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Effect of irrigation methods and tillage system, seed level on water use efficiency and wheat (Triticum aestivum L.) growth

Alaa M. Akol [1], Nadine Nassif [2], Khudhair Abbas Jaddoa [3], Kareem Radhi [4]
[1]Ecole Doctorale en Sciences et Technologie, Lebanese University
[2]Faculty of Agronomy and Veterinary Sciences, Environment and Natural Resources department, Lebanese University
[3]College of Agricultural Engineering Sciences, Baghdad University
[4]Al-Qasim Green University, Water Resources Engineering College

ABSTRACT

Afield trial was conducted at Al- Hashimya area, Babylon district, Iraq during the growing seasons 2016-2017 and 2017-2018 to investigate the effect of some agronomic practices viz. irrigation system (sprinkler irrigation (I_1) and surface irrigation (I_2) which occupied the main plots; tillage system (Zero tillage (T_0), minimum tillage (T_1) and deep tillage (T_2) which occupied the subplot); and seeding rates (120 Kg ha^{-1}(S_1), 180 Kg ha^{-1}(S_2),240 Kg ha^{-1} (S_3)and 300 Kg ha^{-1} (S_4) which occupied the sub _ subplots on biological yield, harvest index, water _use efficiency, water consumptive use, crop coefficient of bread wheat (*Triticum aestivum L*.). Results indicated that biological yield was increased in both seasons by 9 and 10%, respectively, following the application of sprinkler irrigation. This may be due to the increased water _use efficiency by 29 and 32% in both seasons, respectively, as influenced by sprinkler irrigation. However, sprinkler irrigation did not affect the harvest index in both seasons. Similarly, minimum tillage increased the biological yield by 10.6,10.2,11.8 and 3.4 % over zero _ tillage and deep tillage in both seasons, respectively. However, the tillage system had no significant effect on the harvest index in both seasons. The seeding rate (240 Kg ha^{-1}) increased the biological yield by 15.1 and 16.0 % over the lowest seeding rate (S_1 120 Kg ha^{-1}) with no significant effect on the harvest index in both seasons, respectively. The exciting result that the application of sprinkler irrigation (I_1) decreased the consumptive use mm. Season in both seasons and consequently the crop coefficient (Kc) was decreased at tillering, elongation, flowering and maturity stages in both seasons. It can be concluded that the application of sprinkler irrigation under the minimum tillage and using the seeding rate 240 Kg ha^{-1} has increased the biological yield via increased water – use efficiency and decreased both consumptive use and crop coefficient.

Keywords: Biological yield, Harvest Index, Water – use efficiency, Consumptive use, Crop coefficient Sprinkler Irrigation, Minimum Tillage

Corresponding Author:

Alaa M. Akol
Departement, Ecole Doctorale en Sciences et Technologie
University, Lebanese University
Address, Beirut, Lebanon
E-mail: alaamahdi@wrec.uoqasim.edu.iq

1. Introduction

Bread wheat (Triticum aestivum L.) is the most widely grown and consumed food crop in Iraq and elsewhere as it's the staple food for 35% of the world population. The irrigation wheat system contributes over 40% of wheat production in the developing world , and water is the most limiting factor for crop production in irrigation farming[1]. Therefore knowledge of crop water management is necessary for irrigation scheduling as water is becoming increasingly scarce worldwide, and more than one _ third of the world population will face absolute water scarcity by the year 2025 [2]. The worst affected areas will be the semi-arid regions of Asia, the Middle East, and Sub_ Saharan Africa. Iraq is classified among the areas that are facing high-water shortage. This is mainly due to the combination of persistent drought conditions and an increase in water demand effect, especially in the irrigation sector. Therefore, an efficient and economical method of irrigation must be adopted to save water, increasing water use efficiency and crop productivity, among then sprinkler irrigation. This system, such as portable rain guns, can be used to apply as the desired depth of the water during presowing and subsequent irrigation [2]. The application of irrigation water with sprinklers has improved on-farm irrigation efficiencies up to 80% under the prevailing conditions in the Indian sub-continent Soil tillage is highly correlated with the irrigation systems as an essential factor affecting Soil properties and crop yield. Among the agronomic practices, factors tillage contributes up to 20% [3, 4]. Tillage plays a crucial role in changing hydro-physical properties [5]. Recently, there is an excellent concern that conservation tillage (zero and minimum) always improves soil proprieties for plant growth and water retention. Conservation is becoming an increasingly acceptable management technology in the wheat or rice_wheat system[6] . This system generally improves soil organic matter, plant available water capacity, aggregation, and soil water transmission [7, 8]. Another factor of agronomic practices, e.g., seeding rate, should be considered as this factor means different plant population densities in the field differ in their exploitation of growth resources, e.g., irrigation water and soil nutritive. Therefore, the present investigation was undertaken to find out the effect of sprinkler irrigation, tillage methods and seeding rate on biomass production, harvest index and some water parameters (crop WUE, consumptive use and crop coefficient Kc) of wheat under the Iraqi conditions as there is a need to develop an appropriate irrigation and tillage methods with suitable seeding rate that will economically feasible and environmentally sustainable.The date of irrigation depends, and the amount of water required for irrigation on what the plant roots have depleted from the water stored in the soil, as most of the water that the plant roots drain directly after irrigation is from the upper layer. When the moisture content of this layer decreases, the tensile forces increase, so the roots work to absorb moisture from the deeper layers [9]. Therefore, irrigation time must be regulated to avoid water stress during the endothelial or flowering stage of the wheat crop to obtain the highest yield and reach the highest efficiency of irrigation water use that can be achieved by following the correct irrigation management methods[10, 11].

2. Materials and methods

2.1 Geographical description of the studied area

The field experiments were performed at Al- Hashimya area, Babylon district, Iraq along the east line of 44°39'34.99" And" 32°24'22.68" to the north area see figure 1. the landform is a plain area about 25.2 m above sea level. The land is characterized by an alluvial, silty clay loam soil., and is classified under the supergroup ‘Typic Torrifluvent’. The region is indicated by a subtropical climate with an average air temperature of 25.6 C^{o}. The average annual rainfall is about 135 mm with evaporation that exceeds 2122 mm. The average wind speed is 3.8 m. sec^{-1} with a relative humidity of 38%. The texture class was clay loam, and soil pH of (7.31) and the land type is a medium-high.

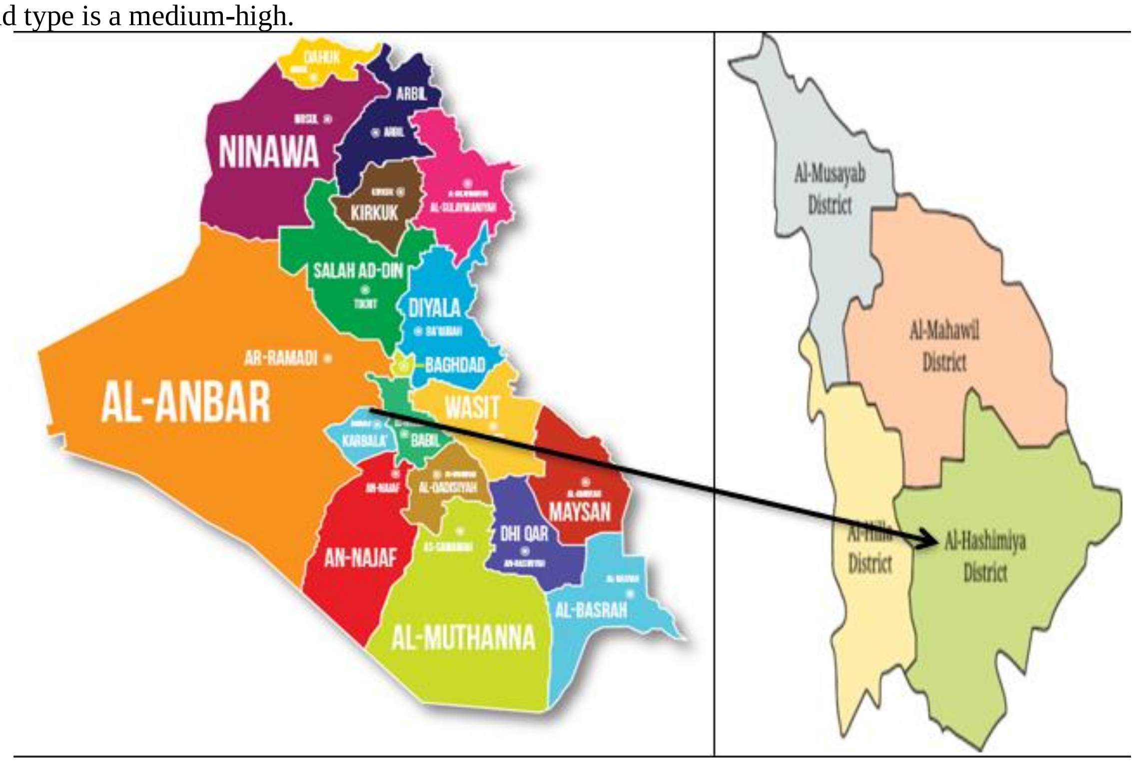

Figure 1. The geographical location of the experimental area

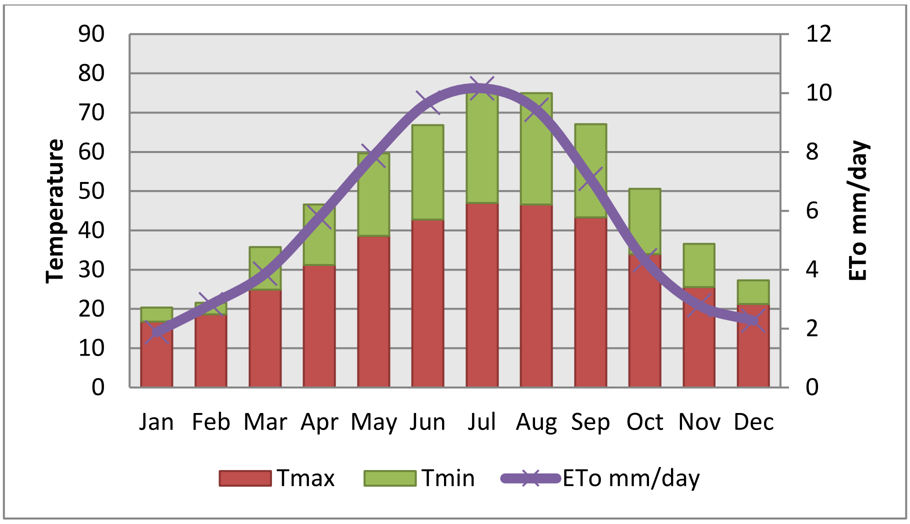

Figure 2.A. Climate data for the 2017 season

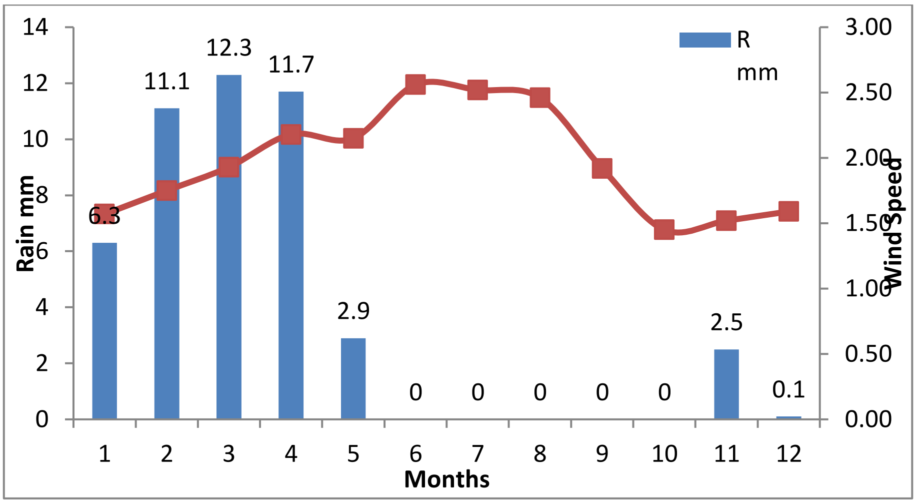

Figure 2.B. Climate data for the 2017 season

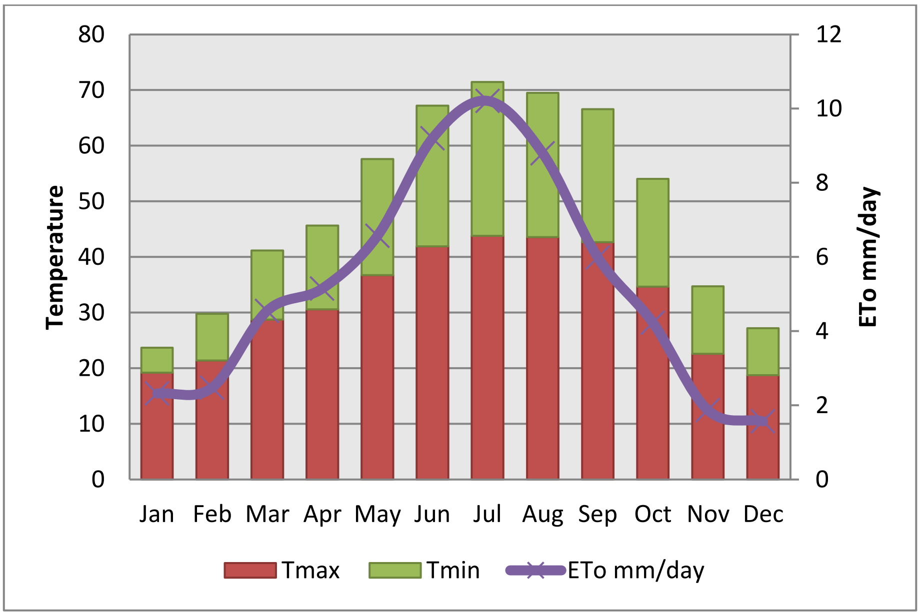

Figure 3.A. Climate data for the 2018 season

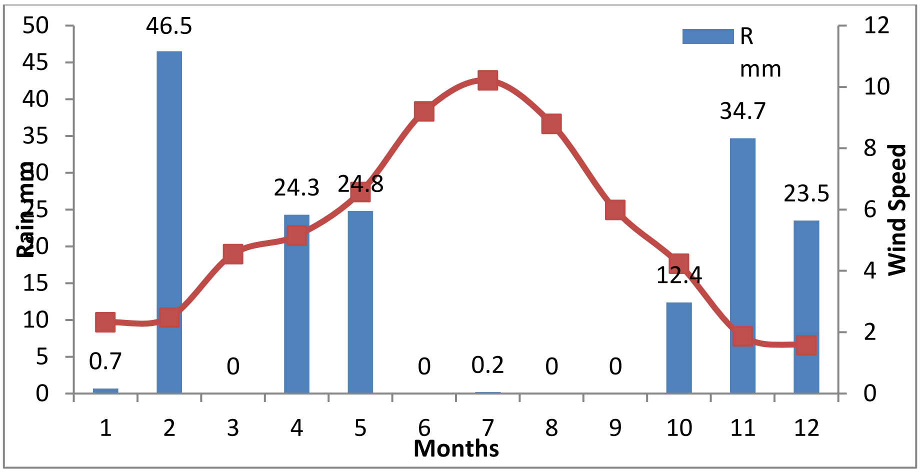

Figure 3.B. Climate data for the 2018 season

2.2 Soil preparation practices

The soil was prepared by ploughing it using three methods of tillage, the table (1) shows some of Physical and Chemical properties for experimental soil, namely (zero tillage, minimum tillage and deep tillage) using The board plough bottom does not exceed 15 cm depth, and the deep plough conducted using chisel plough to 30 cm depth. After that, the soil was levelled and divided into plots with dimensions 4 x 5 m^2. Then the sprinkler irrigation system was installed by laying the main pipes, the distance between the line and another 10 m and the distance between the sprinklers 10 m. As for the surface irrigation system, plastic tubes with a diameter of (2) inches were used, and a meter was attached to measure the amount of irrigation water to be added to each plot. A soil separation distance of 3 m was left between the two systems to prevent the impact of the sprinkler irrigation system on the surface irrigation system.

Table 1. Selected physical and chemical properties for experimental soil

Characteristics	Units	Value
EC	ds.m^{-1}	2.34
PH		7.31
Sand		160
Silt	g kg^{-1}	490
Clay		350
Textural Class		Silty Clay Loam
Ca		12.41
Mg		5.60
Na		3.86
K	meqL^{-1}	1.55
HCO_3		2.89
CL		14.15
SO_4		7.87
Organic Matter	%	1.50
Bulk Density	g cm^{-3}	1.38
Particle Density		2.65
Hydraulic Conductivity	cm h^{-1}	0.72

2.3 Experimental design and treatments

The layout of the experiment was Split Plot Design, with three replicates where irrigation methods (surface and sprinkling) were distributed randomly in the main plots. While the tillage methods (zero tillage, minimum tillage, deep tillage), they were distributed in the secondary plots. The data were statistically analyzed using the least significant difference which chosen at the level of 5% to compare the averages of the treatments—figure (3).

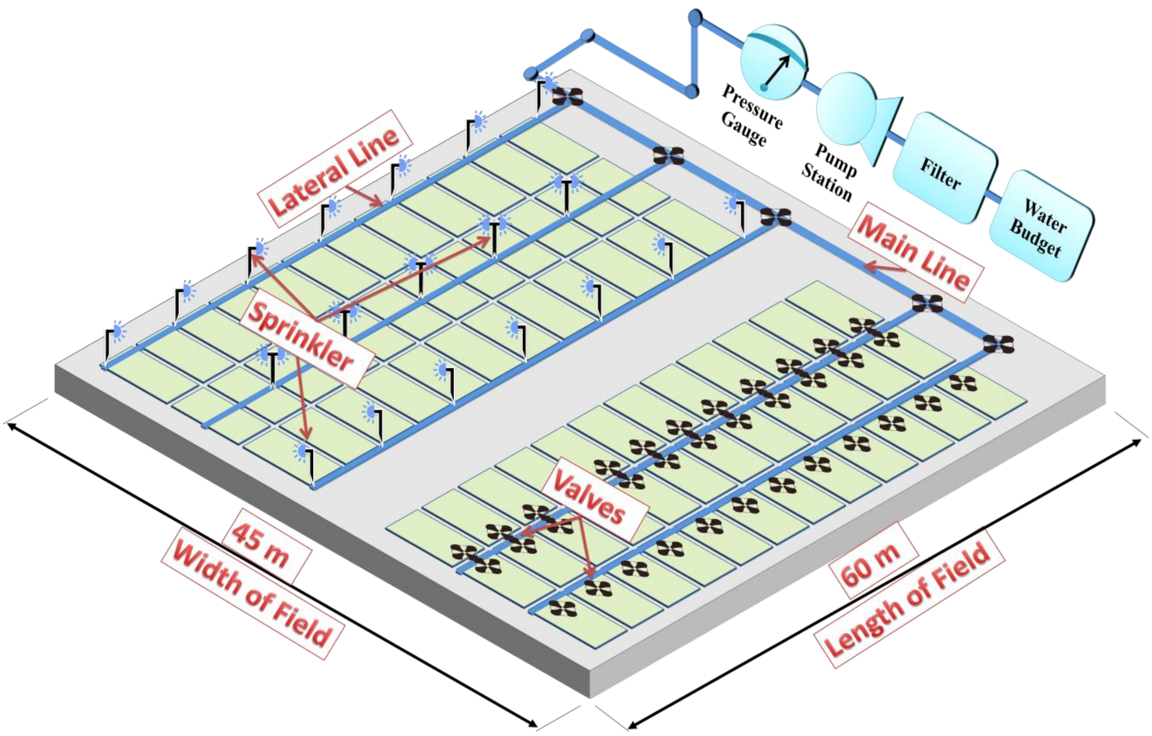

Figure 4. Experimental design

2.4 Agronomic practices

Seeds of wheat were sown on 1st December in the 2016 and 2017 seasons, respectively. Seeds were planted in rows, the distance between the rows 20 cm. The experimental units were fertilized according to agricultural extension recommendation of the experiment region by adding 100 kg ha^{-1} (P_2O_5 46%) once at the soil preparation, and nitrogen 200 kg ha as urea 46% was added as top dressing three times at the beginning of tillring stem elongation and booting[12]. The harvest was performed on 10/5/2017 and 8/5/2018.

2.5 Irrigation water supply

The irrigation process was preformed after depletion of 50% of the available water. The amount of supplied water each time was measured depending on the calculation of the soil moisture content before irrigation. The irrigation was carried out based on moisture depletion of the 0–10 cm layer from the sowing until the end of the vegetative growth phase. The depth of irrigation was increased to 10–20 cm based on moisture depletion for the flowering stage and to 20–30 cm to the end of physiological maturity, to reach moisture content close to field capacity. Soil field capacity and permanent wilting point were measured using a pressure plate apparatus, while available water content was calculated using Equation (1).

$$d = (f.c - pwp/100)*BD*soil\ depth \quad (1)$$

Where
d = available water depth (%).
f.c = field capacity.
pwp = permanent wilting point.
B = bulk density.
d = soil depth (cm).

Precipitation Intensity: the water balance formula of Equation (2) was used as a direct method for calculating the actual water consumption of the wheat crop [13].

$$(I + P + C) - (ET_a + D + R) = \triangle S \quad (2)$$

Where
$\triangle S$: The storage soil moisture change.

I: The water applied by irrigation.
P: The rainfall.
C: The capillary rise.
ETa : Crop evapotranspiration [mm d^{-1}].
D: the deep soil drainage.
R: The surface runoff.
Where
ΔS = zero because the soil moisture storage is the same at the beginning and end of the season; P = zero, to block rain by covering, and D = zero because irrigation is conducted with a drainage limit of 50% of available water and a certain depth of the soil layer 0–30 cm. Therefore, the equation becomes:

$$ETa = I + C \quad (3)$$

2.5.1. Water use efficiency

Whereas, the efficiency of using crop water was calculated through the following equation[14].

$$\mathbf{WUEc} = \frac{Y}{ETa} \quad (4)$$

WUE_C= Efficient use of crop water ($kg.m^{-3}$).
ET_a= Evapotranspiration (m^3. $season^{-1}$).
Y= grain yield (kg).

2.5.2. crop coefficient (Kc)

The yield factor (Kc) of the wheat crop was calculated from the following equation [13].

$$Kc = \frac{ETa}{ETo} \quad (5)$$

Where:
ET_a= actual Evapotranspiration (mm).
ET_o= Reference Evapotranspiration (mm).
Kc= crop coefficient.

2.6 Studied characters:

2.6.1. Growth parameters:

2.6.1.1. Biological yield: It was calculated from the dry matter product (grains + straw) for three middle lines for each experimental unit (A.O.A.C,1975) and then converted to tons per hectare.
2.6.1.2. Harvest index (HI): It was calculated from the following equation [15]

$$\mathbf{HI}(\%) = \frac{GY}{BY} x100 \quad (6)$$

2.6.1.3. statistical analysis:

The data were analyzed statistically and for all the studied characters using the test of the least significant difference (L.S.D) at the significance level 0.05 to compare the arithmetic mean using the Genstat statistical program to analyze data.

3. Results and discussion

Table (2 and 3) illustrates the effect of study factors on this character. Sprinkler irrigation (I_1) in both seasons increased the crop water _ use efficiency from 0.72 and 0.70 (in surface irrigation) to 0.93 and 0.93, respectively. Minimum tillage (T_1) gave the highest averages of 0.87 and 0.86 of crop water _ use efficiency in both seasons, respectively compared with zero (T_0) and deep tillage (T_2). For seeding rate, (S_3) (240 Kg ha^{-1}) recorded the highest values, 0.87 and 0.88 with no significant differences with S2seeding rate. However, the lowest seeding rate (S_1) gave the lowest values of 0.77 and 0.76 in both seasons, respectively. The combination of sprinkler irrigation (I_1), minimum tillage (T_1) and seeding rate (S_3) gave the highest values of crop water use efficiency 1.05 and 1.07 compared with 0.66 and 0.62 under the influence of surface irrigation (I_2), zero _ tillage

(T_0) and the highest seeding rate (S_4) in both seasons, respectively. The improved crop water _ use efficiency of wheat plants following sprinkler irrigation and minimum tillage may be due to the fact that in sprinkler irrigation, wheat plants received a uniform distribution of water across the entire field and hence crop water _ use efficiency was maximized under the sprinkler irrigatio[2, 16, 17] to reach 0.83 Kg m^{-3}. The same authors found that crop water _ use efficiency was increased from 0.671 Kg m^{-3} in conventional tillage to 0.773 Kg m^{-3} in minimum tillage. The autors [18], found that minimum tillage had a significant influence on soil physical and chemical properties, water _ use efficiency and yield of wheat in wheat _ mung bean cropping system, compared to the conventional and deep tillage practices. The reason is that the actual water consumption of irrigation treatment reached its highest value because the moisture content is available to the plant at a depth that provides for its water needs, which led to an increase in the water consumption of plants whose stomata are widely open allowing water loss by transpiration (As the rate of plant consumption of water increases with the increase in the moisture content, in which the soil moisture is close to the field capacity[20] .

Table 2. Effect of Irrigation methods, tillage systems and seed level on Crop water use efficiency: season (1)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	0.81	0.90	0.94	0.89	0.89
	T1	0.92	0.99	1.05	0.96	0.98
	T2	0.87	0.96	0.98	0.93	0.93
I2	T0	0.62	0.69	0.70	0.66	0.66
	T1	0.70	0.79	0.79	0.74	0.75
	T2	0.68	0.78	0.77	0.72	0.74
L.S.D 0.05		1.01				0.50
						I
I	I1	0.87	0.95	0.99	0.92	0.93
	I2	0.66	0.75	0.75	0.71	0.72
L.S.D 0.05		0.57				0.26
						T
	T0	0.71	0.79	0.82	0.78	0.77
	T1	0.81	0.89	0.92	0.85	0.87
	T2	0.77	0.87	0.88	0.82	0.83
L.S.D 0.05		0.72				0.37
S		0.77	0.85	0.87	0.82	
L.S.D 0.05		0.418				

Table 3. Effect of Irrigation methods, Tillage systems and seed level on Crop water _ use Efficiency: season (2)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	0.82	0.91	0.96	0.87	0.89
	T1	0.92	1.01	1.07	0.93	0.98
	T2	0.87	0.98	1.00	0.89	0.93

I2	T0	0.60	0.67	0.69	0.62	0.64
	T1	0.69	0.75	0.78	0.69	0.73
	T2	0.65	0.77	0.77	0.68	0.72
L.S.D 0.05		0.14				0.12
						I
I	I1	0.87	0.97	1.01	0.90	0.93
	I2	0.65	0.73	0.75	0.66	0.70
L.S.D 0.05		0.07				0.27
						T
	T0	0.71	0.79	0.87	0.74	0.77
	T1	0.80	0.88	0.93	0.81	0.86
	T2	0.76	0.87	0.88	0.79	0.83
L.S.D 0.05		0.10				0.06
S		0.76	0.85	0.88	0.78	
L.S.D 0.05		0.05				

3.1. Crop coefficient (Kc) and consumptive use consumptive use mm. season:

Knowledge of crop water requirement is necessary for agricultural water management and irrigation scheduling. This is directly related to an accurate estimation of crop evapotranspiration (ETc) and reference evapotranspiration (ETa). Table (4) shows the effect of sprinkler irrigation on consumptive use mm. Season it was compared to the surface irrigation in both seasons. It is clear from Table (4) that sprinkler irrigation in both seasons reduced the ETo, △S and ETa compared to the surface irrigation, respectively. This may be due to the lowest water use caused by sprinkler irrigation due to its uniform distribution of water droplets through the entire field which, in turn, maximizes the crop water _ use efficiency (Table 4). Tables 4 show the water balance equation factors for the different irrigation treatments for the wheat crop, it is noticed that there are noticeable differences in the values of actual water consumption ETa of wheat crop under different irrigation parameters, as the highest water consumption of wheat crop when surface irrigation treatment in 2016 was 557.5 mm in season-1, followed by surface irrigation treatment for the year 2017 by 535.9 mm, season-1. The treatment of sprinkler irrigation was 460.9, and it reached 442.6 mm for season-1 for the seasons 2016 and 2017, respectively. The reason for the difference in the actual water consumption values ETa is due to the depth of irrigation water used during the season at different irrigation treatments. Table (4) shows the water consumption of the plant, which resulted in a difference in the number of irrigation during the growing season, as it reached 13 and 14 irrigation treatments for surface irrigation for the seasons 2016 and 2017, respectively, and 16. And 17 litters for the sprinkler irrigation treatment for the seasons 2016 and 2017, respectively. The reason is that the actual water consumption of the surface irrigation treatment has reached its highest value because the moisture content is available to the plant in the depth that provides for its water needs, which led to an increase in the water consumption of the plant whose stomata are widely open allowing the loss of water by transpiration [20-22]. The rate of plant water consumption increases with the increase in the moisture content, in which the soil moisture is close to the field capacity.

3.2. Water consumption during growth stages

The figure of actual water consumption ETa for each stage of wheat crop growth for surface irrigation and sprinkling treatments for the years 2016 and 2017, as the water consumption in the tillering stage, reached 104.4, 99.3, 84.7 and 76.2 mm, with a rate of 3, 4, 4 and 5 irrigations for surface irrigation and sprinkling for the two years 2016 and 2017 respectively. The water consumption in the elongation stage was 119.6, 87.7, 113.8 and 102.4 mm for surface irrigation and sprinkler treatments for the years 2016 and 2017 respectively, at a rate of 4 irrigations. The actual water consumption in the flowering stage was 127.8, 118.4, 263.5 and 169.3 mm of total consumption. Total watery. The water consumption during the maturity stage reached 129.8, 118.6.4, 151.7 and 94.7 mm for surface irrigation and sprinkling treatments for the two years 2016 respectively, at a rate of 2, 3, 3 and 2 irrigations. Thus, it is evident that the highest water consumption was at the flowering stage.

3.3. Crop coefficient (Kc)

The crop coefficient is defined as the ratio of crop evapotranspiration (ETc) to references evapotranspiration (ETo). Thus (Kc) has been introduced as an important parameter for calculation crop evapotranspiration [23, 24]. Table (4) illustrates the effect of sprinkler irrigation on Kc in both seasons. The Kc was decreased at tillering, elongation, flowering and maturity stage in both seasons following the application of sprinkler irrigation which, in turn, improved the crop water _use efficiency (Table 4). Table 4 The relationship between evaporation ETO transpiration (mm day -1) depending on “climate information, using the Penman-Monteith equation, the ready-to-solve program for the Cropwatt equation and the water consumption ETa, sediment treatment, and station from soil moisture depletion [26]. Growth stages and irrigation treatments. The values ranged from 0.69 to 0.77 for the stage of germination, a total of 0.70 to 0.95 for the stage of growth, and they were from 1.11 to 1.48 for the staging of flowering, to decrease at maturity to the range of 0.60 to 0.96. From the results, the Crop coefficient values continued to increase from the branching stage to the beginning stage, flowering stage, then decreased in the physiological maturity stage, and for all treatments, irrigation management. Its value is a value for the Crop coefficient when spraying for the year 2017, the growing season because this varies according to the different stages of growth and climatic conditions and is also affected by factors that are affected by the area, the percentage of coverage, the upgrading, the tenderness, the vegetation and the age of the leaves. The values of the Crop coefficient are between 0.3 to 1.87, depending on Climatic data for the agricultural season. As for the decrease of the yield factor Kc in the stage of physiological maturity, while the values of the Crop Coefficient Kc increased in the early stages of growth, to focus on water consumption and evaporation, leading to higher ETa and ETO values[13, 27, 28].

Table 4. Effect of Irrigation methods, Tillage systems and seed level crop coefficient KC

Irrigation Treatment	Growth stage	Tillering	Elongation	Flowering	Maturity	Sum
Surface irrigation 2016	No. days	45	40	43	32	160
	No. irrigation	3	4	4	2	13
	ETa mm	104.4	119.6	203.7	129.8	557.5
	Eto mm	138.1	124.6	137.4	137.7	537.8
	KC	0.75	0.95	1.48	0.94	
	Percentage of water applied (%)	18.7	21.5	36.5	23.3	100%
Sprinkler irrigation 2016	No. days	45	40	43	32	160
	No. irrigation	4	4	5	3	16
	ETa mm	99.3	87.7	155.3	118.6	460.9
	Eto mm	138.1	124.6	137.4	137.7	537.8
	KC	0.72	0.70	1.13	0.86	
	Percentage of water applied (%)	23.9	24.3	26.8	25	100%
Surface irrigation 2017	No. days	45	40	43	32	160
	No. irrigation					
	ETa mm	84.7	113.8	185.7	151.7	535.9
	Eto mm	109.3	122.2	151.6	157.2	540.3
	KC	0.77	0.93	1.22	0.96	

Irrigation Treatment	Growth stage	Tillering	Elongation	Flowering	Maturity	Sum
	Percentage of water applied (%)	16.4	21	34.6	28	100%
Sprinkler irrigation 2017	No. days	45	40	43	32	160
	No. irrigation	5	4	5	3	17
	ETa mm	76.2	102.4	169.3	94.7	442.6
	Eto mm	109.3	122.2	151.6	157.2	540.3
	KC	0.69	0.84	1.11	0.60	
	Percentage of water applied (%)	17	23	38	22	100%

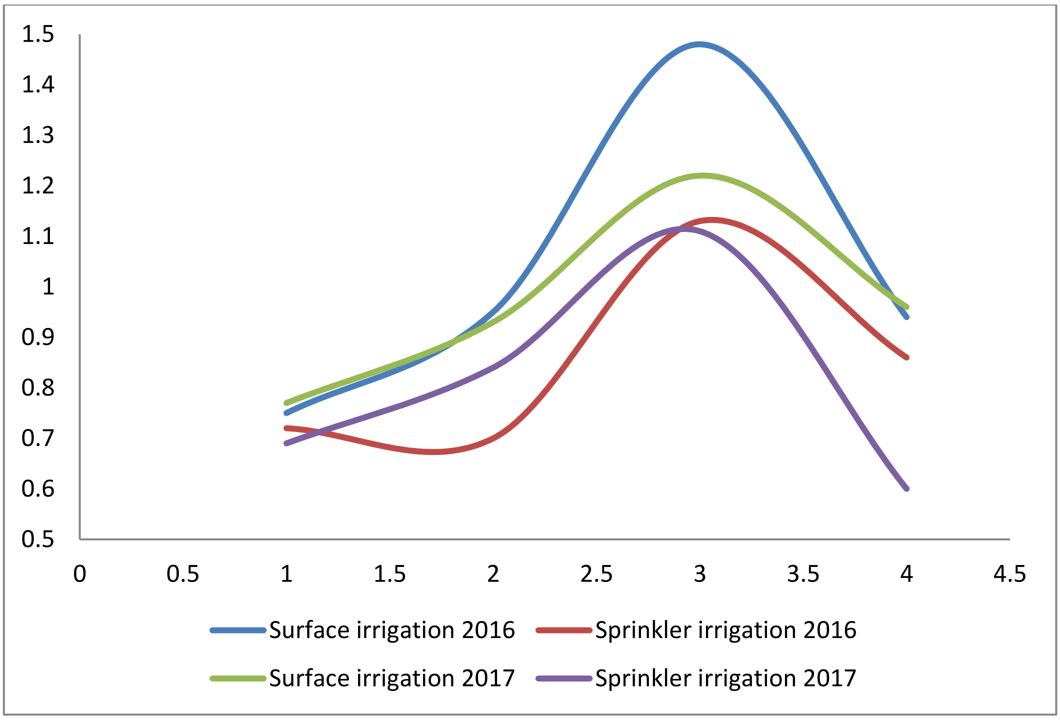

Figure 5. show the kc for each irrigation type

3.4. Biological yield (t ha^{-1})

It is clear from the table (5) that sprinkler irrigation (I_1) increased biological yield in both seasons by 9 and 10 %, respectively, over surface irrigation (I_2). Similarly, minimum tillage (T_1) increased the biological yield by 10.6, 10.2, 11.8 and 3.4% over zero and deep tillage in both seasons, respectively. Also, the seeding rate 240 Kg ha^{-1}(S_3) has increased this character by 15 and 16% over the lowest seeding rate (S_1)(120 Kg ha^{-1}) in both seasons, respectively. The highest biological yield 11.44 and 10.97 to^{-1} was obtained under the effect of sprinkler irrigation (I_1), minimum tillage (T_1) and seeding rate (S_3) in both seasons, respectively. This suggests that the three factors acted in a synergism action. The increased biological yield may be due to the increased crop – water use efficiency by 29, 32, 11.29, 11.16, 11.29 and 11.57% as influenced by sprinkler irrigation, tillage system and seeding rate in both seasons, respectively (Table 6). Many researchers found similar results as sprinkler method recorded the lowest water use than other methods due to uniform distribution of water across the field and consequently, water –use efficiency was maximized in the sprinkler irrigation. The same authors found that minimum tillage (reduced tillage) improved the water –use efficiency from 0.671 (in conventional tillage) to 0.773 Km^{-3} in reduced tillage[2, 29]. Soil tillage is among the essential factors affecting soil properties and crop yield[30, 31]. A four years trialing, indicated that minimum tillage had a significant influence on soil physical and chemical properties and yield of wheat compared to the conventional and deep tillage practices[30, 32, 33].

Table 5. Effect of Irrigation methods, Tillage systems and seed level Biological yield (t ha^{-1}): season(1)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	8.97	9.95	10.47	9.66	9.76
	T1	9.66	10.9	11.44	10.50	10.62
	T2	9.29	10.467	10.82	10.09	10.16
I2	T0	8.09	8.973	8.89	8.51	8.61
	T1	9.09	9.95	10.32	9.54	9.72
	T2	8.78	10.00	10.10	9.66	9.63
L.S.D 0.05		0.83				0.63
						I
I	I1	9.30	10.43	10.91	10.08	10.18
	I2	8.65	9.64	9.77	9.23	9.32
L.S.D 0.05		0.39				0.93
						T
	T0	8.53	9.46	9.68	9.08	9.19
	T1	9.37	10.42	10.88	10.02	10.17
	T2	9.03	10.23	10.46	9.87	9.90
L.S.D 0.05		0.64				0.53
S		8.98	10.04	10.34	9.66	
L.S.D 0.05		0.38				

Table 6. Effect of Irrigation methods, Tillage systems and seed level Biological yield (t ha^{-1}): season (2)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	8.49	9.35	9.92	8.88	9.16
	T1	9.15	10.39	10.97	9.83	10.08
	T2	8.78	9.95	10.34	9.44	9.63
I2	T0	7.61	8.45	8.40	7.85	8.08
	T1	8.61	9.43	9.83	8.89	9.19
	T2	8.3	9.48	9.61	8.65	9.01
L.S.D 0.05		1.26				0.85
						I
I	I1	8.80	9.89	10.41	9.38	9.62
	I2	8.17	9.12	9.28	8.46	8.76
L.S.D 0.05		0.90				

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
						T
	T0	8.05	8.90	9.16	8.37	8.62
	T1	8.88	9.91	10.40	9.36	9.64
	T2	8.54	9.72	9.97	9.04	9.32
L.S.D 0.05		0.72				0.40
S		8.49	9.51	9.85	8.92	
L.S.D 0.05		0.41				

3.5. Harvest index

Harvest index is defined as the ratio of grain yield to the biological yield. Table (7) indicates the effect of study factors on this character in both seasons. No significant impact of an irrigation system, tillage system and seeding rate on the harvest index in both seasons. However, the highest values of harvest index were 43.99 and 44.63% obtained under the influence of sprinkler irrigation, minimum tillage and lowest seeding rate (S1) compared to the lowest average 39.91 and 41.89% following the application of surface irrigation, deep tillage and highest seeding rate in both seasons, respectively[15, 34, 35].

Table 7. Effect of Irrigation methods, Tillage systems and seed level on Harvest index: season (1)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	42.07	41.75	41.61	42.98	42.10
	T1	43.99	42.18	42.55	42.55	42.81
	T2	43.29	42.4	41.86	42.51	42.51
I2	T0	40.47	40.62	41.96	41.51	41.14
	T1	41.39	40.94	40.97	41.36	41.16
	T2	40.88	41.55	40.98	39.91	40.83
L.S.D 0.05		4.15				2.65
						I
I	I1	43.11	42.11	42.00	42.68	42.47
	I2	40.91	41.03	41.30	40.92	41.04
L.S.D 0.05		2.58				3.03
						T
	T0	41.27	41.18	41.78	42.24	41.62
	T1	42.69	41.56	41.76	41.95	41.99
	T2	42.08	41.97	41.42	41.21	41.67
L.S.D 0.05		2.91				1.85
S		42.01	41.57	41.65	41.80	

L.S.D 0.05	1.62	

Table 8. Effect of Irrigation methods, Tillage systems and seed level on Harvest index: season (2)

Irrigation Treatment	Tillage Treatment	Seed level Treatment				I X T
		S1	S2	S3	S4	
I1	T0	42.85	43.39	42.91	43.62	43.19
	T1	44.63	43.29	43.46	42.03	43.35
	T2	43.93	43.57	42.84	42.07	43.10
I2	T0	42.35	43.75	42.99	42.41	42.87
	T1	42.43	42.97	44.20	42.21	42.95
	T2	43.23	43.05	42.85	41.89	42.75
L.S.D 0.05		2.82				1.80
						I
I	I1	43.80	43.41	43.07	42.57	43.21
	I2	42.67	43.25	43.34	42.17	42.86
L.S.D 0.05		1.64				1.07
						T
	T0	43.14	43.66	42.91	42.24	42.98
	T1	43.93	43.17	43.15	41.96	43.05
	T2	42.64	43.18	43.55	42.91	43.07
L.S.D 0.05		1.98				1.26
S		43.23	43.33	43.20	42.37	
L.S.D 0.05		1.023				

4. Conclusion

Results of the present study highlighted the importance of sprinkler irrigation is affecting some water parameters towards improving water _ use efficiency, reducing water _ use consumptive. Season and, hence, saving water. This was achieved via the combination of sprinkler irrigation, minimum tillage and moderate seeding rate. This might represent an excellent strategy to increase the biological yield which the grain yield is derived from it via increased crop water_use efficiency and decreased both consumptive use—season and crop coefficient.

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