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WHEAT CROP YIELD AND WATER USE AS INFLUENCED BY SPRINKLER IRRIGATION UNIFORMITY

Hani A. Mansour[1]*, Mohamed Abd El-Hady[1], Ebtisam I. Eldardiry[1] and A. M. Aziz[2]

[1]Water Relations and Irrigation Field Dept., National Research Centre, Dokki, El- Behouth St., Cairo 12622, Egypt.

[2]Soil and Water Use Dept., National Research Centre, Dokki, El- Behouth St., Cairo 12622, Egypt.

Corresponding author: mansourhani2011@gmail.com

Abstract

In this work, an assessment of the effect of distribution uniformity over water use efficiency is shown. The experimental study took place in Field experiment was carried out in the Experimental Research Station of Nubaria, during winter seasons of 2016/2017, which characterized by semi-arid climate and interested a wheat field. The present study is carried out to determine the relationship between pressure head and discharge for a given set of sprinkler irrigation system. An experimental set of 8m x 8m grid of sprinklers is examined for the discharge and pressure head relationship for different pressures (1.8 tell 3.0 bar). The relationship developed is non-linear.

Obtained results indicated that minimum and maximum discharges observed are 0.105, 0.125 m^3/h at pressures 1.8, 3.0 bar respectively. It can be concluded that discharge is directly proportional to head loss raised to power m. The power m varies from 1.07 to 1.24 for a given set of sprinkler irrigation system. The results of consumed of irrigation water in the sprinkler irrigation system with respect to the operating pressure (P) is reported with respect to distribution uniformity and water use efficiency. The results emerged in this work can be useful for similar arid regions, in order to overcoming the problems related to water scarcity. So, the best operating pressure were 2.8 and 3.0 bar and comparison between them should depend on consumed energy in operation. Operating pressure more than 2.8 bar has an positive effect on the irrigation uniformity, defined through the coefficients CU, DU and were studied. The best operating condition observed was operating pressure 2.8 and 3.0 bar, respectively, which corresponds to a water pressure of 3 bar and a sprinkler spacing 8X8, that gained the highest CU and DU values were obtained, and such effect affected also the grain yield GY, the wheat crop and water use efficiency WUE. Also, these results are in good accordance with those present in the dedicated literature. For arid regions characterized by environmental conditions comparable to the experimental site (Nubaria), it is recommend operating the solid set sprinkler irrigation system at the high operating pressure to achieve a positive effect over grain yield and WUE.

Keywords: wheat, distribution uniformity, water use efficiency, sprinkler irrigation, saving water.

Introduction

Irrigation is the limited factor in agriculture crop production that contributes in food security. Great efforts have been made in the past decades to increase the irrigated area with the same water income. Promiscuous, unscientific and inefficient use of water over the years has led to undesirable effect threatening long term sustainability of agricultural production. The surface methods of irrigation cause uneven distribution of water loss affect the land and crop productivity. Additional food grain production from the existing irrigated area need to maximize output crop production per water unit (Abd-Elmabod *et al*., 2019; Eldardiry *et al*., 2015; El-Hagarey *et al*., 2015; Goyal and Mansour, 2015; Ibrahim *et al*., 2018 and Mansour *et al*., 2019a,b, Mansour, 2015; Mansour *et al*. 2014, 2016a-c, 2015a-f).

Available water appeared as the most important factor limiting wheat crop yields under the semi-arid condition. The amount of grain yield produces per water use increased with the increase of availability of soil water and consequently water used efficiency increased (Chennafi *et al*., 2006). So, development of the irrigation sector and improvement of its planning system as part of the small-scale irrigation project activities are a big challenge for the government of Egypt. Furthermore, according to Hajare *et al*. (2008), knowledge of exact amount of water required by different crops in a given set of climatological condition of a region is great help in planning of irrigation scheme, irrigation scheduling, effective design and management of irrigation system. Indeed, the reference ET is an important quantity for computing the irrigation demands for various crops (Chowdhary and Shrivastava, 2010).

A sprinkler irrigation system represents one of the most common types of irrigation system. In many areas, the water and energy required for irrigation are scarce; hence, sprinkler irrigation systems must apply water with less energy consumption. This generally requires an improvement in the application of water (Martin-Benito *et al*., 1992). The improvement of irrigation water management is becoming critical to increase the efficiency of irrigation water use and to reduce irrigation water demands. The field evaluation of sprinkler irrigation systems is essentially required for standing the efficiency and performance of the system during operation. Sprinkler irrigation is becoming a preferred method for cereal crop cultivation as the water available for irrigation around the world becomes increasingly scarce, especially in arid and semi-arid regions like Egypt, which is normally used under more favorable operational conditions (Montazar and Moridnejad, 2008). The increase in water scarcity and wrong dimensioning of irrigation systems has threatened the viability and sustainability of agricultural production (Khatri *et al*., 2013). Whereas, increasing productivity rates with profitability under farming systems pass through good management of both water and soil resources. Thereby, improving the use of resources has become a challenge for irrigators who, by the necessity of prioritizing the application of water more accurately, need to know the main characteristics of the equipment to be used, to prepare them for better use in field conditions (Martins, 2011 and Martins *et al*., 2012).

Efficient use of water and energy are the basic requirements of sustainable agriculture and for arid and semi-arid regions the problem of water scarcity is even more relevant, (Mansour and Aljughaiman 2012, 2015, Mansour and El-Melhem 2012, 2015; Attia *et al*., 2019). They added that efficient use of water to maximize agriculture crop production is a must. The efficiency of a sprinkler irrigation system, which needs to be improved in many areas of the world, both in terms of water management and water application (Tarjuelo et al., 1992), depends mainly on the various water losses that take place from the sprinkler nozzle until the point that water reaches the root zone (Uddin et al., 2013).

Evaporation losses in sprinkler irrigation contain canopy evaporation, soil evaporation and droplet evaporation, which is considered the main source of loss. Water distribution under sprinkler irrigation system is function of design and operational (Keller and Bliesner, 1990). It is impossible to gain a good uniformity in irrigation as parts of the field will be either over or under irrigation (Haman et al., 2003), and low DU has manifest to decrease yield due water stress. Meanwhile, excessive irrigation can adversely enhance nutrients leaching out of the soil. According to Naeem and Rai (2005) water shortage requires developing new technologies and methods of irrigation that can be helpful to utilize this precious input in an effective way. In addition, there is also a need to carry out practices of irrigation water management to achieve high water use efficiency and to increase the productivity of existing water resources and to produce more food with less water (Bharat, 2006).

The aim of this study is to evaluate the impact of some parameters characterizing a sprinkler irrigation system on barley crop yield and water use efficiency, after having assessed the sprinkler irrigation uniformity.

Materials and Method

Field experiment was carried out in the Experimental Research Station Farm (ERSF) of Nubaria, during winter seasons of 2017/2018, which is located in west east of Egypt, at 27°01’ north latitude and 14°26’ east longitude. Considered area is a Mediterranean zone with homogeneity and deep soil profile. Its climate is characterized by long hot dry summer and short cool rainy winter typical of sub-arid region, defined as "Arid Mediterranean". Monthly temperature varied between 15 and 27.5 ^{o}C, wind speed averaged at 14.3 km/hr, and the average annual rainfall about 124 mm. The main source of irrigation water in the area is canal water. The experimental soil appeared mostly sandy (84.50 sand, 10.25 silt and 4.25% clay). Soil classified as Typic Torripsamments as Silty loam. The surface soil sample (0-20 cm) of the experimental area was subjected to the different laboratory analysis to determine some physical and chemical properties according to the standard methods (Rebecca, 2004).

The chemical and physical properties of the study soil were estimated. Values of the soil pH (1:2.5), Soil EC (extracted soil paste), $CaCO_3$, OM and soil exchangeable capacity were 8.05, 1.82 dS m^{-1}, 3.6 %, 0.28 % and 7.47 CEC meq/100 g soil, respectively.

Hydraulic conductivity (HC) was measured for undisturbed samples in the laboratory (12.3 cm h^{-1}) under a constant head technique (Klute and Dirksen, 1986) using the following formula: HC = (QL)/(At ΔH)

Where: HC: water quantity flowing through saturated soil sample / unit time, Q: volume of water flowing through saturated soil sample per unite time (L^3 t^{-1}), A: cross sectional flow area (L^2) L: length of the soil sample and ΔH: differences in hydraulic head across the sample (L) and t: time (hr). Soil water retention at 0.1 (field capacity) 15.0 (wilting point) bars and available water were 13.2, 5.6 and 7.6 % on weight basis after Klute (1986).

A solid set sprinkler system was used to investigate the effect of operating pressure P (1.8, 2.0, 2.2, 2.4, 2.6, 2.8 and 3.0 bar) and distance between sprinklers (8x8) on irrigation uniformity and then wheat crop yield and water use efficiency. The discharge from the sprinkler jet was measured volumetrically by placing two flexible hoses over the sprinkler nozzles and receiving the flowing water in a calibrated container relatively to the measured time.

Sprinklers are subjected to six different pressures.

The water supplied for the experiment is a closed loop and regulated from the pump. Irrigation water is supplied from a tube well. The water collected in the containers is measured with the help of measuring cylinder.

The collected water depth was calculated by dividing the volume caught by the open area of each catch-can. Uniformity coefficients are used to quantify uniformity of water distribution resulting from the catch cans data. In this study the coefficient of uniformity CU, the low quarter distribution uniformity DUlq, and the coefficient of variation CV were used. Cu depends on the amount of water collected by each singular catch can; given n catch cans distributed over the field, CU is given by(ASAE, 2001):

$$CU = \left[1 - \frac{\sum_{i=1}^{n}|d_i - \bar{d}|}{n \times \bar{d}}\right] \times 100 \quad [\%] \qquad (1)$$

Where is the depth of water collected in the collector, [mm] is the average water collected . The low quarter irrigation distribution uniformity DU is usually defined as the ratio of the smallest accumulated depths in the distribution and the average depths of the whole distribution and is calculated using the following equations.

$$DU = \frac{ADC_{lq}}{\bar{d}} \times 100 \quad \% \qquad (2)$$

Where [mm] is the average water depth collected by the 25% of the catch cans that collected the least amount of. Generally, a negative correlation between DU and the operating pressure P is verified (Tarjuelo *et al*., 1999). Note that CU and DU give complementary information: empirical evidences confirm that uniformity is increased when their values are closer (Ortiz *et al*., 2010).

Planting and fertilization, seeds of wheat (*Triticum aestivum* L. /seds 1) were planted on 1/05/2017, in the form of the lines between the line and the last 20 cm seeds were added at a rate of 140 kg seeds. Nitrogen fertilizer was added to experimental units at a rate of 200 kg urea (46% N).

The quantity was divided into two equal batches, the first after planting, up to three weeks, and the second at the beginning of the forest. Superphosphate fertilizer was added by 100 kg P_2O_5 e1-one batch before smoothing. Potassium fertilizer was added in potassium sulfate form K_2SO_4 (41.5% K). Potassium fertilizer was divided by four equal batches according to plant growth stages, elongation, flowering and maturation.

Moisture Measurement and Water Management: The first irrigation (Germination Irrigation) was applied until saturation limits to be available soil moisture for encourage seeds germination. The sequent irrigation was applied during the growing season on the basis of moisture depletion of 0.30 m depth. Soil moisture was monitored on a weekly by the gravimetric method (weight basis).

Water productivity was determined by dividing grain yield by evapotranspiration as following (Howell, 2003) Where: WP = Water productivity (Kg m-3) GY = Grain yield (Kg / ha) ET = Corn total water consumption of the growing season (m3/ha) Productivity of irrigation water was calculated as (Howell, 2003)

Where: PIW = Productivity of irrigation water GY = Grain yield (Kg / ha) I = Irrigation water applied (m3/ ha) Crop coefficient (Kc) According to the yield coefficient (Kc) of wheat yield from the following equation (Allen et al., 1998) Kc = ETa / ETo , where: ETa: Actual evaporation-transpiration (mm) ETo: Evaporation-Nectar Reference (mm) Kc: Crop coefficient (without units) (Coefficient of response (Ky)was calculated as (Stewart et al., 1977)

Ky = (1-Ya / Ym) / (1-ETa / ETm).

Where: Ky = response coefficient. Ya= Actual production (ton / ha), Ym = the highest production at the highest evaporation-nit (ton / ha ETa =evaporation-actual transpiration (mm ETm = Evaporation - Maximum Nucleus (mm 1-Ya / Ym = the percentage of the decrease in the sum

Wheat grains were planted on the 3rd of November 2016 (75-80 kg fed $^{-1}$), urea 46% N was applied. Irrigation process was carried out weekly using the amounts of IWA (Irrigation Water Applied) index, which was calculated according to Eq.(4). [m^3] (4)Where A [m^2] is the plot area, [days] is the irrigation intervals, LR [m^3] is the leaching requirement,= 15% is the application efficiency characterizing a typical sprinkler system, [mm days^{-1}] is the gross water requirement adjusted by the crop coefficient [%] is the crop coefficient.

According to Allen *et al.* (Allen *et al.* (1998), crop coefficients of wheat equal to 0.30 initial, 1.15 mid and 0.25 late season stage were used. An average was estimated using the monthly mean weather data for a 15-year period (January 1994 –December 2008) recorded at ERSF station.

The monthly average calculated was 3.88 for December, 3.69 for January, 4.73 for February, 7.14 for March and 9.86 for April. After harvest, the WUE (water use efficiency) was estimated, in terms of grain yield per cubic meters of water applied, to the Jensen (Jensen, 1983):

WUE (WP)= GY/WR (kg m^{-3}) Where GY [kg] is the grain yield. At harvest, 3 units of 36 were randomly taken from each sub-plot to determine averages for grain yield GY.

Generally, the climate in this region is classified as arid, and the climatological data measured at the experimental site during this study period are provided (Table 1). The field experiments consisted of two irrigation methods and three different irrigation levels.

Statistical analyses

The experimental design was a split plot and an analysis of variance was performed to analyze the data. The LSD test (P < 0.05) was used to compare treatment means. The CoHort software program version 6.311(2005) was used for all the statistical analysis.

Results and Discussion

The results in Table (1) show the depth of the added water and the actual water consumption during the wheat crop growth season for the complete irrigation treatments (I0) and the deficient irrigation for the winter season 2017-2018. The total irrigation treatment showed the highest water value added to complete irrigation it was 430 mm for the season and was reduced to 356, 388, 371 and 353 mm for the deficient irrigation treatments (I1, I2, I3 and I4) Which is higher than the rest of the deficient irrigation treatments, due to the fact that the irrigation water additions were higher in the irrigation treatment due to the increase in the number of irrigation, which amounted to 12 number of irrigation while the irrigation limited to 10, due to the increase in the consumption rate. The plant is waterproof by increasing moisture content of the soil as a result of increasing the amount of irrigation water added (20.7%, 10.8%, 15.9%, and 21.8%) for deficient irrigation treatments at the tillering, elongation, flowering and grain maturity levels, respectively, compared with the complete irrigation treatment, and these results are consistent with (Abedinpour, 2017 and Hassan, 2018) he found Elongation, flowering and grain growth have reduced the water requirements of the plant and provided an important amount of irrigation water amounting to 11-14% compared to the full irrigation treatment 431 mm.

Field features and evaluation of irrigation practices

Solid sprinkler irrigation systems were installed. These systems were evaluated and found to be capable to achieve high performance and water uniformity for irrigated area. Irrigation systems were equipped with controllers to control the pressure by using pressure regulators, and flow meters to measure the amount of water applied in each irrigation event. This sprinkler system has been designed and installed for each field plot with PVC laterals, and were connected to the sub main and main pipes. The sprinkler heads were fitted on the top of the sprinkler risers, which were galvanized steel pipes. The field evaluations of sprinkler system were carried out. Uniformity index values were found to be within acceptable results and representing good water distribution uniformity.

Wheat evapotranspiration

Average of daily and weekly *ETc* rates for wheat crops in experiments during growing seasons were calculated from daily records (Table 1). Table 1 shows that the *ETc* determined from the *Kc* multiplied by *ETr* for different stages of wheat crop development. The average weekly wheat *ETc* throughout growth period of the two seasons was obtained and recorded for both treatments.

From Fig. 1 the average total amounts of irrigation water applied during the two seasons for wheat in SIS treatments (100% of *ETc*, 80% of *ETc*, and 60% of *ETc*) were 528.89 mm, 444.77 mm and 317.33 mm, respectively.

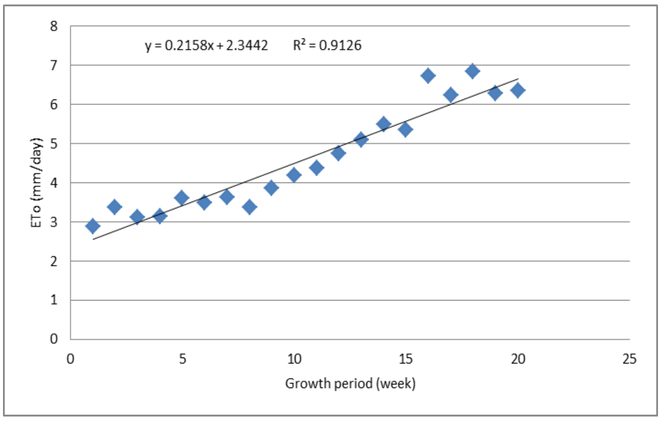

Fig. 1: Relation between growth period by week and evapotranspiration (ETo) by mm/day of wheat crop

The uniformity coefficient of a sprinkler irrigation system has a direct effect not only on the system's application efficiency, but also on the crop yield (Li and Rao, 2000). Without good uniformity, it is impossible to irrigate efficiently as parts of the field will be either over-irrigated or under-irrigated (Haman *et al*., 2003).

Effect of pressure on sprinkler irrigation uniformity

Data in table (1) showed the relation between operating pressure and sprinkler and wetted area parameters (discharge, diameter, wetted area, calculated and actual precipitation rate and overlap percentage). Data on hand revealed that increased operation pressure associated with increasing in most studied parameters. Also, data noticed that the most suitable operation pressure that fulfill the work objective were 2.8 and 3.0 bar with increasing percentage 15,39,93,60; 15 % and 19, 51, 151, 52 and 19 % for Q, D, A and actual and calculated precipitation as comparing with normal operating pressure (1.8 bar), respectively. From the above mentioned data (Table 1 and Fig. 1). So, the best operating pressure were 2.8 and 3.0 bar and comparison between them should depend on consumed energy in operation.

With respect to the effect of operating pressure with actual and calculated precipitation rate, data in Table (1) indicated that actual precipitation rate was higher than calculated on by 53, 36 and 27 % than for 1.8, 2.0 and 2.2 bar while the opposite was true in case of 2.4, 2.8; 3.0 bar were the percentage -1, -21 ; -33, respectively. This result there is homogeneity between calculated and actual rate till 2.4 and 2.8 with correction factor.

Table (1) Effect of sprinkler operating pressure on the wetted and precipitation rate.

	Operating pressure (bar)					
	1.8	2.0	2.2	2.4	2.8	3.0
Q (m3/h)	0.105	0.11	0.11	0.12	0.12	0.13
D (m)	8.20	8.70	9.00	10.20	11.40	12.40
Area	52.78	59.42	63.59	81.67	102.02	120.70
Precipitation rate (mm/h)						
individual	1.99	1.83	1.79	1.46	1.19	1.04
equation	1.30	1.35	1.41	1.47	1.49	1.54
Overlap %	-8.9	-3.3	0.0	13.3	26.7	37.8

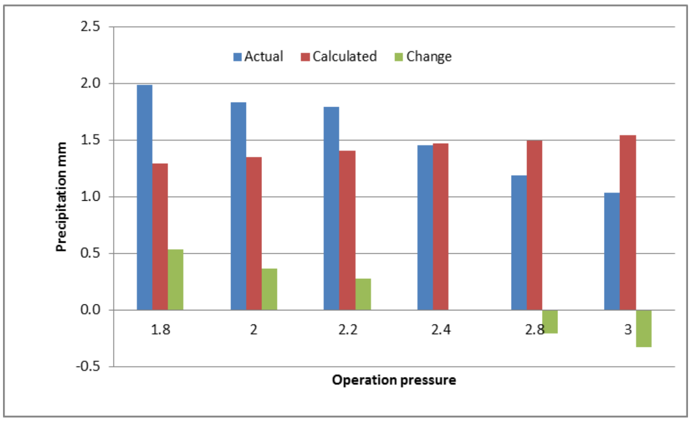

Fig. 2: Effect of sprinkler operating pressure on the sprinkler discharge and diameter of wetted area.

Note that these trends are in accordance with Suharto and Susanawati (2012), who reported that to get good irrigation uniformity in the sprinkler irrigation operating pressure might be ranged 2 and 3.5 bar. This result is in full agreement with (Moazed *et al*, 2010). In

Effect of riser height (H) on sprinkler irrigation uniformity

About riser height H, CU and DU values were increased with increasing H, as shown in Table 2. CU values increased by 6.12% and 10.15% when H1 was increased to H2 and H3, respectively. However, the highest and the lowest values of CU were recorded at H3 (88.69%) and H1 (80.52%), respectively. This result was due to larger water amounts that some soil points received, whereas water distribution at other points was very scarce

Effect of operation pressure on grain yield, plant height and water use efficiency

In good accordance with Dechmi *et al*. (2003), who argued that, CU has a direct effect on GY. In contrast, 1.8 bar recorded the lowest CU, 78.21%. At this regard, Haman *et al*. (2003) stated that, without a good uniformity, it is impossible to irrigate efficiently, as parts of the field will be either over-irrigated or under-irrigated, with a consequent negative effect over GY.

WUE was significantly affected by different operating pressures and riser heights, as reported in Table 4(c). WUE values calculated in this work were 0.48, 0.52 and 0.59 kg m^{-3} for D1, D2 and D3 diameter, respectively, and 0.39, 0.52 and 0.68 kg m^{-3} for 1.8, 2.2 and 3.0 bar, respectively. The highest WUE value, 0.75 kg m^{-3} was obtained when P3-H3 treatment was applied, while the lowest result, 0.36 kg m-3, was recorded at P1-H1. In conclusion, without achieving a good uniformity in irrigation, the reduced crop negatively reflected in WUE. Therefore, it is recommended to operate sprinkler system at 2.8 to 3.2 bar to obtain the highest WUE value, which is in direct correlation with CU, GY and plant height values.

There is an urgent need to improve WUE in crop production and promote sustainable use of water resources. To improve WUE on the basis of increasing crop yields, there must be a proper irrigation scheduling strategy that has been well studied and widely practiced for improving crop yield and/or increasing irrigation water use efficiency (Kang et al., 2002)

Sprinkler operating pressure and wheat yield

In order to conserve water resources, close attention has to be paid to the performance of irrigation systems. The irrigation system must also be managed correctly and effectively. The distribution uniformity of a system must be as uniform as possible to ensure higher yields and the efficient application of water. It should also be included in the calculation of water allocations and the determination of gross irrigation water requirement. The results of the study conducted show that more attention needs to be paid to the distribution uniformity of an irrigation system.

Both operating pressure and riser height will affect uniformity which will consequently affect GY and PH. Data presented in Table (2) show the effect of operating pressure and riser height on grain yield (GY) and plant height (PH). H3P3 treatment recorded the highest values of GY and PH (5.50 t ha^{-1} and 63.49 cm, respectively) as compared with other treatments. Meanwhile, H1P1 collected the lowest values for previous parameters 2.63 t. ha^{-1} and 38.82 cm, respectively. In this concern, Li and Rao (2000) and Dechmi *et al.* (2003) indicated that the uniformity coefficient of a sprinkler irrigation system has a direct effect on the crop yield. In contrast, H1P1 recorded the lowest CU (78.21%). Haman *et al.* (2003) proved that, without a good uniformity, it is impossible to irrigate efficiently; parts of the field will be either over-irrigated or under-irrigated, and consequently the reduction in yield will be obtainable.

To improve the distribution uniformity of irrigation systems they need to be properly maintained and operated. Especially, overhead irrigation systems need to be operated at the correct pressure and in low wind conditions. The results also show that a well-maintained and correctly operated system can achieve or exceed a distribution uniformity that is considered reasonable and acceptable. An irrigation system can have high application efficiency and have poor DU. Even though the water is being used efficiently, with minimal spray and/or evaporation loss, large areas of the crop may not be receiving an adequate amount of water. This could lead to crop stress and reduced yields. Therefore the importance of the uniformity should not be ignored. It is only possible to achieve high application efficiencies with minimal under-irrigation if the DUs are high (Mansour et al., 2018).

Figure (2) showed that irrigation coefficients did not cause a significant decrease in grain yield and in all stages of growth compared to complete irrigation treatment, except irrigation treatment during the elongation period, in which the yield decreased significantly and achieved a mean average yield of 4.043 tons. The decrease was 8%, 20.8%, 14.2%, and 12.2% for irrigation cuttings during the stages, elongation, flowering and grain maturity respectively, compared with the complete irrigation treatment which achieved the highest average of 4.885 $ton.ha^{-1}$. The decrease in the elongation phase is due to the fact that the water stress reduced the number of spikes per square meter, the number of grains per spike and the weight of the grain, because at this stage the development of the branches bearing Spike is determined as well as the emergence and development of the saplings. The water pressure can also reduce the number of grains in the spike (Abdul-Jabbar *et al*., 2016)

Water use efficiency crop and field ($kg.m^{-3}$)

Table (2) showed the results of water use efficiency of field and crop calculated during the stages of wheat growth and the effect of irrigation treatments, where the efficiency values of field and crop water use were different.

This is because the quantity of water requirements added to the field is not equal to the actual water consumption of the crop and to all the full and deficient irrigation treatments due to the contribution of ground water to evaporation values. The irrigation treatment during the tillering phase gave the highest value for the efficiency of field and crop water use of 1.27 and 1.16 ($kg.m^{-3}$). The irrigation treatment during the elongation phase gave the lowest value of the field and crop water use efficiency of 1.04. 0.96 ($kg.m^{-3}$).

Also, the efficiency values of field and crop water use for irrigation deficient irrigation during the tillering stages and grain maturity are greater than their values for complete irrigation, elongation and flowering treatment irrigation. The reason was that the plant was not exposed to water stress and did not significantly affect the grain yield, which showed the results in Table (2). There were no significant differences between the complete irrigation and the deficient irrigation except for the irrigation treatment during the elongation phase, thus increasing the efficiency of field water use and crop. This finding was consistent with (International Telecommunication Union. 2015) and Brihma et al (2011) found that increasing the irrigation led to a reduction in water use efficiency, while irrigation at the sensitive elongation stage gave the lowest value for field and crop water use efficiency. The reason might be that under larger irrigation amounts soil surface was wetter which promoted higher soil evaporation. Generally with the increase in irrigation, evaporation was increased. But the evaporation beneath wheat canopy among the different irrigation level was similar between stem elongation and maturation for the plant factors (Mansour et al., 2016c).

Data in Table (1) showed the relation between sprinkler operation pressure (1.8, 2.0, 2.2, 2.4, 2.6, 2.8 and 3.0 bar) and sprinkler discharge (m^3/h), maximum distance (m), covered area (m^2), individual and calculated from equation of precipitation. Obtained data indicated that the maximum and minimum values of the discharge was attained under 3 bar and 1.8 bar, respectively. Same trend was attained for covered area diameter and covered area. Respecting to the precipitation values, data on hand revealed that that there were a negative effect of the pressure on the absolute covered area, where the opposite was true in case of computed one.

Table (2) effect of the studied sprinkler operation pressure and wheat plant characters

P	PL (cm)	No. of Spike m^{-2}	SL (cm)	Bio Y	Grain Y	Harvest Index	WUE
1.8	76.7	245.5	9.8	4.341	1.751	0.40	1.46
2.0*	76.7	208.0	9.0	4.236	1.536	0.36	1.28
2.2	75.2	249.3	9.7	4.897	1.590	0.32	1.33
2.4*	79.7	276.3	9.3	4.985	1.650	0.33	1.16
2.8*	87.8	288.3	9.5	5.105	1.710	0.33	1.11
3.0	93.5	291.3	9.8	5.185	1.715	0.33	1.02
LSD 5%	2.1	11.3	0.1	0.125	0.089	0.06	0.02

*: estimated from equation, P: Operation pressure, PL: plant length, SP: Spike length, Bio Y: biological yield, WUE: water use efficiency

Calculated Precipitation (Individual) = discharge/ area

Precipitation = (discharge x1000)/dimension (9x9 m)

Conclusions

Operating pressure more than 2.8 bar has an positive effect on the irrigation uniformity, defined through the coefficients CU, DU and were studied. The best operating condition observed was 2.8 and 3.0 bar, which corresponds to a water pressure of 3 bar and a sprinkler spacing 8X8. Under these conditions, the highest CU and DU values were obtained, and such effect affected also the grain yield GY, the wheat crop height and water use efficiency WUE. Also, these results are in good accordance with those present in the dedicated literature. Therefore, for arid regions characterized by environmental conditions comparable to that of Nubaria, it is recommend to operate the solid set sprinkler irrigation system at the high operating pressure in order to achieve a positive effect over grain yield, crop height and water use efficiency.

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