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EFFECT OF DEFICIT IRRIGATION SCHEDULING AND MINIMUM TILLAGE ON THE WATER STRESS, WATER APPLICATION EFFICIENCY, YIELD AND WATER PRODUCTIVITY OF BARLEY UNDER SANDY SOIL CONDITIONS

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Abstract

With the worldwide increasing use of sustainable of tillage systems and irrigation water management, it is important to make sure achieved their long-term effects on yield performance of most crops under limited water supplies. So that, tillage depth reducing with deficit irrigation scheduling could increase the viability of dry land agriculture in semiarid zones. In 2017–2018, two field experiments were carried out in Egypt at National Research Centre farm in Al-Nubariya Region, Al-Buhayrah Governorate, with a two-factorial used split-plot experiment based on a randomized complete block design with three replications. The aim of the experiment was to evaluate the water stress inside root zone, application efficiency of irrigation water, yield components as well as harvest index of barley crop and productivity, water productivity under effect of different tillage depths, i.e. 10 cm, 20 cm and 30 cm and deficit irrigation scheduling i.e. 50%, 75% and 100% of Full Irrigation "FI". Planting of barley under irrigation with 100% of FI gave the highest significant values for plant height under tillage level at 10 cm depth when barley plants were irrigated at either 100% or 75% of FI, followed by tillage level at 20 cm depth at 100% of FI, compared with tillage level at 30 cm depth under irrigated at either 50%, 75% or 100% of FI. Results detect that the highest of grain yield [(4.08 and 3.98 ton/ha) and (4.05 and 3.97 ton/ha)] in 2017 and 2018 seasons respectively under tillage level at 10 cm depth at irrigation at either 100% or 75% of FI as well as biological yield in both seasons. While, tillage level at 10 cm depth with irrigation at 75% of FI recorded the highest significant water productivity values (2.07 and 2.00 kg/m^3) in the first and the second seasons respectively. From the aforementioned results it could be noticed that tillage level at 10 cm depth with irrigation at 75% of FI and 20 cm depth under irrigation by100% of FI respectively lead to improvement grain yield, biological yield and straw yield. In addition to that water productivity was achieved the highest values under tillage level at 10 cm depth with irrigation at 75% of FI. This is believed to be related to improving soil water conservation and thus increasing water use efficiency under minimum tillage compared with other tillage systems. The study concluded after discussing the previous results above that there were no significant differences between the highest values of barley productivity when irrigating at 100% or 75% of water requirements when tillage at the lowest depth of 10 cm. Therefore, it was the most appropriate and best treatment recommended for application when planting barley under the conditions of dry sandy soils is the scheduling of irrigation by adding 75% of the requirements for irrigation of barley and the depth of tillage 10 cm. This resulted in providing 25% of the water needs for irrigating barley, and also energy will be provided from two sides, the first of which is due to the low fuel consumption of the tractor resulting from the application of a less-depth tillage technology, and the second result from providing energy to pump 25% of irrigation water when scheduling irrigation by 75% instead 100% of barley irrigation needs.

Keywords: Tillage depths, deficit irrigation scheduling, water stress, application efficiency, grain yield, water productivity, and barley crop

Introduction

Water shortage and scarcity are one of the major and serious problems facing crops cultivation and production in the Arab Republic of Egypt, and it is important and necessary to reduce irrigation water consumption through developing and improving new and innovative technologies that can be an effective tool and affect effectively (Abdelraouf *et al*., 2013b and El-Metwally *et al*., 2015). In arid and semi-arid countries with large population growth and limited fresh water, there is significant stress and pressure on the agricultural sector to reduce and limit fresh water consumption for irrigation for the urban and industrial sectors (Abdelraouf, *et al*., 2020 b; Abdelraouf and Abuarab 2012) and (Hozayn, *et al*., 2016). The agricultural sector faces a serious challenge in increasing food production with less irrigation water, which can be accomplished by increasing crop water productivity (Abdelraouf *et al*., 2013c; Dewedar *et al*., 2019). Increasing crop water productivity is an important goal and is to increase demand while increasing high population growth (Bakry *et al*., 2012) and (Abdelraouf and Ragab, 2018). The limited water resources in Egypt suffer from severe water scarcity, which increases with the increasing population. The increasing competition for scarce water resources is competing for innovative and new application of new irrigation techniques to increase water productivity and improve crop productivity and quality (Abdelraouf and Habasha, 2014; El-Shafie *et al*., 2017; Marwa, *et al*., 2017). The water productivity of crops in the Arab Republic of Egypt is extremely important because water resources are limited and precipitation and rainfall is a very limited and low factor (Hozayn *et al*., 2013). The application of modern irrigation methods and accompanying technologies is an important concept that you must do in arid and semi-arid areas as in Egypt for providing part of irrigation water due to limited water resources (El-Habbasha *et al*., 2014; Abdelraouf *et al*., 2012; Hussein *et al*., 2016).

Water use efficiency is an important concept for understanding crop–soil systems and designing practices for conservation of water (El-Shafie *et al*., 2018; Hozayn *et al*., 2020). Irrigation water efficient use is becoming increasingly important, may contribute basically to the best use of water for agriculture and improving irrigation efficiency (Wahba *et* *al*., 2016; Marwa *et al*., 2020). The effect of water deficit on yield during different growth period of crops is greater under conditions of high temperature and low humidity (Youssef *et al*., 2018). Controlled irrigation is essential for high yields because the crop is sensitive to both over and under irrigation (Al-Harbi *et al*., 2008).

Barley (*Hordeum vulgare*, L.) is a major grain of cereal crops, grown in moderate climates globally. It is ranked fourth important cereal crops of the world after wheat, rice and maize (FAO, 2016). Barley is one of the most tolerant crops under the adverse environmental conditions (Lakshmi *et al*., 2016). Barley is mainly used as food, fodder for animal and as a raw material for beer production (Pour-Aboughadareh *et al*., 2013).

Deficit irrigation water during the rapid spike – growth stage from booting to anthesis decrease grain set and number of grain bearing tillers (Rajala *et al*., 2011). Terminal drought during period of grain filling is known it leads to reduce single grain weight (Samarah *et al*., 2009 and Alireza and Yazdachi, 2012).

The purpose from tillage of soil is to prepare the soil with sufficient conditions of physical for plant growth. Traditional tillage (TT) is used to mix top-soil to return losses of nutrient due to crop exportations. Nevertheless, excessive tillage could make compaction, soil crusting and damages to soil biota (Urbano, 1992).process of tillage works to dissociation of the soil and blending, and lead to change some of soil physical properties related to roots growth and permeation the soil, which affects the productivity of crops due to the impact of those processes in porous soil and water characteristics and the movement of water and air (Baver *et al*., 1977). The negative effects have been attributed to the direct effects of tillage in breaking aggregates of soil as a result of crushed and compaction at the passage of agricultural machinery (Edwards *et al*., 1992).

Mechanical tillage effects on physical soil properties which are important to supply nutrient for plant, moisture regime and soil air (Kouwenhoven *et al*., 2002). One of the solutions to the deficiency of soil moisture is application of sustainable tillage systems (Riley, 2014). Conventional tillage can decrease organic matter in the soil by mixing crop residue into the soil, damage of aggregates, and increasing aeration compared with no-tillage (Bowman *et al*., 1999; Schomberg and Jones, 1999). Conventional tillage systems have been accountable for depletion of soil organic matter, soil erosion, and losses in soil productivity (Campbell 1978).

In general, conventional tillage reduces organic matter of soil due to a faster mineralization. No tillage (NT) techniques decrease the interaction between fresh soil organic matter and soil aggregates so that the rate of mineralization has been often slower, which improves soil properties, such as higher resistance of soil structure against water erosive action (Beare *et al*., 1994).

Changes in condition of soil due to residue accumulation of surface in continuous conservation tillage are essential and characterized by increased organic matter of soil (López-Fando and Pardo 2009). Progressive increase in content of organic matter in the first few centimeters of the soil profile lead to increase the availability of the main of nutrients (Fernández *et al*., 2007).

Tillage systems were clearly affected on physical properties of soil; namely moisture content and bulk density and it is necessary to modify environment to make optimum conditions for increasing crop production as showed by (Mohamed *et al*., 2017). Also, the use of conservation tillage technologies such as strip tillage direct seeding and that decrease depth and number of tillage operations has been shown to decrease energy use and facilitate conservation of soil water (Evans *et al*., 2010). In addition, these practices have decreased both production inputs and use of equipment, which help producers of irrigated crop to remain competitive in world markets.

Conservation tillage has many positive effects on soil, such as a water content improvement (Husnjak *et al*., 2002) and decreasing erosion of soil (Morris *et al*., 2010). In several studies which comparing between tillage systems, greater bulk density and penetration resistance were achieved under reduced tillage and direct drilling, particularly in the top layer, than under conventional tillage (Boydaδ and Turgut 2007 and Thomas *et al*., 2007).

McAndrew *et al*. (1994) studied the agronomic feasibility of reduced tillage management for barley (*Hordeum vulgare* L.) production was estimated with regard to straw yield and grain. Tillage management systems were studied including four treatments as follows zero (ZT), minimum (MT), and (Cl and C2) as treatment of conventional systems. Tillage systems significantly affected on straw yields and grain. In general, straw yields and grain of barley under ZT were equal or superior to yields obtained under Cl, C2 and MT systems respectively. Straw yields followed carefully the direction observed for grain yields. This is believed to be concerning to better soil water conservation and greater water use efficiency (WUE) under ZT compared with other tillage systems in years with below normal precipitation and particularly when June and July precipitation was low.

Influence of tillage on yields of spring barley has been variable, with decrease (Peterson and Potts, 1985), similar (O' Sullivan and Ball, 1982; Sainju *et al*., 2013), or increased (Ciha, 1982) yields in no-tillage compared with conventional tillage.

Conservation cultivation is now widely recognized as an applicable concept for sustainable agriculture due to its inclusive advantages in environmental, economic and social sustainability. Therefore, the objectives of this investigation were to evaluate the effects of deficit irrigation scheduling and minimum tillage systems on the productivity of barley crop under sandy soil conditions.

Materials and Methods

Description of study site and irrigation system: Field experiments were conducted during two potato cultivation seasons at the experimental farm of National Research Centre, El-Nubaria, Al-Buhayrah Governorate in northern Egypt (Figure 1). The farm has a latitude of 30^{o} 30'1.4''\ N, longitude 30^{o}9' 10.9'' E and with 21m mean altitude above sea level. The experimental area has a semi-arid climate with mild winters and hot dry summers. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from the local weather station at El-Nubaria Farm.

Fig. 1 : Location of study site in Al Buhayrah Governorate in Egypt.

Irrigation system components: pumping system, control pressure head and filtration unit: The irrigation system consisted of a centrifugal pump with 45 m^3/h discharge rate, a screen filter and a backflow prevention device, a pressure regulator, pressure gauges, control valves and a flow meter. The main line, a polyvinyl chloride (PVC) pipe with 110 mm outer diameter (OD), conveyed the water from the source to the main control points in the field. Sub-main lines, connected to the main line, were PVC pipes with 75mm OD. Manifold lines, polyethylene (PE) pipes of 63 mm OD, were connected to the sub-main line and control valves and discharge gauges. The Sprinkler was 3/4" diameter with a discharge of 1.17 m^3/h, wetted radius of 12 m, and working pressure of 250 KPa.

Physical and chemical properties of soil and irrigation water: The soil texture is sandy (87.4% sand, 7.9% silt, and 4.7% clay), pH is 7.8, salinity expressed as electric conductivity, EC is1.68dS/m and organic matter content in the upper 30cm of the soils 0.44%. Available soil N, P, and K contents were 17.1, 4.4, and 26.0 mg/kg soil, respectively, and extractable-Fe, Mn and Zn were 2.98, 1.74, 0.66 mg/kg soil, respectively. The chemical characteristics of irrigation water are shown in Table 1.

Table 1: Chemical characteristics of the irrigation water.

pH	EC* (dS m^{-1})	Cations and anions (meq/l)								SAR**
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	
7.13	0.44	1.42	0.65	2.61	0.31	--	0.1	1.72	1.45	2.8

*EC= Electrical Conductivity **SAR= Sodium Adsorption Ratio

Crop water requirements*:* Seasonal irrigation requirements for barley crop were calculated for seasons 2017 and 2018. The seasonal irrigation water applied, obtained from Equation 1, was 2640 m^3/ha/season for 2017 and 2660 m^3/ha/season for 2018.

$$IRg = [ET_o \times Kc] / Ei - R + LR \quad .....(1)$$

Where IRg = gross irrigation requirements, mm/day, ET_o = reference evapotranspiration, mm/day (estimated from the Central Laboratory for Climate - Agricultural Research Center Egyptian Ministry of Agriculture at El-Nubaryia farm and according to Penman-Monteith equation), Kc = crop factor (Allen *et al*., 1998), Ei = irrigation efficiency, %, R = water received by the plant from sources other than irrigation, for example rainfall, mm, LR = amount of water required for the leaching of salts, mm.

Experimental Design: Experimental design and treatments was split plot with three replications. Deficit irrigation (100% of Full Irrigation" FI", 75% of FI and 50% of FI) in main plots and minimum tillage depth (10 cm depth "D10", 20 cm depth "D20" and 30 cm depth "D30") were used in sub main plots as shown in Figures 2 and 3.

Fig. 2 : Adjustment the depths of tillage under the sprinkler irrigation system.

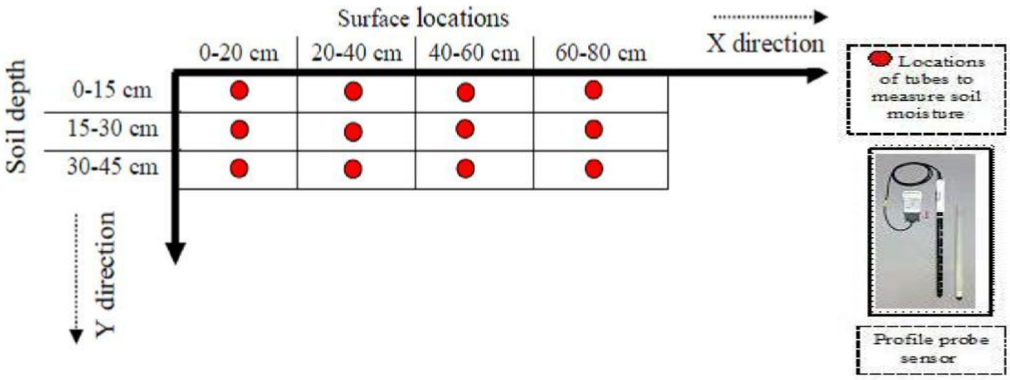

Fig. 3 : Different locations for measuring soil moisture content under sprinkler irrigation system.

Evaluation parameters

Water stress in the effective roots zone: Soil moisture was measured in effective roots zone before irrigation and the field capacity and wilting point were taken as evaluation lines in consideration as an evaluation parameter for exposure range of the plants to water stress "WS" (Abdelraouf *et al*., 2020 a). Measurements were taken at soil depths at mid-growth stage. Soil moisture was measured by profile probe device.

Application efficiency of irrigation water: Application efficiency of irrigation water (AE_{IW}) is the actual storage of water in the root zone to the water applied to the field. The AE_{IW} was calculated using equation 2:

$$AE_{IW} = Ds/\ Da \qquad ...(2)$$

Where AE_{IW} is the application efficiency of irrigation water, %, Ds is the depth of stored water in the root zone, cm by Equation 3

$$Ds = (\theta_1 - \theta_2) * d * \rho \qquad ...(3)$$

Where: Da is the depth of applied water (mm), d is the soil layer depth (mm), θ_1 is the average soil moisture content after irrigation (g/g) in the root zone, θ_2 is the average of soil moisture content before irrigation (g/g) in the root zone as shown in figure (3), ρ = bulk density of soil (g/cm^3) as shown as in Table 2.

Table 2: Field sheet to record the application efficiency of irrigation at peak of irrigation requirements for barley.

Soil depth, cm	θ_1 %	θ_2 %	d, mm	ρ, g.mm^{-3}	$D_s = (\theta_1 - \theta_2)*d*\rho$ mm		$D_s = \sum D_{s1} + D_{s2} + D_{s3}$ mm	D_a, mm	$AE_{IW} = [D_s / D_a]*100$
0 – 15					D_{s1}				
15 – 30					D_{s2}				
30 – 45					D_{s3}				

AE_{IW} = Application efficiency of irrigation water, D_s =Depth of stored water in root zone, D_a =Depth of applied water, d =Soil layer depth, θ_1 =Average of soil moisture content after irrigation, θ_2 = Average of soil moisture content before irrigation, ρ = Relative bulk density of soil (Dimensionless).D_{s1}= Depth of stored water in root zone from 0 – 15 cm ,D_{s2}= Depth of stored water in root zone from 15 – 30 cm, D_{s3}= Depth of stored water in root zone from 30 – 45cm

Yield components of barley

At harvest, ten plants in the two central rows were taken at random form each plot to determine, plant height (cm), spike length (cm) and one m^2 was harvested to determine number of spikes/m^2.

Grain yield of barley: A random area of 100 x 100 cm was harvested from each plot and grain, straw and biological yields were determined and then converted to yield per hectare. Then, harvest index was calculated as: grain yield/biological yield and grain yield of barley was expressed in (ton/ha).

Water productivity of barley: "WP_{Barley}": The water productivity of barley was calculated according to James (1988) as follows:

$$WP_{Barley} = Ey/Ir \qquad ...(4)$$

Where WP_{Barley} is water productivity (kg_{Barley} m^{-3}_{water}), Ey is the economical yield (kg_{Barley} /ha); Ir is the amount of applied irrigation water (m^3_{water}/ha/season).

Statistical Analysis: Combined analysis of data for the two studied growing seasons was carried out according to Snedecor and Cochran (1982) and the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of the different treatments.

Results

The effect of deficit irrigation scheduling and minimum tillage on the water stress inside the root zone of barley, application efficiency of irrigation water, yield components of barley and grain yield and water productivity of barley under sandy soil conditions was studied and the detailed results as follows:

Water stress inside the root zone of barley

Figure 4 shows the extent of exposure of barley roots to water stress when studied under the influence of scheduling irrigation deficits and the different depths of soil tillage. This effect is evident after measuring the moisture content of the root zone before the irrigation process at any stage of growth, especially at the maturity stage and the completion of green growth. The least water stress for barley roots was when adding 100% and 75% of the water requirements required for irrigating barley, while the maximum water stress for these roots was when irrigating at 50% of the water requirements needed for irrigating barley. There was a positive effect on the depth of plowing on the extent of exposure of the roots of barley plants to water stress, where the lowest water bodies when plowing were at the lowest depth of plowing (10 cm), while the water stress increases with increasing depth of tillage.

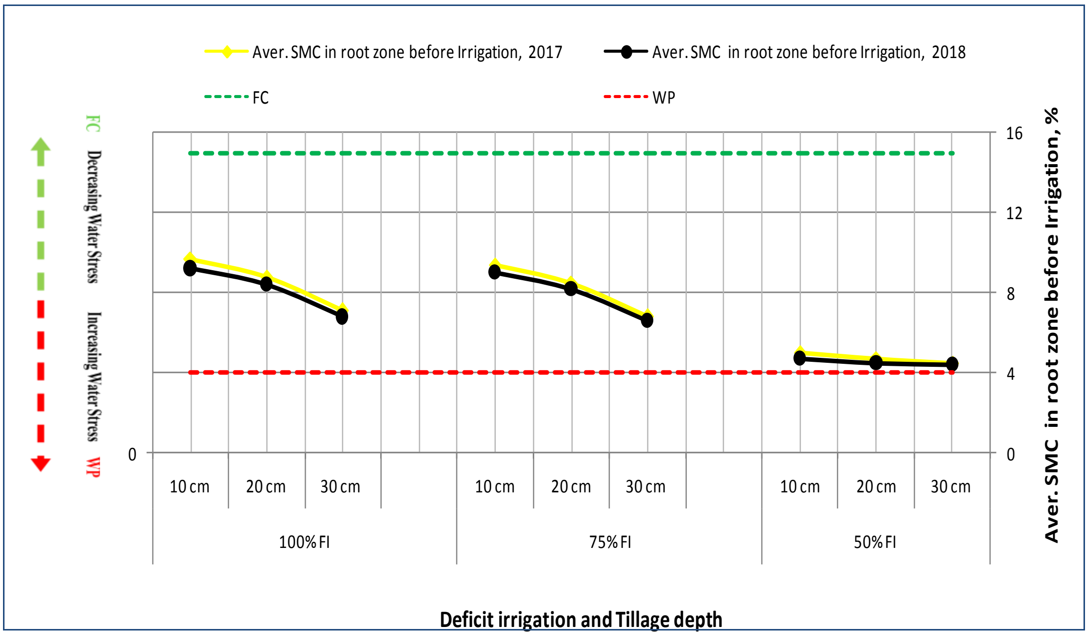

Fig. 4 : Effect of deficit irrigation scheduling and minimum tillage on the water stress (average of soil moisture content "SMC" in the root zone before irrigation) of barley roots.

Application efficiency of irrigation water

The effect of scheduling irrigation deficit and different tillage depth on the efficiency of adding irrigation water was studied. It became clear from the Figure 5 that with the decrease in the amount of water added for irrigation, the efficiency of adding irrigation water increases, while the efficiency of the addition decreases by increasing the depth of plowing when irrigation by 100% and 75% of the irrigation needs necessary for the growth of the barley crop, while the opposite happened when irrigation was 50% of the irrigation needs where The efficiency of adding water increased with increasing depth of tillage. The highest value of the application efficiency of irrigation water when scheduling irrigation was 50% of FI and at a tillage depth of 30 cm, while the lowest value was when scheduling irrigation with 100% of FI and at a depth of tillage of 30 cm.

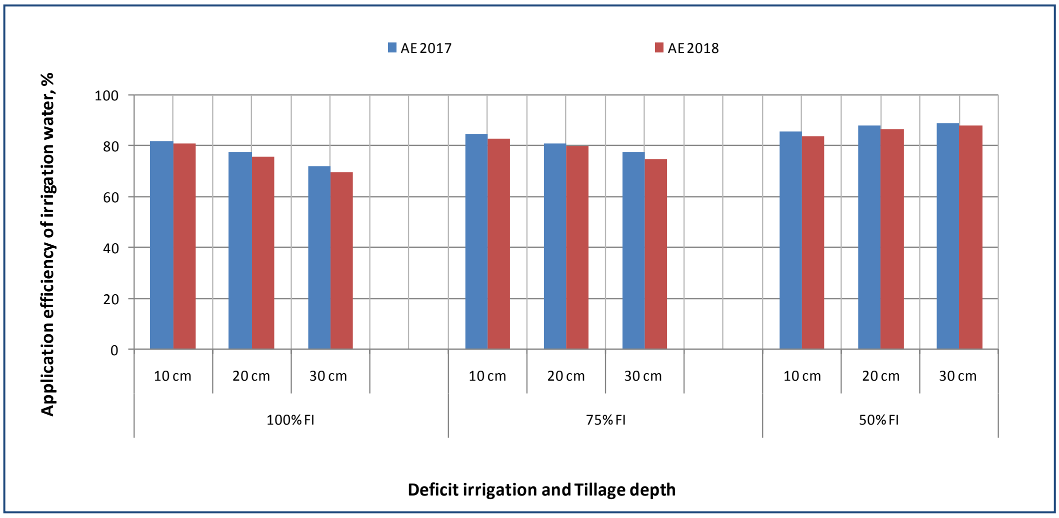

Fig. 5 : Effect of deficit irrigation scheduling and minimum tillage on the application efficiency of irrigation water.

Yield components of barley

Effect of deficit irrigation scheduling i.e. 50%, 75% and 100% of FI on yield components characters (plant height, Spike length and No. of spikes/m^2) of barley crop in both seasons are presented in Table 3. It is clear from that, there are significant differences due to variation of irrigation rates in all studied component characters of yield. In the two experimental seasons, it is observed the highest values of plant height, spike length and No. of spikes/m^2 were increased significantly by increasing irrigation level to 100% of FI followed by 75% of FI where as irrigation at 50% of FI showed significant decreases on plant height, spike length and No. of spikes/m^2 compared to 100% and 75% of FI treatments respectively.

Concerning the effect of different tillage depths, i.e. 10 cm, 20 cm and 30 cm, on the yield components characters (plant height, Spike length and No. of spikes/m^2) of barley crop, it could be observed from data demonstrate in Table 3. It is clear from data in table that a quite similar trend was obtained in both experimental seasons regarding the effect of different tillage depths on yield components characters of barley crop. In both seasons, plant height, Spike length and No. of spikes/m^2 were increased significantly by decreasing tillage level to 10 cm. On the other hand, data indicated that, the medium level of tillage at 20 cm ranked second, whereas the low level of tillage ranked third concerning their effect on plant height, spike length and No. of spikes/m^2.

Data exhibited in Table 3 illustrate the effect of interaction between deficit irrigation scheduling and different tillage depths on yield component characters viz., plant height, spike length, and number of spike m^2. Not significant differences due to interaction were attained in all yield component characters in both experimental seasons except for plant height in the two seasons, where that the highest value of plant height was achieved under tillage level at 10 cm depth when barley plants were irrigated at either 100% or 75% FI, followed by tillage level at 20 cm depth at 100% of FI, compared with tillage level at 30 cm depth under irrigated at either 50%, 75% or 100% of FI in 2017 and 2018 seasons. In addition, 50% of FI under different tillage depths exhibited significantly the lowest values for plant height in the same regard in both seasons.

Table 3: Effect of deficit irrigation scheduling and minimum tillage on the yield components of barley

Deficit irrigation, (%)	Tillage depth, (cm)	Plant height, cm		Spike length, cm		No. of spikes/m^2	
		2017	2018	2017	2018	2017	2018
Effect of deficit irrigation scheduling on the yield components of barley crop							
100		84.06 a	82.23 a	14.66 a	14.17 a	351.3 a	347.6 a
75		81.04 b	79.33 b	14.57 a	14.11 a	348.2 b	344.6 a
50		58.60 c	57.01 c	10.70 b	10.36 b	250.9 c	248.1 b
LSD at 5%		1.91	2.04	0.34	0.42	3.0	3.4
Effect of minimum tillage on the yield components of barley crop							
	10	79.10 a	77.42 a	13.89 a	13.45 a	320.7 a	317.0 a
	20	74.53 b	73.01 b	13.28 b	12.85 b	317.1 b	313.8 b
	30	70.07 c	68.14 c	12.76 c	12.34 c	312.7 c	309.5 c
LSD at 5%		1.01	1.13	0.26	0.27	2.1	2.2
Effect of the interaction between deficit irrigation scheduling and minimum tillage on the yield components of barley crop							
100	10	87.23 a	85.49 a	15.23	14.78	355.0	350.67
	20	84.33 b	82.54 b	14.63	14.14	351.3	347.82
	30	80.60 c	78.66 c	14.10	13.59	347.7	344.19
75	10	87.23 a	85.20 a	15.07	14.61	353.3	349.48
	20	80.47 c	78.86 c	14.60	14.11	349.7	346.17
	30	75.43 d	73.93 d	14.03	13.62	341.7	338.25
50	10	62.83 e	61.58 e	11.37	10.97	253.7	250.82
	20	58.80 f	57.63 f	10.60	10.29	250.3	247.50
	30	54.17 g	51.83 g	10.13	9.83	248.7	246.01
LSD at 5%		1.75	1.96	N.S	N.S	N.S	N.S

Grain yield

The effect of scheduling the irrigation deficit and the depth of tillage on the biological yield, straw yield and harvest index was studied, leading to the grain yield of barley. Below is a detailed presentation for each part separately.

Biological yield: biological yield of barley crop was significantly affected by different deficit irrigation scheduling treatments during the crop season as shown in Table 4 in 2017 and 2018 seasons where that the higher value of biological yield was obtained under 100 % and 75 % of FI treatments compared with 50% of FI which recorded the lowest values in the first and the second seasons. The effect of different tillage depths was presented in Table 4. It's obvious from the data that, the biological yield increased significantly under tillage level at 10 cm depth followed by tillage level at 20 cm depth, while the lowest values was achieved under tillage level at 30 cm depth in both seasons. The interaction between deficit irrigation scheduling and different tillage depths both had significant effects on the biological yield as shown in Table 4 through seasons 2017 and 2018. Data demonstrated regarding the highest and lowest values of the studied parameter that the highest values of the significantly affected character in the two seasons were exhibited by tillage levels at 10 and 20 cm depths when barley plants were irrigated at either 100% and 75% of FI followed by tillage level at 30 cm depth with irrigated at either 100% and 75% of FI comparing with the other three tillage levels under irrigated with 50% of FI which recorded the lowest significant values on the biological yield.

Straw yield: As illustrated in Table 4 different deficit irrigation significantly affected straw yield. Where, that the highest values of straw yield were given under irrigation treatments at either 100% or 75% of FI as compared to 50% of FI treatment in the first and the second seasons. Regarding the effect of different tillage depths on straw yield were presented in Table 4. The data showed that tillage levels at either at 10 or 20 cm depth has caused marked increase significant values in straw yield in both seasons while the lowest values were obtained at 30 cm depth. The effect of deficit irrigation and different tillage depths as an interaction was demonstrated in Table 4 in the two experimental seasons. It's obvious from the data that straw yield increased significantly under all tillage levels at the three depths when barley plants were irrigated at 75% of FI in both seasons. In addition, data showed that the highest values of straw yield were recorded under tillage level at 10 cm depth with irrigation at either 50% or 100% of FI followed by tillage levels at either 20 or 30 cm depth at irrigation by100% of FI in 2017 and 2018 seasons where as the lowest values were achieved under tillage levels at 20 and 30 cm depths when barley plants were irrigated at 50 % of FI in the two seasons.

Harvest index: Data in Table 4 showed that, in both growing seasons harvest index percentage significant values were increased with increasing deficit irrigation scheduling with irrigation at either 75% or 100% of FI comparing the lowest values under irrigation by 50% of FI. The data in Table 4 indicated that there was no significant effect due to different tillage depths and interaction between deficit irrigation scheduling and different tillage depths on harvest index percentage in 2017 and 2018 experimental seasons respectively.

Grain yield: Grain yield in barley is a complex character which, depending on a large number of agronomical, physiological and environmental characters. Measured grain yield different under deficit irrigation scheduling has been presented in table (4) in both seasons. The results display that, there is a significant increase in grain yield when barley plants were irrigated at 100% of FI followed by 75% of FI in the first and the second seasons while the lowest values were obtained at 50% of FI. Data of grain yield for barley crop in the two experimental seasons of 2017 and 2018 are tabulated in Table 4. Data showed that grain yield was significantly affected by different tillage depths in the first and the second seasons. In this regard, tillage level at 10 cm depth surpassed the other tillage levels at 20 and 30 cm depth for grain yield in the two seasons. The effect of the interaction between deficit irrigation scheduling and different tillage depths on grain yield character is exhibited in Table 4 and Figure 6. Significant differences due to interaction were attained of barley grain yield in both experimental seasons, whereas the highest significant interaction values of barley grain yield were recorded under tillage level at 10 cm depth at irrigation at either 100% or 75% of FI followed by tillage level at 20 cm depth at irrigation with 75% of FI compare the other treatments in both seasons.

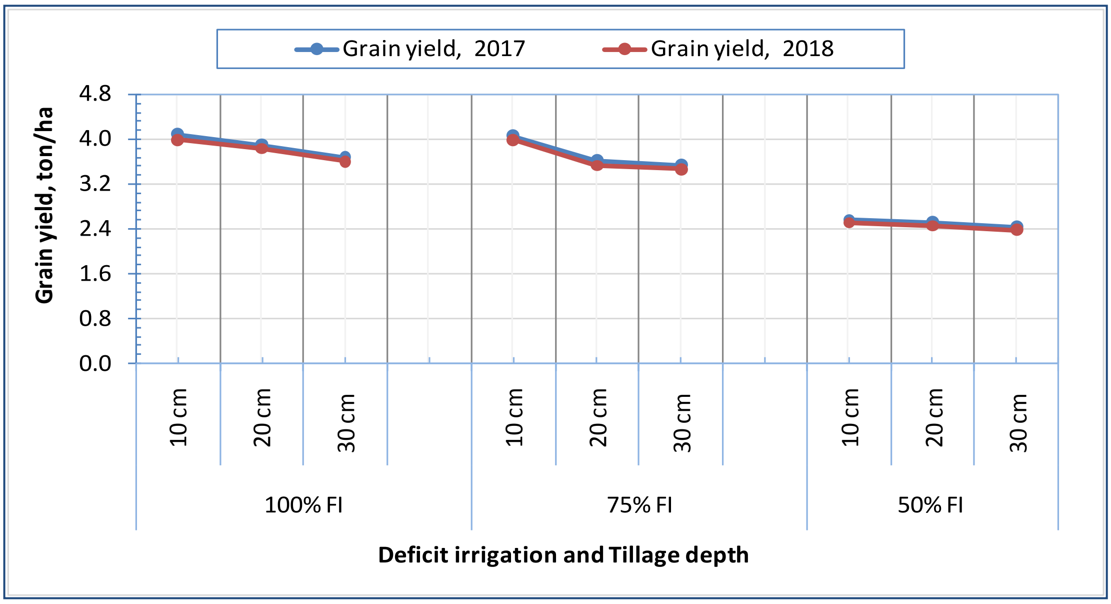

Fig. 6 : Effect of deficit irrigation scheduling and minimum tillage on the grain yield of barley crop.

Water productivity

It is clear from the data displayed in Table 4 that there are significant differences due to variation of deficit irrigation treatments on water productivity parameter in both growth seasons. it is observed the highest values of water productivity were achieved by 50% and 75% of FI treatments compare with treatment 100% of FI, which recorded the lowest significant values. Regarding water productivity under different tillage depths studied, there is significant differences in water productivity were found as shown in Table 4 in 2017 and 2018 seasons respectively. Tillage level at10 cm depth surpassed significantly the other two levels of tillage in water productivity. Meanwhile tillage levels at both 20 and 30 cm depth recorded the lowest significant in water productivity in both seasons. Effect of interaction between deficit irrigation scheduling and different tillage depths on water productivity is illustrated in Table 4 and Figure 7 in both experimental seasons. The highest significant interaction values of water productivity were obtained in the first and second seasons under tillage level 10 cm depth when barley plants were irrigated at 75% of FI followed by tillage level 10 cm depth with irrigation by 50% of FI comparing with the other two tillage levels at 20 and 30 cm depth under irrigation at 50% and 75% of FI as well as under the three tillage levels with irrigation by 100% of FI in both season.

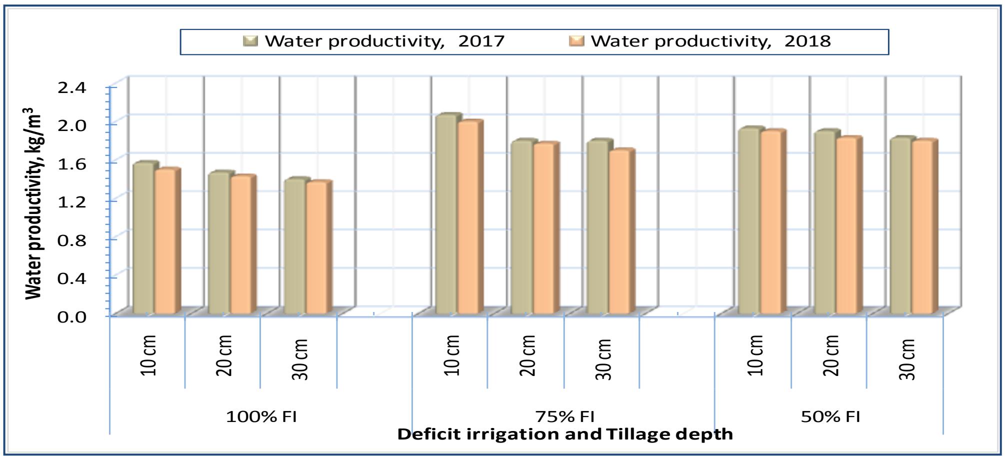

Fig. 7 : Effect of deficit irrigation scheduling and minimum tillage on the Water productivity of barley crop.

Table 4: Effect of deficit irrigation scheduling and minimum tillage on the biological, straw, harvest index, grain yield and water productivity of barley crop

Deficit irrigation, (%)	Tillage depth, (cm)	Grain yield, ton/ha		Biological yield, ton/ha		Straw yield, ton/ha		H.I., %		Water productivity, kg/m^3	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Effect of deficit irrigation scheduling on the biological, straw, harvest index, grain yield and water productivity of barley crop											
100		3.88 a	3.80 a	11.93 a	11.69 a	8.05 a	7.89 a	0.30 a	0.30 a	1.48 b	1.43 b
75		3.72 b	3.64 b	11.99 a	11.75 a	8.27 a	8.10 a	0.30 a	0.30 a	1.89 a	1.82 a
50		2.49 c	2.44 c	10.11 b	9.90 b	7.62 b	7.47 b	0.21 b	0.21 b	1.89 a	1.84 a
LSD at 5%		0.06	0.06	0.22	0.22	0.26	0.26	0.07	0.07	0.06	0.06
Effect of minimum tillage on the biological, straw, harvest index, grain yield and water productivity of barley crop											
	10	3.56 a	3.48 a	11.68 a	11.44 a	8.12 a	7.96 a	0.27	0.27	1.86 a	1.80 a
	20	3.33 b	3.26 b	11.35 b	11.11 b	8.02 a	7.85 a	0.27	0.27	1.72 b	1.68 b
	30	3.20 c	3.14 c	11.01 c	10.78 c	7.81 b	7.65 b	0.28	0.28	1.68 b	1.62 c
LSD at 5%		0.05	0.05	0.17	0.17	0.18	0.18	N.S	N.S	0.05	0.03
Effect the interaction between deficit irrigation scheduling and minimum tillage on the biological, straw, harvest index, grain yield and water productivity of barley crop											
100	10	4.08 a	3.98 a	12.20 a	11.95 a	8.12 abc	7.97 ab	0.30	0.30	1.57 e	1.50 f
	20	3.90 b	3.82 b	11.97 ab	11.72 ab	8.07 bc	7.90 b	0.30	0.30	1.47 f	1.43 g
	30	3.67 c	3.59 c	11.63 c	11.39 c	7.96 c	7.81 b	0.30	0.30	1.40 f	1.37 h
75	**10**	**4.05 a**	**3.97 a**	12.18 a	11.93 a	8.13 abc	7.97 ab	0.30	0.30	**2.07 a**	**2.00 a**
	20	3.60 c	3.52 cd	12.00 ab	11.75 ab	8.40 a	8.23 a	0.30	0.30	1.80 d	1.77 d
	30	3.52 d	3.45 d	11.80 bc	11.56 bc	8.28 ab	8.12 ab	0.30	0.30	1.80 d	1.70 e
50	10	2.55 e	2.50 e	10.66 d	10.44 d	8.11 abc	7.95 ab	0.20	0.20	1.93 b	1.90 b
	20	2.50 ef	2.44 ef	10.08 e	9.870 e	7.58 d	7.43 c	0.20	0.20	1.90 bc	1.83 c
	30	2.42 f	2.37 f	9.597 f	9.397 f	7.17 e	7.02 d	0.23	0.23	1.83 cd	1.80 cd
LSD at 5%		0.08	0.08	0.29	0.29	0.32	0.31	N.S	N.S	0.08	0.06

Discussion

Water shortage in many regions is a major cause of decrease of crop production. Under these conditions, irrigation management and search about a new ways to save irrigation water is very important.

The results are presented above for the effect of irrigation deficit scheduling and tillage depth on several criteria to assess the effect of these factors, namely water stresses inside root zone of barley, application efficiency of irrigation water, yield components and grain yield and water productivity of barley under sandy soil conditions.

The results display that, there is an increase in grain yield when barley plants were irrigated at 100% of FI followed by 75% of FI while the lowest values were obtained at 50% of FI and this is due to the increase in the moisture stress of the barley root zone, due to the decrease in the amount of irrigation water added. Despite the increase in productivity when irrigation by 100% of FI, there are no significant differences between them and the values of productivity when irrigation with 75% of FI, while there were significant differences when irrigation with 50% of FI for irrigation of barley and this is due to moisture stress when irrigating with 75% of FI did not significantly affect productivity between it and moisture content when irrigating with 100% of FI, while moisture stress was very large when irrigating with 50% of FI, which led to significant moral differences in the productivity values.

The highest yields of barley were at a depth of 10 cm of tillage, while the productivity of barley decreased by increasing the depth of tillage to 20 cm and 30 cm. Perhaps this was due to the increased loss of irrigation water by deep leakage as a result of increased porosity and the apparent density of sandy loose soil, which resulted in an increase in the vertical movement of irrigation water down and a decrease in the water reserve of the root-spreading area and the exposure of the root-spreading area of barley plants to water stress, where this stress increased with increasing depth of tillage.

The application efficiency of irrigation water is defined as the amount of irrigation water stored in the root zone to the amount of irrigation water that was added without regard to whether this amount of irrigation water stored is sufficient for healthy growth without stress or not. This explains that all the characteristics that were studied took the same direction in response to the factors of the study except for the application efficiency of irrigation water, as it had the opposite direction. The application efficiency of irrigation water increased by decreasing the amount of added irrigation water and also by increasing the depth of tillage when irrigation by 50% of FI. This may have been due to the decrease in the rate of loss of water by deep leakage by the decrease in the amount of added irrigation water. As for the increase in the efficiency of the addition by increasing the depth of tillage when irrigation by 50% of FI, this is due to the small quantity of the added amount of water that was stored all without loss of deep leakage or without surface runoff and evaporation from the wet surface area of the soil.

In general, it should be taken into account when studying the efficiency of adding irrigation water, studying the water stress of the root zone, along with it, especially when studying the effect of irrigation deficiency among the factors of the study as shown as in Figure 8.

The study concluded after discussing the previous results above that there were no significant differences between the highest values of barley productivity when irrigating at 100% or 75% of water requirements when tillage at the lowest depth of 10 cm. Therefore, it was the most appropriate and best treatment recommended for application when planting barley under the conditions of dry sandy soils is the scheduling of irrigation by adding 75% of the requirements for irrigation of barley and the depth of tillage 10 cm. This resulted in providing 25% of the water needs for irrigating barley, and also energy will be provided from two sides, the first of which is due to the low fuel consumption of the tractor resulting from the application of a less-depth tillage technology, and the second result from providing energy to pump 25% of irrigation water when scheduling irrigation by 75% instead 100% of barley irrigation needs.

The results agreed with the result which obtained by Mohamed *et al.* (2017) who showed that, different tillage systems had different effects on properties of soil physical. The higher content of moisture under minimum tillage system at might be attributed to the predominance of micro pores. Our results were in line with result which obtained by Mohamed *et al.* (2017) who illustrated that amount of irrigation water and tillage systems are necessary to create the optimum conditions for increasing crop production. Discussion of barley crop performance in response to tillage and deficit irrigation water is of great interest and importance to farmers considering a shift from conventional tillage to minimum tillage. As might be expected in our experiment with barley crop tested under irrigated conditions agriculture over two growing seasons, there was considerable interaction in the various parameters of barley crop measured between the treatments of tillage and deficit irrigation water. Also, Kovacev *et al.* (2011) calculated economic efficiency of non-conventional tillage systems in production of winter barley. The comparison shows that conventional system has the highest fuel consumption. The most economical system in crop production was identified in reduced tillage variant.

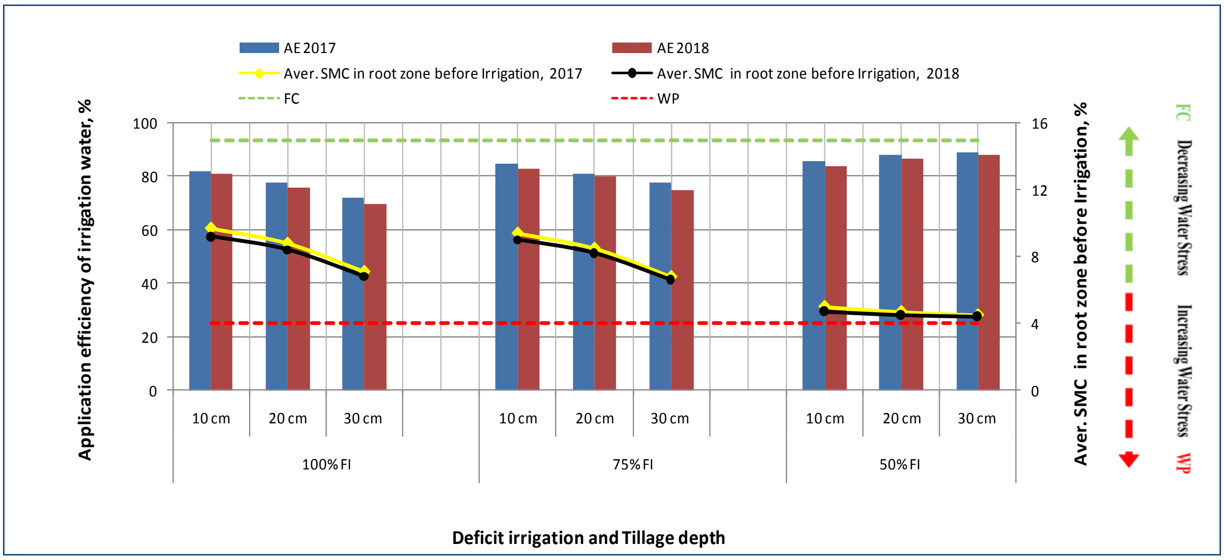

Fig. 8 : Effect of deficit irrigation scheduling and minimum tillage on the water stress and application efficiency of irrigation water.

Conclusion

The results of the present study reported that, the highest average grain production of barley crop was achieved under minimum tillage at 10 cm depth with irrigation at either 75% and 100% of FI. The highest values of the biological yield were recorded under minimum tillage at 10 and 20 cm depth when barley plants with irrigation at 75% and 100% of FI. While, the highest straw yield and water productivity values were obtained with irrigation by 75% of FI and minimum tillage at 20 and 10 cm depth respectively.

The study concluded after discussing the previous results above that, there were no significant differences between the highest values of barley productivity when irrigating at 100% or 75% of water requirements when tillage at the lowest depth of 10 cm. Therefore, it was the most appropriate and best treatment recommended for application when planting barley under the conditions of dry sandy soils is the scheduling of irrigation by adding 75% of the requirements for irrigation of barley and the depth of tillage 10 cm. This resulted in providing 25% of the water needs for irrigating barley. Also, energy will be provided from two sides, the first of which is due to the low fuel consumption of the tractor resulting from the application of a less-depth tillage technology, and the second result from providing energy to pump 25% of irrigation water when scheduling irrigation by 75% instead 100% of barley irrigation needs. Finally from our results we can say that minimum tillage and deficit irrigation scheduling significantly increased productivity of barley crop. We recommend that farmers use this method, while adopting it as one of the most important technical packages.

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