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Drip irrigation management for wheat under clay soil in arid conditions

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ABSTRACT

Uneven water distribution, misuse of water and inefficient watering techniques are some of the major causes playing devastation with water security, therefore, the aim of this work was to explore managing drip irrigation of wheat grown under heavy soil conditions as a tool for increasing crop yield, enlarging water productivity and saving irrigation water for newly reclaimed areas. A field investigation was conducted to study the impact of drip irrigation lateral arrangements (single and double lateral line a bed) and irrigation intervals (4-, 8-, and 12-days) on yield and water efficiency of wheat. Results revealed the grain yield was marginally influenced by irrigation intervals under double and single line a bed. As well, the grain yield got at 8- and 12-day intervals with double lateral line (8.28 and 7.62 Mg.ha^{-1}, respectively), were higher compared with 4-day and the less grain yield was achieved by surface irrigation (control). Distributing water and salts were better under double lines a bed compared to single line under the same irrigation intervals. The highest value of water use efficiency of grain yield was 7.4 at 8-day followed by 6.62, 5.50 and 1.58 kgm^{-3} for 12-, 4-day and surface irrigation, respectively performed for double lines a bed with water saving 6.7% and 65% compared to 12-day and surface irrigation respectively.

1. Introduction

Egypt faces a challenging on decreasing water availability and the area of arable land mentioned for wheat production (Boutros 2013). Most small farmers (those with the land property of one ha or less) cultivate their soil (including straw) for consumption purposes, selling the excess for income generation (RISE 2014). Small farmers are represented by the 70% of Egypt's poor living in rural areas (IFAD, 2012). Otherwise, field application efficiency in most traditional irrigation methods is still low and often as low as 30% (Molden 2007). Excessive application of water entails losses because of surface run-off and deep percolation below the root zone within the area and both of them difficult to control under the surface irrigation, where a large volume of water is applied at a single instance.

According to FAO (2012), the area of cultivated wheat in Egypt is 1.34 million hectares and the yield that comes out of it is 6.6 Mg.ha^{-1}, resulting in a total wheat production of around 8.8 million tons and domestic consumption was 19 million tons. In 2010, according to the FAO, Egypt imported 10.6 million tons of wheat as well as the use of the domestic production (Boutros 2013).

Bashour and Nimah (2004) revealed that trickle irrigation saves around 50 percent of the water used as a part of surface water. Aujla et al. (2007) revealed a saving of 25 percent water on trickle irrigation as contrasted furrow irrigation. Ibragimov et al. (2007) analyzed trickle and furrow irrigation, acquiring that 18–42% of the irrigation water was saved with drip systems and the water use efficiency (WUE) expanded by 35–103% contrasted with furrow irrigation.

The shape and the total volume of the wet soil beneath a diaper change with hydraulic parameters of the soil, number of drippers, release rate and irrigation frequency. It needs to be settled so the crops could be provided with a satisfactory wet soil volume to meet their water needs (Kao and Hunt 1996; Al-Qinna and Abu-Awwad, 2001).

Particularly in drip irrigation, distributing salts that dissolved in the soil profile follows the shape of the water flux with the tendency to aggregation at the fringe of the wet soil volume, and the salt collection is much greater near the surface than at the deeper layers and increases with distance from the emitters (Wang et al., 2011).

The aim of this work was to examine the issue of irrigation treatments (single and double drip lateral lines a bed) and irrigation intervals on soil moisture and salt distribution patterns, vegetative growth, yield and WUE of wheat (Triticum aestivum (vulgar)).

2. Materials and methods

2.1. Site description

To achieve the objectives of this study, two years field experiment was conducted in a private land at Village Damalo, Banha, Kalyobia

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Table 1
Mechanical and chemical analysis of the experimental soil.

Clay%	Silt%	Sand%	Texture	pH	FC %	EC $dS.m^{-1}$	$CaCO_3$ g/kg	O.M g/kg	Available (mg/kg)		
									N	P	K
50	27	23	Clay	7.9	36	0.5	14.1	15.3	22.5	9.1	120

Trace elements*	B	Fe	Zn	Mn	Cu	Cd	Ni	Pb
Total content (ppm)	13.15	49574	87.73	929	63.65	0.14	60.5	9.16

* Aqua Regia was used to digest soil sample for total contents of the investigated trace elements (Cottenie et al., 1982).

Governorate, Egypt, which located at latitude 31° 27‘ N and longitude 31° 10‘ E during the growing seasons of years 2015 and 2016 in winter season. The growing season for wheat extends from mid-November to early May. The dominant soils of the experimental site are described in Table 1.

2.2. Irrigation system description

Polyethylene (PE) laterals of 16 mm outer diameter with 18 m length, which has built-in drippers with a discharge of 4 Lh^{-1} and 30 cm spacing at 100 kPa operating pressure were installed at 130 cm distance of apart in treating single lateral line a bed and at 65 cm apart in the treatment of double line a bed. The irrigation interval treatments were 4-, 8- and 12-day. Each plot had the needed volume of applied water according to the water needs of wheat based on Central Laboratory for Agricultural Climate (CLAL) data. The irrigation time for double line treatments was half the calculated time for single line.

The trial was arranged in a split plot design with two drip irrigation lateral arrangements (single line a bed and double line a bed) in the main plots and three drip irrigation intervals (4-, 8- and 12-day) in subplots with four replications, making up a total of 24 plots (12 with single line a bed and 12 with double line a bed) plus 4 plots as a control (surface irrigation) as shown in Fig. 1.

The experimental plots were planted with wheat (Giza 168) on November in the two successive seasons 2014 and 2015. The soil was prepared and planted at a seed rate of 125 kg ha^{-1}. The harvest was done on May 6th at 2015 and 2016, after 180 days from the sowing of wheat. Yield, yield components, and plant characteristics were assessed. The maturity data were collected on grain yield, straw yield and harvest index to assess wheat crop phenology and evaluate the effects of irrigation treatments on it.

2.3. Crop water requirement

Daily evapotranspiration (ETo) values were obtained from CLAC expected data which always available 5 days in advance. Kc for wheat during the growing season was got from FAO (2001). The got ET_0 and Kc were used to calculate water requirements for wheat under drip irrigation (m^3 ha^{-1}/irrigation) by Eq. (1) of Keller and Karmeli 1975:

$$IW_1 = \left[\frac{ETo \times Kc \times Kr \times I_1}{Ea_1} + LR\right] \times 10 \quad (1)$$

Where:

IW_1 = Irrigation water applied under drip irrigation, m^3 ha^{-1}/irrigation.

ET_0 = Reference evapotranspiration (mm day^{-1}).

Kc = Crop coefficient.

Kr = Reduction factor

I_1 = Irrigation intervals with drip system, day.

Ea_1 = Irrigation efficiency of drip system, %.

LR = Leaching requirement (10% of the total amount water), $m^3.ha^{-1}$/irrigation.

For the control experiment (surface irrigation), it was irrigated by a farmer as a traditional method that used in the location. A digital water meter was used to measure the consumed water for each irrigation. The irrigation intervals for the control were decided according to the farmer experience. This experiment was carried out to measure the total water requirements for the traditional method, the total yield and calculate the water use efficiency (WUE).

2.4. Soil moisture distribution

Soil moisture distribution "SMD" was resolved by Liven and Van Rooyen (1979). Samples were taken at three points (each one-third) along each lateral by using the auger after irrigation throughout the season from perpendicular to the lateral line, at 0, 15 and 30 cm from the emission point throughout the root zone at depths of 0 − 20, 20 − 40 and 40 − 60 cm after irrigation for different irrigation treatments (4-, 8- and 12-day under single and double lateral lines a bed). The soil water content was determined using the gravimetric method. According to this method, soil samples were weighed (by electronic balance to a precision of 0.01 g) and dried in an oven (Fisher Scientific Isotemp Oven- Model − 655F Cat. No. 13-245-655, Fisher Scientific, Toronto, Ontario, Canada) at 105 °C for about 24 h until all the moisture was driven off. Soil moisture content was determined as a percentage of dry weight base as follows:

$$M.C = 100\,(W_1 - W_2)/W_2 \quad (2)$$

Where:

W_1 = wet soil sample's weight (g)

W_2 = weight of the oven dried soil sample (g) at 105 °C for 24 h.

2.5. Salt distribution patterns

Soil salinity content was evaluated for all treatments in saturated soil extract with a 1:5 soil: water ratio and determined by measuring electrical conductivity for all soil samples. Soil samples that used for preparing dilute soil extract solutions were air dried and sieved through a 1 mm mesh. Electrical conductivity (EC) in $dS.m^{-1}$ for each gravimetric soil sample has been measured using EC meter (ECtestr 11; Oakton Instruments, Vernon Hills, IL). The same procedure in deriving moisture pattern for the moisture distribution pattern was used in getting the contour maps for the salt distribution pattern for each irrigation treatment. SURFER (Version 10) was used to get the contour maps for moisture and salt distribution pattern.

2.6. Growth and yield parameters

For estimating growth parameters, a random sample of five plants from each plot was taken in 80, 100 and 120 days after planting in both