater by full irrigation. We could notice that irrigation treatment effect on dry matter per plant began to be noticeable from heading stage for T2 and T3. This could be explained by progressive water stress imposed during vegetative stage.

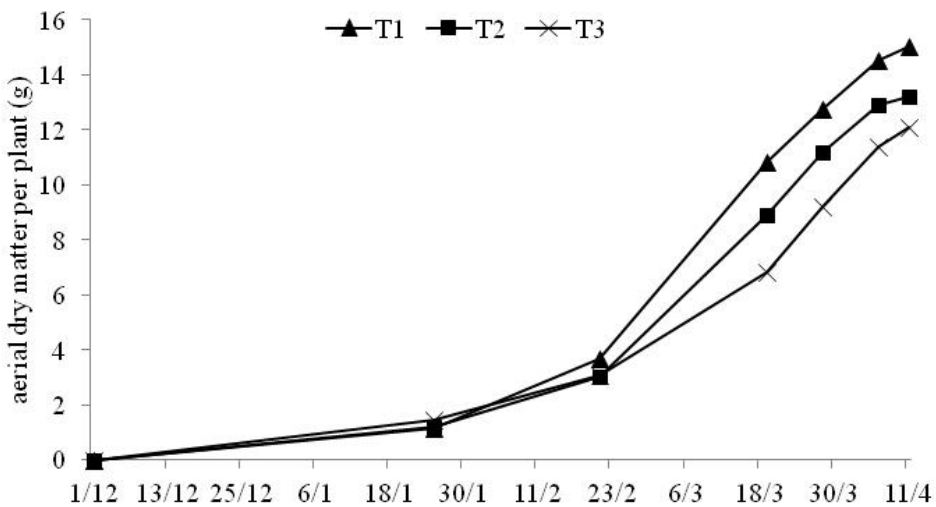

Fig 5. Aerial dry matter per plant evolution during the growing period in different irrigation treatments.

Yield components

The effects of the irrigation strategies applied in this study were statistically significant for yield components (table 5). Responses to irrigation vary among yield components because of the differences in soil water conditions during the growing season [30]. It was found that these components were higher in full irrigation treatment as compared to the deficit irrigation treatments. No statistical difference was found in yield components between T2 and T3. This could be explained by the fact that water stress conditions affected yield similarly in plants conducted in T2 and T3. In these treatments, when comparing estimated crop evapotranspiration and irrigation amounts, we could notice that irrigation water deficit evolved similarly. In T2 and T3 water stress occurred from heading and increased gradually up to maturity stage. This could be attributed to the fact that, during critical stages, soil moisture deficit exceeded the allowable soil moisture depletion for optimal wheat growth. It should be noticed that during these critical stages even a moderate water deficit leads to a severe yield reduction [11] [31].

Table 5. Yield components as affected by irrigation treatments

	treatments		
	T1	T2	T3
Number of grains per ear	37.1 a	34.8 b	33 b
1000 grain weight (g)	56 a	47.54 b	42.34 b
Number of ear per plant	3.21 a	2.88 b	2.55 b
Aerial dry matter at harvest ($t.ha^{-1}$)	25.97 a	15.20 b	14.01 b

Highest 1000 grain weight was obtained in fully irrigated treatment with 56 g and the lowest one was found in T3 with 42 g. Mean 1000 grain weight in plots receiving full irrigation was 21 and 24% higher than plots receiving respectively 75 and 50% of the fully irrigated amount. This finding is consistent with the findings given by [32], [33], [34] [35] and [36] who indicated that grain weight was increased as irrigation increased. These results are similar to those found by [22] on corn. Low grain number obtained in T2 and T3 could be explained by the fact that water stress during grain filling period contributes highly in reducing grain weight [37] [38].

Number of spikes per plant for various irrigation treatments differed significantly. Highest number of spikes per plant (3,22 spikes per plant) was obtained in plants conducted in T1. These findings confirm those of [39]. T1 produced 10 and 20 % higher number of spikes per plant with regard respectively to T2 and T3 treatment. Highest number of spikes per plant, obtained in fully irrigated treatment, might be due to the sufficient availability of water at tillering and heading stage with more uptakes of nutrients.

Highest number of grains per spike was obtained in fully irrigated treatment with 37 grains and the lowest one was found in T3 with 33 grains per spike. These findings confirm those of [34] and [35]. Water stress occurring during the spike growth period decreases sharply grain number [36].

Irrigation significantly affected aerial dry matter production (figure 6). Dry matter at harvest was significantly increased as the volume of irrigation water increased. This is in agreement with the results reported by [40], who indicated that biological yield was increased as irrigation increased. It seems that fully irrigated treatment creates more suitable conditions in the root zone area for plant production. Highest value, averaging 259.74 q ha^{-1} was measured in T1 treatment, while T3 had the lowest dry matter value. Plants conducted in T2 and T3 treatments produced in average respectively 41 and 46% lower dry matter with regard to T1.

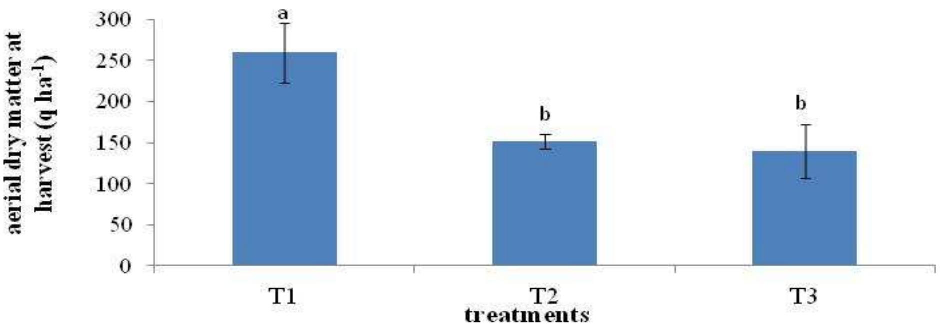

Fig 6. Aerial dry matter as affected by different irrigation treatments

Grain yield was increased by increased irrigation amounts (figure 7). The highest grain yield was obtained in T1 treatment with 71.7 q ha^{-1}. T3 resulted in almost 50% reduction in grain yield respect to T1. This reduction was attributed to reduced number of spikes m^{-2}, number of grains per spike and 1000-grain weight. This reduction could be explained by water stress conditions during heading and maturity. This caused premature maturity as grain filling rate is faster in plots receiving less irrigation than plots receiving high irrigation amount which is in conformity to the finding of other studies [41] [42] [43]. Increased yield with increasing irrigation amounts shows a positive effect of full irrigation treatment (T1) on grain yield compared to deficit irrigation treatments. These results corroborate the findings of several studies [37] [33] [32] [34] [35] [36] and [44].

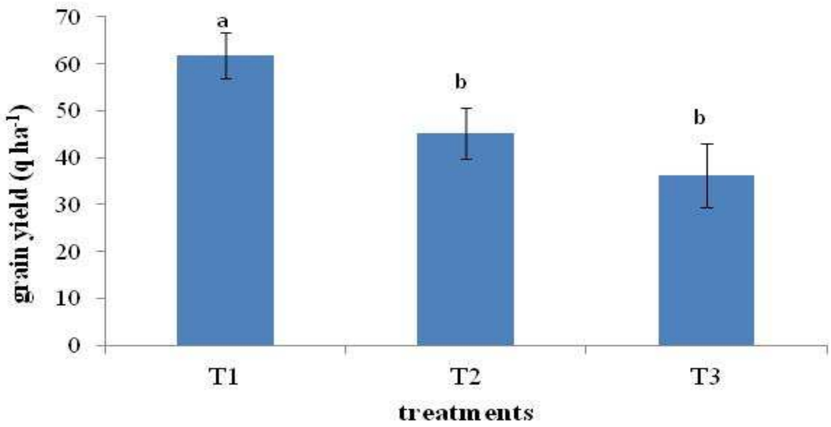

Fig 7. Grain yield as affected by different irrigation treatments

Water use efficiency

Figure 8 showed the effects of different irrigation treatments on irrigation water use efficiency (IWUE). It proved that the irrigation amount has a significant effect on IWUE. T1 and T3 were classified in the same group. T2 resulted, in average, in 17% and 10% lower IWUE with regard respectively to T1 and T3 treatments.

Average IWUE was 1.72, 1.43 and 1.6 kg/m3 respectively for T1, T2 and T3 treatments. These values are higher than average water use efficiency observed for the whole Mediterranean region [17]. However the water use efficiency of irrigated crops can present a large range of values. It should also be noticed that the limit between WUE measured on irrigated and non-irrigated winter crops is not clear [15].

Although T3 produced the lowest yield values, we notice that it resulted, in high IWUE as compared to T1. This is in agreement with the results of several studies [23] which showed that the low irrigation resulted in highest water use efficiency. This result is also consistent with the findings of [27] for corn. This confirms that water used in supplemental irrigation can be much more efficient [11] [45]. High value IWUE obtained in T3 could be attributed to low irrigation amount supplied to T3 compared to T2 and T1.

Water use efficiency obtained in T2 and T1 confirm the findings of [28] showing that water use efficiency increased with increasing water supply. However, these findings were not verified when comparing water use efficiencies obtained in T2 and T3, where increasing irrigation hadn't a positive effect on WUE. This could be attributed to differences, observed between studies, in conducting irrigation. In fact, the generic term "irrigated crops" can include, in reality, extremely different situations of plant water supply [11]. In such studies, even if total applied irrigation amounts are similar, irrigation amount per time and irrigation frequency could be extremely diverse. This means that, in each study, water stress evolves differently over the growing stages of the studied crops. So the difference observed between results on crop growth, water uptake and water use efficiency depends mostly on the sensitivity of the growing stage on which water stress occurred. During critical stages a moderate water deficit leads to a considerable variation of WUE [11].

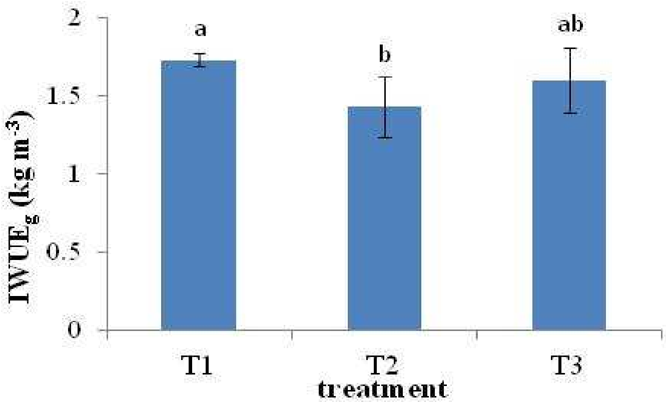

Fig 8.Water use efficiency as affected by irrigation treatments.

CONCLUSION

In this study the effects of different irrigation levels on yield, plant growth parameters and water use efficiency of wheat were examined. It was determined that the irrigation levels had statistically significant effects on yield, water use efficiency and the plant growth parameters. According to the research results, it was found that continuously providing 50% of the crop water requirements (T3 treatment) in semi arid climate could result in highly efficient irrigation water use. Although T3 treatment produced the lowest yield value with an average of 44 q ha^{-1}, it resulted, substantially in the same value of water use efficiency (1.63 kg/m3) obtained from fully irrigated treatment. T2 resulted in 17% and 10% lower IWUE with regard respectively to T1 and T3 treatments. Effects of irrigation regimes were observed for, grain weight, number of grains per spike and grain yield. Yield components were significantly higher in T1 than in the other irrigation treatments. Analyses of variance for grain yield and its components revealed that these characters were affected significantly by irrigation levels. No statistical difference was found in yield components between T2 and T3. Highest grain yield was obtained in T1 treatment with 71.7 q ha^{-1}. The significantly higher grain yield obtained from T1 was attributed to the sufficient availability of water during grain filling period. The results of this research indicated that irrigating winter wheat with 50% of crop water requirements is especially well suited to a limited irrigation water supply in the Mediterranean climatic conditions of Tunisia. These results, however, are preliminary and need to be confirmed by reproducing experiments in other years. Larger studies should also be conducted, taking into account the effects of soil properties and the combined effects of fertilization and irrigation.

REFERENCES

[1]. A Laajimi. Les notes d'alerte du CIHEAM, no: 30, Bari, Italy, Mediterranean Agronomic Institute of Bari, **2007**.

[2]. N Sakiss, N Ennabli, MS Slimani, H Baccour. La pluviométrie en Tunisie a-t-elle changé depuis **2000** ans: Recherche de tendances et de cycles dans les séries pluviométriques, Tunis, Tunisia, National Agronomic Institute of Tunisia, **1994**.

[3]. MEH Louati, HJ Mellouli, ML El Echi. In: A Iglesias, M Moneo (Eds.) Cahier Options méditerranéennes, Series B: Etudes et Recherches no: 51, **2004**, pp. 155-190.

[4]. L Yankovitch. Annales du Service Botanique et Agronomique de Tunisie, Tunis, Tunisia, **1956**, 29, pp. 1-223.

[5]. E Kopp. Annales de l'Institut National de la Recherche Agronomique de Tunisie, Tunis, Tunisia,, National Institute of Agronomic Research, **1981**

[6]. M Sanaâ. PhD Thesis, University of Gand (Gand, Belgium, **1993**).

[7]. K Latiri-Souki. PhD Thesis, University of Reading (Reading, U K, **1994**)

[8]. H Mellouli. In: Lamaddalena, N., et al. (Eds.) Cahier Options méditerranéennes, Series B, no:57, Bari, **2007**, pp. 179 – 190.

[9]. T Oweis, H Zhang, M Pala. *Agronomy Journal*, **2000**, 92, pp. 231-238.

[10]. M Fanadzo, C Chiduza, PNS Mnkeni, I Van der Stoep, J Stevens. *Water* SA, **2010**, 36, 1, pp. 27-36

[11]. N Katerji, M Mastrorilli, G Rana. *European Journal of Agronomy*, **2008**, 28, pp. 493-507.

[12]. MR Khaledian, JC Mailhol, P Ruelle, I Mubarak, F Maraux. *Irrigation Science*, **2011**, 29, pp. 413–422

[13]. N Ben Mechlia. In : A Hamdy and G Trisorio Liuzzi (Eds.) Cahier Options méditerranéennes, Series B, n°47, Bari, **2004**, pp 169 – 185.

[14]. A Hamdy. In: Lamaddalena, N., et al. (Eds.) Cahier Options méditerranéennes, Series B, no:57, Bari, **2005**, pp 9 – 19.

[15]. T Oweis. Supplemental Irrigation: A Highly Efficient Water Use Practice, ICARDA Editions, Syria, **1997**.

[16]. C De Fraiture, D Wichelns. In: D Molden (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture, International Water Management Institute, Spikethscan and Colombo, London, **2007**, pp. 91–145

[17]. VO Sadras; JF Angus. *Australian Journal of Agricultural Research*, **2006**, 57, pp. 847–856

[18]. B Ben Nouna,; N Katerji; M Mastrorilli. *European Journal of Agronomy*, **2000**, 13, pp. 309–322

[19]. SJ Zwart, WGM Bastiaanssen. *Agricultural Water Management*, **2004**, 69, pp. 115–133

[20]. RG Allen, LS Pereira, D Raes, M Smith. Irrigation and Drainage Paper no: 56, FAO, Rome, Italy, **1998**

[21]. M Smith. Irrigation and Drainage Paper no: 26, FAO, Rome, Italy, **1992**.

[22]. JO Payero, D D Tarkalson, S Irmak, D Davison, J L Petersen. *Agricultural Water Management*, **2008**, 95, pp. 895–908.

[23]. TS Du, SZ Kang, J Sun, X Zhang, JH Zhang. *Agricultural Water Management*, 2**0**10, 97, pp. 66–74.

[24]. I Farré, JM Faci. *Agricultural Water Management*, **2006**, 83, pp. 135–143.

[25]. B Blümling, H Yang, C Pahl-Wostl. In: N Lamaddalena et al. (Eds.), Cahier Options Méditerranéennes, Série B. Etudes et Recherches, no: 57, Bari, **2007**, pp. 263–280.

[26]. H Cherni, PhD Thesis, Mediterranean Agronomic Institute of Bari (Bari, Italy, **2008**).

[27]. N Katerji, M Mastrorilli, H Cherni. *European Journal of Agronomy*, **2010**, 32, pp. 177–185

[28]. W Li, W Li, Z Li. *Agricultural Water Management*, **2003**, 67, pp. 35–46.
[29]. M Akram. *Bangladesh J. Agri. Res*, **2011**, 36, 3, pp. 455-468.
[30]. JR Frederick, JJ Camberato. *Agronomy Journal*, **1995**, 4, pp. 241-248.
[31]. E Acevedo, P Silva, H Silva. In: BC Curtis, S Rajaram, H Gómez Macpherson. FAO Plant Production and Protection, paper no: 30, FAO, Rome, **2002**
[32]. N Sarwar, M Maqsood, K Mubeen, M Shehzad, M.S Bhullar, K Qamar, N Akbar. *Pakistan Journal of Agricultural Sciences*, **2010**, 3, 1, pp. 22-24.
[33]. A Wajid, A Hussain, M Maqsood, A Ahmad, M Awais. *Pakistan Journal of Agricultural Sciences*, **2002**, 47, 3, pp. 371-374.
[34]. K Shamsi, S Kobraee. *Annals of Biological Research*, **2011**, 2, 3, pp. 352-358.
[35]. K Shamsi, S Kobraee and B Rasekhi. *Annals of Biological Research*, **2011**, 2, 2, pp. 372-377
[36]. ME Ghobadi, H Felehkari, GR Mohammadi, SJ Honarmand. *Annals of Biological Research*, **2012**, 3, 5, pp. 2127-2133.
[37]. ZVI Hochman. *Field Crops Research*, **1982**, 5, pp. 55-67.
[38]. T Kobata, JA Palta, NC Turner. *Crop Science*, **1992**, 32, pp. 1238-1242.
[39]. M Karrou, T Oweis. *Agricultural Water Management*, **2012**, 107, pp. 94– 103.
[40]. R Tahmasabi, H Fardad. *Iranian Journal of Agricultural Sciences*, **2000**, 31, pp. 111-118.
[41]. H Zhang, T Oweis, S Garabet, M Pala. *Plant and Soil*, **1998**, 201, pp. 295-305.
[42]. J Yang, J Zhang, Z Huang, Q Zhu, L Wang. *Crop Science*, **2000**, 40, pp. 1645-1665.
[43]. R Hafid, M El-Mourid, K Samir. Al-Awamia, **1996**, 93, pp. 7-25.
[44]. MH Romena, A Najaphy. *Annals of Biological Research*, **2012**, 3, 7, pp. 3178-3182
[45]. T Oweis, M Pala, R John. *European Journal of Agronomy*, **1999**, 11, pp. 255–266.