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Research Article
Improving Yield and Water Productivity of Canola under Sprinkler Irrigation and High Frequency of N-Fertigation

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Abstract
Background and Objective: Under different environmental conditions, the productivity and water productivity of canola were affected by different irrigation systems and different fertilization schedules. This study aimed to improve the canola production and saving of irrigation water by selecting the appropriate irrigation system and determining the best frequency for adding nitrogen fertigation dose under sandy and arid regions conditions in Egypt. **Materials and Methods:** The criteria for evaluating the study factors were yield, yield components, seed oil and water productivity as well as nitrogen use efficiency of canola. Five nitrogen fertilization frequencies (N10, N9, N8, N7 and N6) and two irrigation systems i.e., sprinkler irrigation system and drip irrigation system was arranged into the randomized complete block design. **Results:** Values of seeds productivity, oil productivity and water productivity of canola improved to 4557 (kg_{seeds} ha^{-1}), 2506 ($kg_{oil\ yield}$ ha^{-1}) and 1.26 (kg_{seed} yield $m^{-3}{}_{water}$) under SIS and N10 (the number of nitrogen fertilizers is repeated at ten times) respectively and the same positive effect of the second season occurred. **Conclusion:** The results of the study showed an improvement in productivity, water productivity, oil production and the efficiency of using the nitrogen fertilization unit for canola under the sprinkler irrigation system "SIS" compared to the drip irrigation system "DIS". The same characteristics improved by increasing the number of fertilization times as the highest values were ten times instead of 6 during two growing seasons.

Key words: Sprinkler and drip irrigation systems, N-fertilization frequencies, water productivity, N-Use efficiency, water stress, soil salt accumulation, canola crop, sandy soil

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Egypt, the sector of agriculture faces a serious challenge to increase food production with low water, which can be achieved by increasing crop water productivity. Increasing water productivity of crops is an important goal of increasing demand with high population rate[1]. Water scarcity considers one of the serious problems facing the crop production in sandy and arid Egypt and it is important to reduce the irrigation water consumption by developing the innovative technologies that can be effective technology[2]. In arid and dry areas with high population density and freshwater borders, there is significant pressure on the sector of agricultural to reduce the limited freshwater consumption for the irrigation to the other sectors[3]. The water resources in Egypt suffer from severe water scarcity, which increases with increasing population growth. Increasing competition is competing for scarce water resources through the application of new irrigation techniques to increase water productivity and improve crop productivity and quality characteristics[4]. Water productivity of crops in Egypt is extremely important, due to the limited water resources, precipitation and precipitation area very limited and low factor[5]. The application of modern methods of irrigation and associated techniques is an important concept that we must do in arid regions as in Egypt to provide a portion of irrigation water[6]. On-farm water productivity for crops and irrigation water use efficiency can be improved by using an effective irrigation system (i.e., sprinkler and drip irrigation systems which can decrease non-effective loss of water)[7]. One of the demand management mechanisms is the adoption of micro irrigation such as drip and sprinkler methods of irrigation. The sprinkler irrigation system is an advanced technique to irrigation and which water-saving, fertigation and in accurately controlling water amount and irrigation time[8]. Caswell and Zilberman[9] studied the effects of well depth and soil quality on choice of irrigation system by farmers using an approach of the production function. Using "modern" irrigation technologies (e.g., sprinkler or drip systems) is more likely in areas with expensive water (i.e., deep wells) and relatively low soil quality.

Canola (*Brassica napus* L.) is the second largest oil seed after soybeans in the world and produces a high meal of protein used to feed the animals during processing[10,11]. In addition to human consumption, canola is used in various ways depending on its oil content and availability. Additional, canola leaves and stems are a source of high-quality feed due to the low fiber and high protein content[12]. Canola crop can be used as food for human, in industry or even as a green fertilizer[13,14]. Crop of canola is characterized by its high production of the oil, where grains of canola contain 38-50% of the oil[15]. Yield of canola depends on many factors, including soil type, climate, irrigation regime, genotypes, seeding density, rate of fertilizer application and timing, crop rotation, tillage practices, date of cultivation as well as seeding rate and depth[16-20].

With compare to other grains, canola crop has a higher critical demand of nitrogen[21]. One of the most important aspects of successful canola production in arid systems is regulated of the precise rate and timing of nitrogen fertilizer application. White *et al.*[22] found that total plant weight, harvest index and seed yield in some canola crop varieties improved with increased nitrogen levels. Nitrogen is necessary to achieve the potential for yield of canola[23].

In crop of canola, N affects on number of branches/plant, the number and mass of seed pods/plant, shooting of dry matter, leaf area, grains mass/plant as well as oil content in seeds. In general, fertilization with N showed effectiveness in increasing canola yields[24].

Appropriate irrigation management should be followed to maximize crop yield and water productivity because there may be found a significant difference in requirements of irrigation water for a crop. The difference in requirements of irrigation water quantities is due to the variations in soil type, irrigation method, weather conditions and variety. In general, the application of drip irrigation method increases the water productivity because irrigation water can be applied in small and frequent quantities to meet crop water requirements. Irrigation Water Productivity (IWP) ranged from 80-91% when the crop grew in the fields using a surface drip irrigation system. However, under the sprinkler irrigation system it ranged from 55-80%[25]. Additionally, a timely supply of N increases the preservation of photosynthetic active leaves and also improves production of flowers as well as seed pods production[26]. At present, drip irrigation system can specifically overcome any environmental constraints to sustainable crop production. Studies show that drip irrigation can distribute water uniformly and precisely control the amount of water used, in addition to help in increasing plant yields, decrease evapotranspiration and infiltration and reduce the risks of soil degradation and salinity[27].

The aim of this study was to improve the canola production and saving of irrigation water by selecting the appropriate irrigation system and determining the best frequency for adding nitrogen fertigation dose under sandy and arid regions conditions.

MATERIALS AND METHODS

Description of study site and irrigation system: Field experiments were conducted during two canola cultivation seasons at the experimental farm of National Research Centre, El-Nubaria, Al-Buhayrah governorate in northern Egypt started from 17/11/2015 to 8/4/2016 for the first season and started from 17/11/2016 to 8/4/2017 for second season. The farm has a latitude of 30° 30′1.4′′\N, longitude 30°9′ 10.9′′ E and with 21 m 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).

Irrigation system components

Pumping system, control pressure head and filtration unit: The irrigation system consisted of a centrifugal pump with 45 m^3 h^{-1} 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 75 mm OD. Manifold lines, polyethylene (PE) pipes of 63 mm OD were connected to the sub-main line and control valves and discharge gauges. The emitters were built in lateral PE tubes, 50 m long and 16 mm OD. Emitter discharge was 4l h^{-1} at 1.0 bar operating pressure, spacing between the emitters was 30 cm and sprinkler is an impact sprinkler 3/4" diameter with a discharge of 1.17 m^3 h^{-1}, with 100 cm of riser height and wetted radius of 12 m and working pressure of 250 k Pa.

Characteristics of soil and irrigation water: The soil texture is sandy (88.5% sand, 7.8% silt and 4.6% clay), pH is 7.7, salinity expressed as electric conductivity, EC is 1.87dS m^{-1} and organic matter content in the upper 30 cm of the soils 0.45%. Available soil N, P and K contents were 16.8, 4.6 and 25.4 mg kg^{-1} soil, respectively, field capacity and wilting point

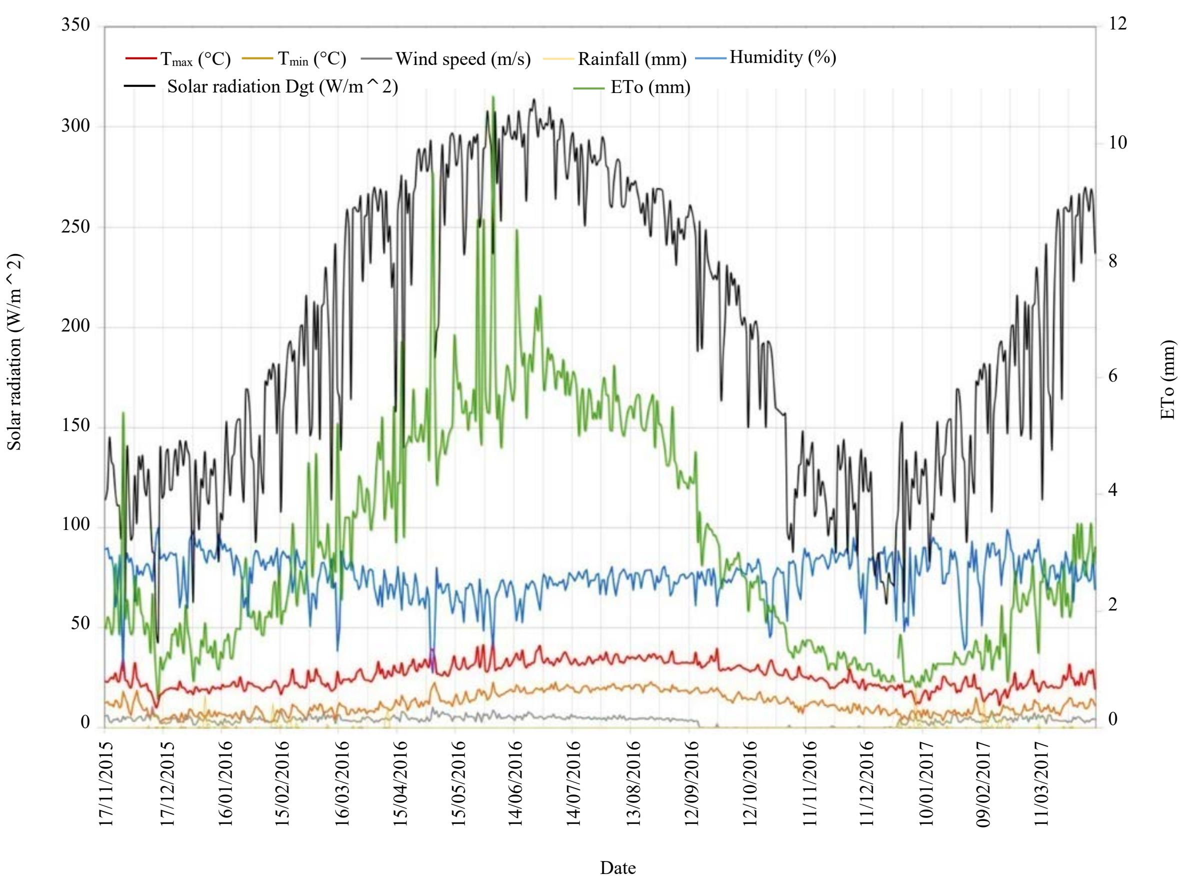

Fig. 1: Weather data during growing seasons obtained from meteorological station at the experimental site

of the soil were 15 and 4, respectively and extractable-Fe, Mn and Zn were 2.98, 1.74, 0.66 mg kg^{-1} soil, respectively.

Irrigation water requirements of canola: Seasonal irrigation requirements for canola crop were calculated for seasons 2015/2016 and 2016/2017. The seasonal irrigation water applied for canola, obtained from equation (1 and 2)[28]. The seasonal irrigation water applied was 3600 and 2900 m^3 ha^{-1} $season^{-1}$ for sprinkler irrigation and drip irrigation system, respectively for 2015/2016 and 3500 and 2800 m^3 ha^{-1} $season^{-1}$ for sprinkler irrigation and drip irrigation system, respectively for 2016/2017:

$$IRg = \left[\frac{(ETo \times Kc \times Kr)}{Ei}\right] - R + LR \quad \text{For drip irrigation system} \quad (1)$$

$$IRg = \left[\frac{(ETo \times Kc)}{Ei}\right] - R + LR \quad \text{For sprinkler irrigation system} \quad (2)$$

Where:

IRg = Gross irrigation requirements, mm day^{-1}

ET_O = Reference evapotranspiration, mm day^{-1} (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

Kr = Ground cover reduction factor

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 were split plot with four replications. Irrigation systems (Sprinkler Irrigation system and Drip Irrigation system) in main plots and N-fertilization frequencies (Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment "N6", N7, N8, N9, N10) were used in sub main plots as shown as in Table 1 and Fig. 2.

Evaluation parameters

Water stress inside root zone: Soil moisture was measured in effective roots zone of canola plants before and after 2 hrs from 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". Measurements were taken at soil depths at mid-growth stage. Soil moisture was measured by profile probe device as shown as in Fig. 3.

Soil salt accumulation: Soil samples were collected for soil EC1:5 before and after land preparation, during and at the harvest stage of canola crop for 2015/2016-2016/2017 seasons. Additional frequent soil EC1:5 sampling was conducted during the same seasons in 4 weeks intervals. The 28 soil samples were taken from the roots zone in each experimental plot. EC1:5 was measured using a handheld conductivity meter (Spectrum Technologies, Inc., USA).

Seed yield and yield component of canola: At harvest, a random area of 100×100 cm was harvested from each plot and the following characters were recorded on a random sample of ten guarded plants from each plot: seed yield (g/plant), plant height (cm), dry weight/plant, (g), biological yield (g/plant), 1000-seed weight (g), biological yield (t ha^{-1}), straw yield (t ha^{-1}) and seed yield (kg ha^{-1}).

Water productivity of canola: "WP_{canola}": The water productivity of canola was calculated according to Terry A. Howellas[29] follows:

$$WP_{canola} = \frac{Ey}{Ir} \quad (3)$$

Table 1: Repeated frequency of nitrogen fertilization of canola under sprinkler and drip irrigation systems for the 2015/16 and 2016/17 seasons

	N-fertilization frequencies, (kg N ha^{-1})									
	Nitrogen fertilization during the effective period of life of canola plants									Σ, (kg N ha^{-1})
N6 (Control)	18.0	18.0	18.0	18.0	18.0	18.0				108
N7	15.4	15.4	15.4	15.4	15.4	15.4	15.4			108
N8	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5		108
N9	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	108
N10	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	108

N6: Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season

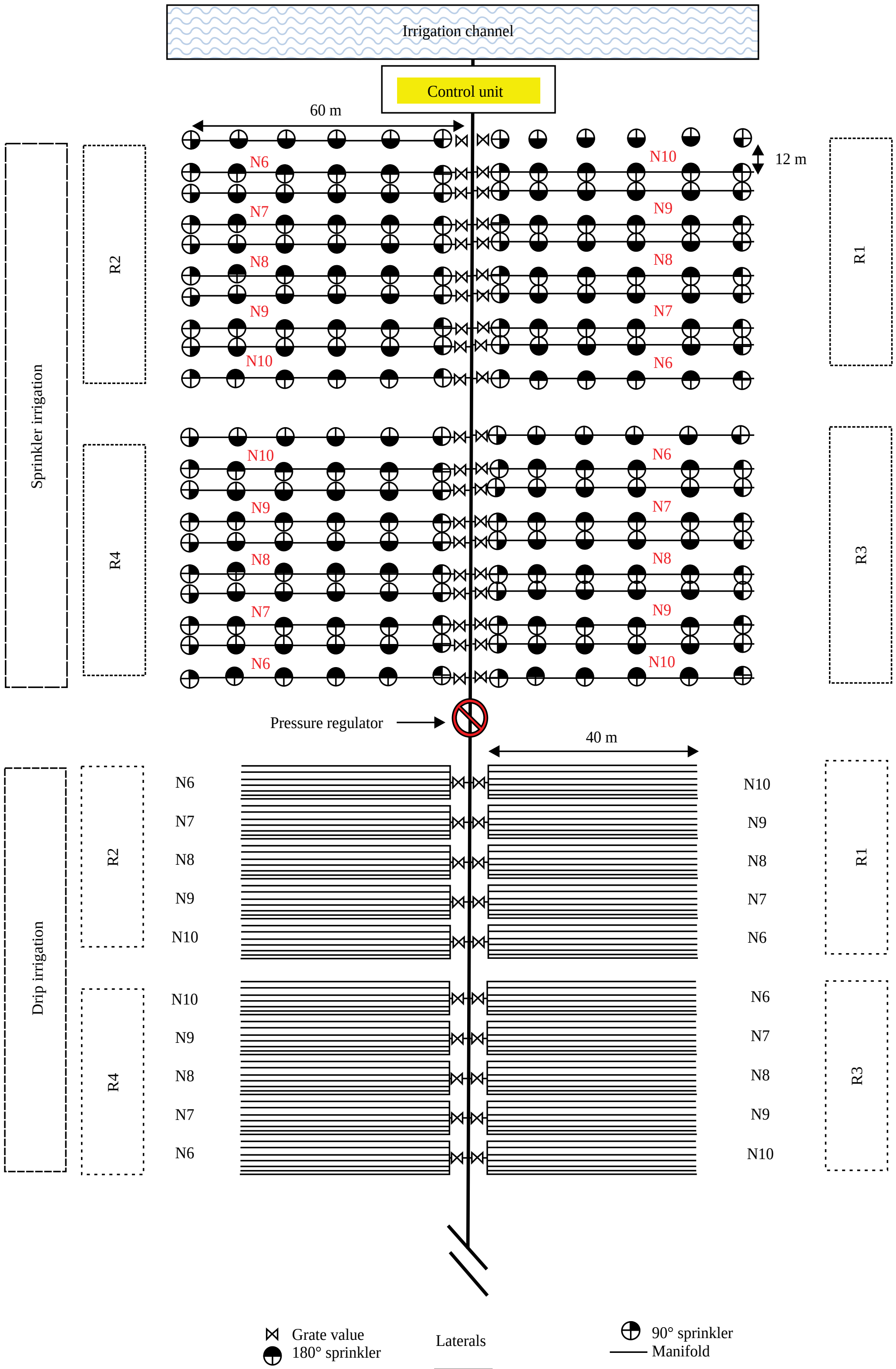

Fig. 2: Layout of experimental design

N6: Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season

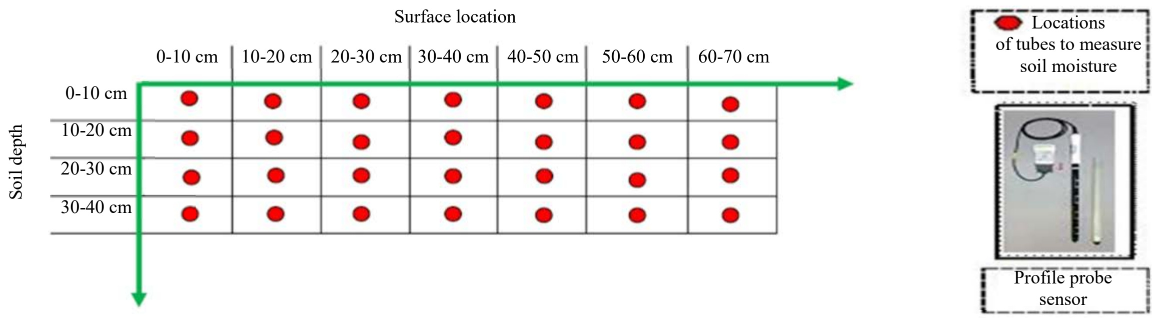

Fig. 3: Measuring the moisture content of the effective area of root growth under the sprinkler and drip irrigation systems

Where:

WP_{canola} = Water productivity of canola (kg_{canola} m^{-3}_{water})
Ey = Economical yield (kg_{canola} ha^{-1})
Ir = Amount of applied irrigation water (m^3_{water} ha^{-1} $season^{-1}$)

Nitrogen use efficiency of canola "N-Use E_{canola}": The nitrogen use efficiency of canola was calculated as follows[30]:

$$\text{N-Use } E_{canola} = \frac{Ey}{N_{kg}} \quad (4)$$

Where:

N-Use E_{canola} = Nitrogen use efficiency of canola (kg_{canola} kg^{-1N})
Ey = Economical yield (kg_{canola} ha^{-1})
N_{kg} = Amount of applied nitrogen (kg_N ha^{-1} $season^{-1}$)

Oil content and oil yield of canola: Oil yield (kg ha^{-1}) was calculated by Seed yield (kg ha^{-1}) * Seed oil content (%).

Seed oil% was determined by Soxhlet apparatus using petroleum ether (40-60°C b.p.) according to the Official Method (A.O.A.C.)[31].

Statistical analysis: The obtained results were subjected to statistical analysis of variance according to method described by Snedecor and Cochran[32] since the trend was similar in both seasons the homogeneity test Bartlett's equation was applied and the combined analysis of the two seasons was done according to the method Gomez and Gomez[33].

RESULTS

Some evaluation criteria were studied to study the effect of the study factors in order to determine the best factors to improve productivity and water productivity of cultivating canola under dry sandy soil conditions. Water Stress inside the root zone, soil salt accumulation, yield component, yield and water productivity of canola was studied as evaluation criteria for this study.

Effect of irrigation systems on water stress inside root zone and soil salt accumulation: The water stress of the root zone of canola plants was studied at the maximum water requirements during the two growing seasons at all treatments under study. It was found that there are clear differences in the moisture distribution inside the root zone, only under the sprinkler and drip irrigation systems before and after irrigation. Figure 4 indicated that, the average of Soil Moisture Content (SMC) inside the root zone spread of canola plants before and after irrigation and during the two growing seasons was the larger under sprinkler irrigation system (8 and 14.25% before and after irrigation, respectively) compared to the drip irrigation (6.32 and 11.78% before and after irrigation, respectively) for season 2015/16 and the same trend occurred for season 2016/17. It was also noted that, the movement of irrigation water in the soil profile under sprinkler irrigation system in one direction where it was vertical down only while the movement of irrigation water under drip irrigation system in two directions where it was horizontal and vertical movement at the same time.

Soil samples were collected to measure the salt concentration of the root zone before and after preparing the soil for canola cultivation and during the two growing seasons up to post-harvest. Figure 5 indicated that the concentration and accumulation of salts in the soil under sprinkler irrigation system is less than the concentration and accumulation of salts under drip irrigation system, whether before or after the soil preparation process for canola cultivation. Figure 5 also showed that there is a noticeable negative effect of the soil preparation process for cultivation on increasing the concentration of salts within the root zone (40 cm) under drip irrigation system, while there was no significant effect of the

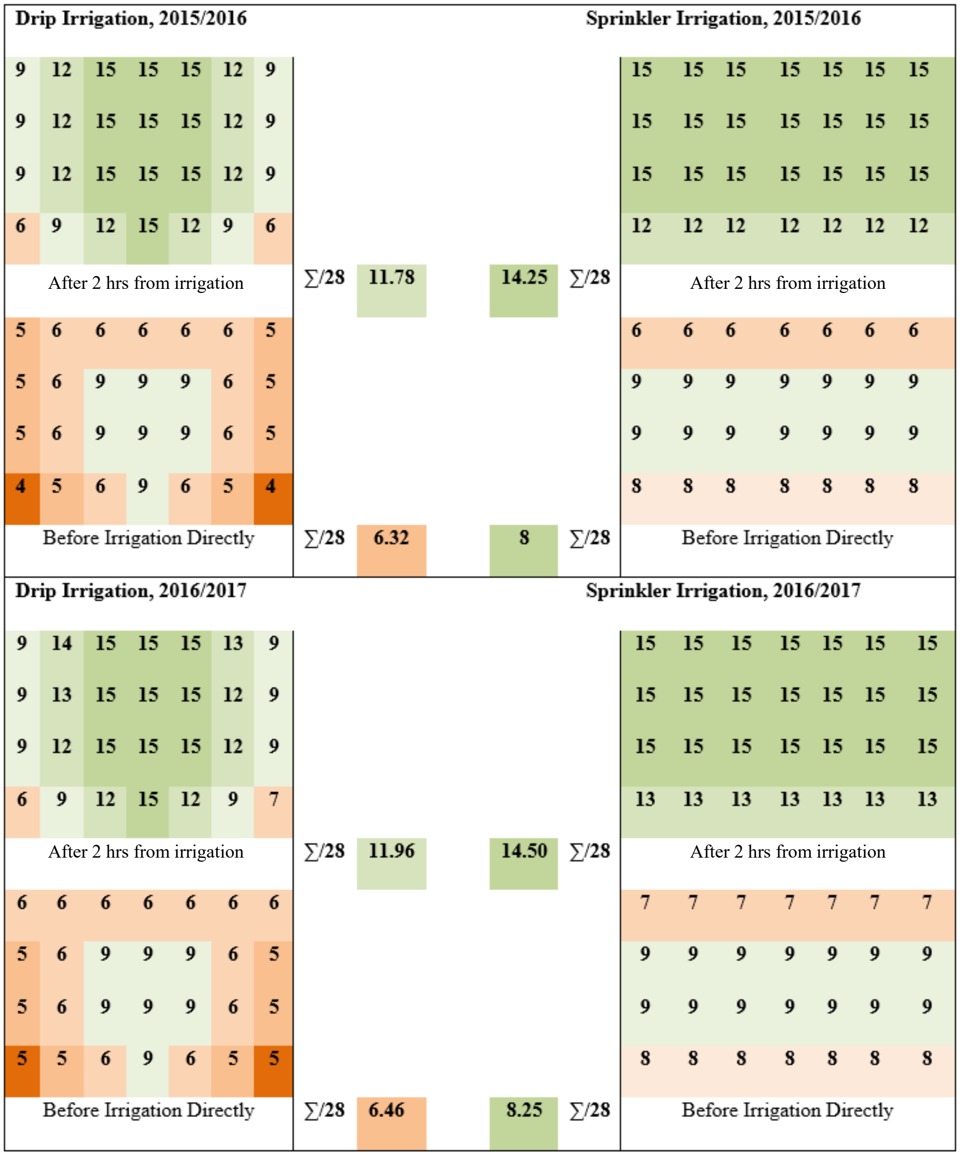

Fig. 4: Water stress inside root zone under drip irrigation and sprinkler irrigation during seasons 2015/2016 and 2016/2017

soil preparation process for cultivation under sprinkler irrigation system. Soil salt concentration ranged from 0.7-0.4 ds m^{-1} under sprinkler irrigation system but it was ranged from 2-0.9 ds m^{-1} under drip irrigation system for season and the same trend occurred for season 2016/17.

In conclusion, minimum water stress and soil salt concentration were occurred under sprinkler irrigation system compared to drip irrigation system for both two seasons.

Effect of irrigation systems on the yield component, yield, water productivity and nitrogen use efficiency of canola: Data in Table 2 displayed the effect of irrigation systems, i.e., drip irrigation system and sprinkler irrigation system on plant height, dry weight/plant, seed yield/plant and 1000 seed weight of canola crop in 2015/2016and 2016/2017seasons. Data showed that, all studied parameters were generally significantly influenced by irrigation systems. In this regard, the sprinkler irrigation system surpassed the drip irrigation system one in all aforementioned studied characters in both the 2 seasons.

It is clear from Table 3 that a quite similar trend was obtained in both experimental seasons regarding the effect of irrigation systems on the studied parameters i.e., biological yield, straw yield and oil content. In both seasons, biological yield, straw yield and oil content were increased significantly by using sprinkler irrigation system (8809, 4545 kg ha^{-1} and

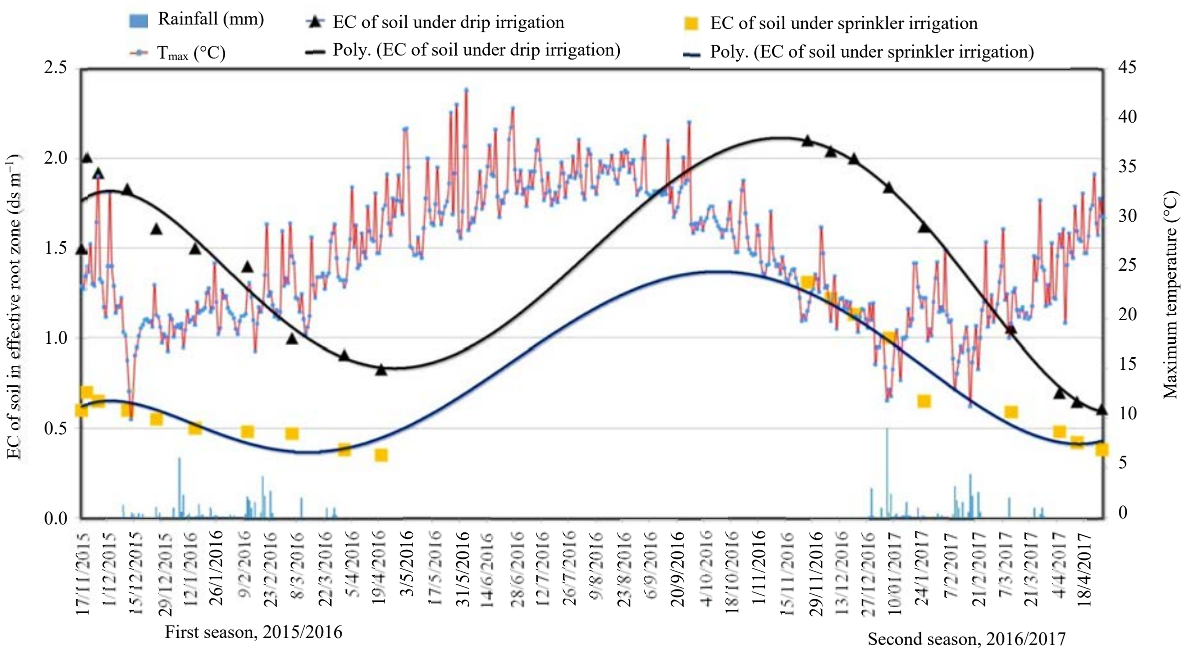

Fig. 5: Effect of sprinkler and drip irrigation systems and land preparation on soil salt accumulation

Table 2: Effect of irrigation systems on yield components characters of canola crop

	Plant height (cm)		Dry weight/ plant (g)		Seed yield/plant (g)		1000 seed weight (g)	
Irrigation systems	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
SIS	131.1^{a}	135.0^{a}	16.21^{a}	16.51^{a}	6.73^{a}	6.89^{a}	3.64^{a}	3.69^{a}
DIS	125.5^{b}	129.3^{b}	12.50^{b}	12.70^{b}	6.01^{b}	6.12^{b}	3.13^{b}	3.15^{b}
LSD at 5%	0.5465	0.5730	0.0496	0.0702	0.0351	0.0702	0.0702	0.204

Different alphabetical letters showed different significant level

Table 3: Effect of irrigation systems on the biological, straw yield and oil content of canola

	Biological yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Oil content (%)	
Irrigation systems	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017
SIS	8809^{a}	9073^{a}	4545^{a}	4635^{a}	50.69^{a}	51.34^{a}
DIS	7154^{b}	7368^{b}	3681^{b}	3754^{b}	46.58^{b}	47.00^{b}
LSD at 5%	70.51	73.14	17.47	17.11	0.1571	0.2766

Different alphabetical letters showed different significant level

Table 4: Effect of irrigation systems on the seed yield, oil yield, water productivity and nitrogen use efficiency of canola crop

Irrigation	Seed yield (kg ha^{-1})		Oil yield (kg ha^{-1})		$WP_{seed\ yield}$ (kg m^{-3})		N-Use $E_{seedyield}$, (kg_{Seed} kg_{N}^{-1})	
systems	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
SIS	4264^{a}	4452^{a}	2174^{a}	2300^{a}	1.18	1.27^{b}	39.47^{a}	41.23^{a}
DIS	3473^{b}	3689^{b}	1632^{b}	1713^{b}	1.20	1.34^{a}	32.17^{b}	34.15^{b}
LSD at 5%	80.32	106.0	23.53	49.29	N.S	0.0351	0.7584	0.9479

SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System, N6: Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season, different alphabetical letters showed different significant level

50.69%, respectively) compare with drip irrigation system (7154, 3681 kg ha^{-1} and 46.58%, respectively) for season 2015/16and the same trend occurred for season 2016/17.

Influence of irrigation systems on seed yield, oil yield, WP_{canola} and N-Use E_{canola} in the two experimental seasons of 2015/2016 and 2016/2017 are exhibited in Table 4. Data showed that, all studied parameters which referred to previously were significantly affected by irrigation systems in the two seasons except for WP_{canola} in the first season. From data in the Table 4 the highest value of seed yield, oil yield

Table 5: Effect of N-Fertigation frequency on the yield components characters of canola crop

N-Fertigation frequency	Plant height (cm)		Dry weight/ plant (g)		Seed yield/plant (g)		1000 seed weight (g)	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
N10	134.1[a]	138.0[a]	15.35[a]	15.60[a]	6.90[a]	7.07[a]	4.03[a]	4.08[a]
N9	130.2[b]	134.1[b]	14.80[b]	15.05[b]	6.70[a]	6.85[a]	3.63[b]	3.67[b]
N8	128.0[c]	131.8[c]	14.50[b]	14.75[b]	6.35[b]	6.48[ab]	3.50[b]	3.50[c]
N7	125.5[d]	129.3[d]	13.95[c]	14.20[c]	6.22[b]	6.33[ab]	3.27[c]	3.30[d]
N6	123.7[e]	127.4[e]	13.18[d]	13.42[d]	5.68[c]	5.78[b]	2.48[d]	2.55[e]
LSD at 5%	1.000	1.034	0.4850	0.4896	0.2120	0.7445	0.1448	0.144

SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System, N6:Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season, Different alphabetical letters showed different significant level

Table 6: Effect of N-Fertigation frequency on the biological, straw yield and oil content of canola

N-Fertigation frequency	Biological yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Oil content (%)	
	2015/2016	2016/2017	2015/2016	2016/2017	2015/2016	2016/2017
N10	8796[a]	9059[a]	4343[a]	4430[a]	52.77[a]	53.73[a]
N9	8217[b]	8463[b]	4240[b]	4324[b]	51.07[b]	51.52[b]
N8	7994[c]	8234[c]	4104[c]	4185[c]	49.17[c]	49.62[c]
N7	7805[d]	8038[d]	3973[d]	4052[d]	47.37[d]	47.78[d]
N6	7095[e]	7308[e]	3905[e]	3982[e]	42.80[e]	43.20[e]
LSD at 5%	86.45	88.83	26.35	26.84	0.4850	1.107

Different alphabetical letters showed different significant level

Table 7: Effect of N-Fertigation frequency on the seed yield, oil yield, water productivity and nitrogen use efficiency of canola crop

N-Fertigation frequency	Seed yield (kg ha^{-1})		Oil yield (kg ha^{-1})		$WP_{seed\ yield}$ (kg m^{-3})		N-Use $E_{seedyield}$, (kg_{Seed} kg_N^{-1})	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
N10	4452[a]	4667[a]	2352[a]	2511[a]	1.38[a]	1.52[a]	41.22[a]	43.20[a]
N9	3977[b]	4138[b]	2042[b]	2144[b]	1.22[b]	1.30[b]	36.82[b]	38.33[b]
N8	3891[c]	4049[c]	1923[c]	2020[c]	1.19[c]	1.30[b]	36.03[c]	37.50[c]
N7	3832[c]	3986[c]	1826[d]	1916[d]	1.18[c]	1.28[b]	35.48[c]	36.90[c]
N6	3190[d]	3513[d]	1372[e]	1443[e]	0.98[d]	1.13[c]	29.55[d]	32.53[d]
LSD at 5%	76.49	77.91	63.72	68.67	0.0244	0.0387	0.7084	0.7189

SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System, N6:Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season, different alphabetical letters showed different significant level

and N-Use E_{canola} were achieved by sprinkler irrigation system (4264, 2174 kg ha^{-1} and 39.47 kg_{Seed} kg^{-1}_N, respectively for season 2015/16) On the contrary, WP_{canola} highest value were recorded under drip irrigation system in second season while, in the first season there were no significant differences for irrigation systems.

In conclusion, maximum yield, WP_{canola} and N-Use E_{canola} were occurred under sprinkler irrigation system compared to drip irrigation system for both two seasons.

Effect of N-fertigation frequency on the yield component, yield, water productivity and nitrogen use efficiency of canola: Data found in Table 5 contain the effect of N-fertigation frequency, i.e., N10, N9, N8, N7 and N6 on plant height, dry weight/plant, seed yield/plant and 1000 seed weight. It is obvious from data in the table that the highest values of plant height, dry weight/plant, seed yield/plant and 1000 seed weight were achieved by N-fertigation frequency at N10 treatment followed by N9 while, the lowest values were observed at N7 and N6-fertigation frequencies.

Significant differences due to N-fertigation frequency were attained on biological yield, straw yield and oil content in both experimental seasons as shown in Table 6. Data showed that the higher values were recorded when canola plants were fertigated with N-fertigation frequency at N10 (8796, 4343 kg ha^{-1} and 52.77%, respectively) followed by N9 (8217, 4240 kg ha^{-1} and 51.07%, respectively) compare with the other treatments for season 2015/16 and the same trend occurred for season 2016/17.

Data in Table 7 illustrated the effect of N-fertigation frequency on seed yield, oil yield, WP_{canola} and N-Use E_{canola}. It is clear from the obtained results that, in the two seasons seed yield, oil yield, WP_{canola} and N-Use E_{canola} exhibited significant

Table 8: Effect of Interaction between Irrigation Systems and N-Fertigation frequency on the yield components characters of canola crop

Irrigation systems	N-Fertigation frequency	Plant height (cm) 2015/16	Plant height (cm) 2016/17	Dry weight/plant (g) 2015/16	Dry weight/plant (g) 2016/17	Seed yield/plant (g) 2015/16	Seed yield/plant (g) 2016/17	1000 seed weight (g) 2015/16	1000 seed weight (g) 2016/17
SIS	N10	134.5[a]	138.5[a]	17.1	17.40	7.30	7.50	4.10[a]	4.20[a]
	N9	133.6[a]	137.5[a]	16.8	17.07	7.07	7.27	3.83[bc]	3.90[bc]
	N8	131.3[b]	135.2[b]	16.4	16.73	6.70	6.87	3.70[c]	3.70[cd]
	N7	128.8[c]	132.6[c]	15.8	16.13	6.57	6.70	3.47[d]	3.50[de]
	N6	127.2[d]	131.0[d]	14.9	15.20	6.00	6.10	3.10[ef]	3.17[f]
DIS	N10	133.6[a]	137.6[a]	13.6	13.80	6.50	6.63	3.97[ab]	3.97[b]
	N9	126.8[d]	130.6[d]	12.8	13.03	6.33	6.43	3.43[d]	3.43[e]
	N8	124.7[e]	128.4[e]	12.6	12.77	6.00	6.10	3.30[de]	3.30[ef]
	N7	122.3[f]	125.9[f]	12.1	12.27	5.87	5.97	3.07[f]	3.10[f]
	N6	120.2[g]	123.8[g]	11.4	11.63	5.37	5.47	1.87[g]	1.93[g]
LSD at 5%		1.415	1.463	N.S	N.S	N.S	N.S	0.205	0.205

SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System, N6: Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season Different alphabetical letters showed different significant level

Table 9: Effect of interaction between irrigation systems and N-Fertigation frequency on the biological, straw yield and oil content of canola

Irrigation systems	N-Fertigation frequency	Biological yield (kg ha^{-1}) 2015/2016	Biological yield (kg ha^{-1}) 2016/2017	Straw yield (kg ha^{-1}) 2015/2016	Straw yield (kg ha^{-1}) 2016/2017	Oil content (%) 2015/2016	Oil content (%) 2016/2017
SIS	N10	9357[a]	9637[a]	4800[a]	4895[a]	55.00	56.43
	N9	9179[b]	9454[b]	4685[b]	4778[b]	53.23	53.73
	N8	8931[c]	9199[c]	4534[c]	4625[c]	51.23	51.73
	N7	8720[d]	8981[d]	4390[d]	4478[d]	49.37	49.80
	N6	7858[f]	8093[f]	4315[e]	4401[e]	44.60	45.00
DIS	N10	8235[e]	8481[e]	3887[f]	3964[f]	50.53	51.03
	N9	7254[g]	7471[g]	3795[g]	3870[g]	48.90	49.30
	N8	7058[h]	7269[h]	3673[h]	3745[h]	47.10	47.50
	N7	6889[i]	7096[i]	3556[i]	3627[i]	45.37	45.77
	N6	6332[j]	6522[j]	3495[j]	3564[j]	41.00	41.40
LSD at 5%		122.3	125.6	37.27	37.96	N.S	N.S

Different alphabetical letters showed different significant level

increases when canola plants were fertigated with N10-fertigation frequency followed by N9-fertigation frequency. Meanwhile fertigation frequency with both N7 and N6 recorded the lowest significant seed yield, oil yield, WP_{canola} and N-Use E_{canola} values.

In general, yield component, yield, water productivity and nitrogen use efficiency of canola were increased with increasing number and frequency of nitrogen fertilization times.

Effect of interaction between irrigation systems and N-fertigation frequency on the yield component, yield, water productivity and nitrogen use efficiency of canola: Data in Table 8 indicated that there were significant differences due to interaction were attained on plant height and 1000 seed weight in both experimental seasons. While, with regard to the dry weight/plant and seed yield/plant, there were no significant differences due to interaction in the two growing seasons. The highest significant interaction value of plant height was recorded at N10 and N9-fertigation frequencies under sprinkler irrigation system as well as at N10-fertigation frequency under drip irrigation system in both season while, the lowe1st value was obtained at N8, N7 and-fertigation frequencies respectively drip irrigation system. Meanwhile, for 1000 seed weight was recorded the highest value with N10-fertigation frequency under sprinkler irrigation system and drip irrigation.

Biological yield, straw yield and oil content of canola seeds in the two experimental seasons of 2015/2016 and 2016/2017 are exhibited in Table 9. Data illustrated that all studied parameters referred to previously were generally significantly influenced by interaction parameters except for oil content. It is worthy to mention that, in most cases the highest values of the significantly affected characters in the two seasons were exhibited by N10-fertigation frequency when the plants were irrigated with using sprinkler irrigation system followed by N9-fertigation frequency under the same irrigation system compare with the other treatments that achieved the lowest significant values.

Table 10: Effect of interaction between irrigation systems and N-Fertigation frequency on the seed yield, oil yield, water productivity and nitrogen use efficiency of canola crop

Irrigation systems	N-Fertigation frequency	Seed yield (kg ha^{-1}) 2015/16	Seed yield (kg ha^{-1}) 2016/17	Oil yield (kg ha^{-1}) 2015/16	Oil yield (kg ha^{-1}) 2016/17	$WP_{seed\ yield}$ (kg m^{-3}) 2015/16	$WP_{seed\ yield}$ (kg m^{-3}) 2016/17	N-Use $E_{seedyield}$, (kg_{Seed} kg_N^{-1}) 2015/16	N-Use $E_{seedyield}$, (kg_{Seed} kg_N^{-1}) 2016/17
SIS	N10	4557^{a}	4817^{a}	2506^{a}	2718^{a}	1.26^{b}	1.40^{b}	42.20^{a}	44.60^{a}
	N9	4494^{ab}	4675^{b}	2392^{b}	2512^{b}	1.25^{bc}	1.30^{c}	41.60^{ab}	43.30^{b}
	N8	4397^{bc}	4574^{bc}	2253^{c}	2366^{c}	1.22^{cd}	1.30^{c}	40.70^{bc}	42.37^{bc}
	N7	4330^{c}	4503^{c}	2138^{d}	2244^{d}	1.20^{d}	1.30^{c}	40.07^{c}	41.70^{c}
	N6	3543^{d}	3693^{d}	1580^{f}	1662^{f}	0.98^{g}	1.07^{e}	32.80^{d}	34.20^{d}
DIS	N10	4348^{c}	4517^{c}	2197^{cd}	2305^{cd}	1.50^{a}	1.63^{a}	40.23^{c}	41.80^{c}
	N9	3460de	3601de	1692^{e}	1776^{e}	1.19^{de}	1.30^{c}	32.03^{de}	33.37^{de}
	N8	3385^{ef}	3523^{ef}	1594^{f}	1674^{f}	1.17^{ef}	1.30^{c}	31.37^{ef}	32.63^{ef}
	N7	3333^{f}	3469^{f}	1513^{f}	1588^{f}	1.15^{f}	1.27^{c}	30.90^{f}	32.10^{f}
	N6	2838^{g}	3333^{g}	1164^{g}	1225^{g}	0.977^{g}	1.20^{d}	26.30^{g}	30.87^{g}
LSD at 5%		108.2	110.2	90.11	97.11	0.0346	0.0547	1.002	1.1.017

SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System, N6: Recommended Nitrogen fertigation dose add on 6 times/season = Control treatment, N7: Recommended Nitrogen fertigation dose add on 7 times/season, N8: Recommended Nitrogen fertigation dose add on 8 times/season, N9: Recommended Nitrogen fertigation dose add on 9 times/season, N10: Recommended Nitrogen fertigation dose add on 10 times/season, Different alphabetical letters showed different significant level

The effect of study factors interaction on seed yield, oil yield, Wp_{canola} and N-Use E_{canola} are illustrated in Table 10. It is worthy to mention that the highest values were obtained from N10-fertigation frequency under sprinkler irrigation system followed by N9-fertigation frequency under the same irrigation system while, the highest values of WP_{canola} were recorded at N10-fertigation frequency under sprinkler irrigation system in both growing seasons. On the other hand, the lowest values were obtained from using N8, N7 and N6-fertigation frequencies under drip irrigation system.

In conclusion, maximum yield, WP_{canola} and N-Use E_{canola} were occurred under sprinkler irrigation system and N10, N9-fertigation frequency compared to other treatments in both two seasons.

DISCUSSION

Through this study, the effect of irrigation systems and nitrogen fertigation frequency on water stress, salt accumulation, productivity and water productivity of the canola were studied to determine the best irrigation system with determining the best scheduling of nitrogen fertilization under the conditions of dry areas in Egypt.

Through comparing the results between sprinkler and drip irrigation systems on the most of studied traits, obviously, the superiority of sprinkler irrigation system and this is due to two reasons. The first one is that water stress within roots distribution zone was lower under sprinkler irrigation system where movement of water was subject to one-dimensional vertical movement, while water movement under drip irrigation system was irregular within roots distribution zone where there are areas with high water stress and other with less water stress zones, this is due to movement of water in the soil which subject to three-dimensional movement and soil moisture distribution pattern under drip irrigation system was high water stress on plants compared to sprinkler irrigation system specially during initial growth stage and development growth stage.

The second reason is due to movement of salts, where its movement was down and in one direction outside of roots distribution zone and that was under the sprinkler irrigation system, while it was not with this form under drip irrigation system as the movement of salts was inside of roots distribution zone, which led to additional salt stress under drip irrigation system where, Tan[34] and Marouelli *et al.*[35] reported that the sprinkler irrigation resulted in a 2l% higher yield than drip irrigation in one hot, dry year in 1988. Also, the sprinkler irrigation system is suitable for all seasonal field crops and most cereals (except jute and paddy), Intensive or closely grown field crops such as wheat, millets, groundnut, sugarcane, cotton, fruits, flowers and condiments have been found to be suitable to cultivate under sprinkler irrigation system. Importantly, an experimental study suggests and recommends that sprinkler irrigation systems can also be used successfully even for cultivating paddy crop and it is becoming a preferred system when available water for irrigation becomes scarce[36].

Also, by comparing the effect of nitrogen fertilization scheduling for a number of times during the period required for fertilization of a canola crop through growing season under sandy soil conditions, it became clear that increased the number of scheduling times, this led to increased and improved of most of the studied characteristics. This may have resulted from the increase in the number of fertilization times, the amount of washed nutrients, especially nitrogen, decreased by deep percolation outside of roots zone, which results in the lack of utilization of grown plants from these lost quantities, which leads to the presence of a poor and not fertilized roots zone, which negatively affected on productivity and quality of the crop. The previous result agrees with Nese and Oner[37] and Ramos *et al.*[38], who simulated water flow and N transport using HYDRUS-2D and indicated that high nitrate uptake occurred when the number of fertigation events was large and the amount of applied fertilizer in each event was small. Also Farneselli *et al.*[39] and Kumar *et al.*[40] reported that, High fertigation frequency improves the nitrogen uptake and crop performance. NO_3-N in lower soil profiles (30-60 cm soil depth) was marginally affected in biweekly and weekly fertigation frequency schedule.

By studying the results of interaction between irrigation systems and times number of nitrogen fertilization scheduling, the scheduling of nitrogen fertilization at 10 times under sprinkler irrigation system showed superiority compared to the scheduling of nitrogen fertilization at 6 times which confirmed the positive effect of each factor separately and did not contradict the positive effect of either of them on the other.

CONCLUSION

From the results which obtained it is concluded that sprinkler irrigation system and nitrogen fertigation frequencies at N10 times as well as interaction by N10-frequency under sprinkler irrigation were recommended for higher yield and yield components of canola crop. The study concluded that most of the studied traits improved, the most important productive and water productivity and oil production and the efficiency of the use of the nitrogen fertilization unit for canola under the sprinkler irrigation system compared to the drip irrigation system as a result of the low water and salt stress of the canola root spread area under the sprinkler irrigation system As a result, creating a more healthy area for growth and absorption of nutrients as well as improved water productivity and productivity, oil productivity and the efficiency of using the nitrogen fertilization unit by increasing the number of fertilization times compared to the control treatment (6 times) where the highest values when fertilizing were ten times instead of 6 times during the effective period For fertilization from canola age during two growing seasons.

SIGNIFICANCE STATEMENT

This study discovered an improvement in the cultivation of canola using the sprinkler irrigation system under dry climatic conditions and an increase in the number of times of adding nitrogen fertilization to 10 times instead of 6 times during the effective period of fertilizer application in the life of the plant. This study will help farmers to choose the appropriate irrigation system while maximizing and improving the use of nitrogenous fertilizers and obtaining greater crop yields without additional costs.

REFERENCES

1. Eid, A.R. and A. Negm, 2018. Improving Agricultural Crop Yield and Water Productivity via Sustainable and Engineering Techniques. In: Conventional Water Resources and Agriculture in Egypt, Negm, A.M. (Ed.)., Springer, Cham, The Handbook of Environmental Chemistry, ISBN: 978-3-319-95065-5 31.
2. El-Shafie A.F., M.A. Marwa and O.M. Dewedar, 2018. Hydraulic performance analysis of flexible gated pipe irrigation technique using gpimod model. Asian Journal of Crop Science 10: 180-189.
3. Rosegrant, M.W., C. Ringler and T. Zhu, 2009. Water for agriculture: Maintaining food security under growing scarcity. Annu. Rev. Environ. Resour., 34: 205-222.
4. Dewedar, O.M., H.M. Mehanna and A.F. El-Shafie, 2019. Validation of winsrfr for some hydraulic parameters of furrow irrigation in Egypt. Plant Arch., 19: 2108-2115.
5. El-Mageed, T.A.A. and W.M. Semida, 2015. Effect of deficit irrigation and growing seasons on plant water status, fruit yield and water use efficiency of squash under saline soil. Sci. Hortic., 186: 89-100.
6. Angelakıs, A.N., D. Zaccaria, J. Krasilnikoff, M. Salgot and M. Bazza *et al.*, 2020. Irrigation of world agricultural lands: Evolution through the millennia. Water, Vol. 12. 10.3390/w12051285.
7. Ali, M.H. and M.S.U. Talukder, 2008. Increasing water productivity in crop production-A synthesis. Agric. Water Manage., 95: 1201-1213.
8. Li, J. and M. Rao, 2003. Field evaluation of crop yield as affected by nonuniformity of sprinkler-applied water and fertilizers. Agric. Water Manage., 59: 1-13.
9. Caswell, M.F. and D. Zilberman, 1986. The effects of well depth and land quality on the choice of irrigation technology. Am. J. Agri. Econ., 68: 798-811.
10. Hergert, G.W., J.F. Margheim, A.D. Pavlista, D.L. Martin, R.J. Supalla and T.A. Isbell, 2016. Yield, irrigation response and water productivity of deficit to fully irrigated spring canola. Agric. Water Manage., 168: 96-103.
11. Safi, S.Z., A.A. Kamgar-Haghighi, S. Zand-Parsa, Y. Emam and T. Honar, 2019. Evaluation of yield, actual crop evapotranspiration and water productivity of two canola cultivars as influenced by transplanting and seeding and deficit irrigation. Int. J. Plant Prod., 13: 23-33.

12. Wiedenhoeft, M.H. and B.A. Barton, 1994. Management and environment effects on brassica forage quality. Agron. J., 86: 227-232.
13. Pavlista, A.D., D.K. Santra, T.A. Isbell, D.D. Baltensperger and G.W. Hergert *et al*., 2011. Adaptability of irrigated spring canola oil production to the US high plains. Ind. Crops Prod., 33: 165-169.
14. Sprague, S.J., J.A. Kirkegaard, J.M. Graham, H. Dove and W.M. Kelman, 2014. Crop and livestock production for dual-purpose winter canola (*Brassica napus*) in the high-rainfall zone of south-eastern Australia. Field Crops Res., 156: 30-39.
15. Mohammadi, K. and A. Rokhzadi, 2012. An integrated fertilization system of canola (*Brassica napus* L.) production under different crop rotations. Ind. Crops Prod., 37: 264-269.
16. Harker, K.N., J.T. O'Donovan, T.K. Turkington, R.E. Blackshaw and N.Z. Lupwayi *et al*., 2012. High-yield no-till canola production on the canadian prairies. Can. J. Plant Sci., 92: 221-233.
17. Fisichelli, N., T. Vor and C. Ammer, 2014. Broadleaf seedling responses to warmer temperatures "chilled" by late frost that favors conifers. Eur. J. Forest Res., 133: 587-596.
18. Rudnick, D.R., S. Irmak, K. Djaman and V. Sharma, 2017. Impact of irrigation and nitrogen fertilizer rate on soil water trends and maize evapotranspiration during the vegetative and reproductive periods. Agri. Water Manage., 191: 77-84.
19. Ma, B.L., D.K. Biswas, A.W. Herath, J.K. Whalen and S.Q. Ruan *et al*., 2015. Growth, yield and yield components of canola as affected by nitrogen, sulfur and boron application. J. Plant Nutr. Soil Sci., 178: 658-670.
20. Assefa, Y., P.V.V. Prasad, C. Foster, Y. Wright and S. Young *et al*., 2018. Major management factors determining spring and winter canola yield in North America. Crop Sci., 58: 1-16.
21. Girondé, A., P. Etienne, J. Trouverie, A. Bouchereau and F. Le Cahérec *et al*., 2015. The contrasting N management of two oilseed rape genotypes reveals the mechanisms of proteolysis associated with leaf N remobilization and the respective contributions of leaves and stems to N storage and remobilization during seed filling. BMC Plant Biol., Vol. 15. 10.1186/s12870-015-0437-1.
22. White, C.A., S.E. Roques and P.M. Berry, 2013. Effects of foliar-applied nitrogen fertilizer on oilseed rape (*Brassica napus*). J. Agric. Sci., 153: 42-55.
23. Hamzei, J. and J. Soltani, 2012. Deficit irrigation of rapeseed for water saving: Effects on biomass accumulation, light interception and radiation use efficiency under different N rates. Agri. Ecosys. Environ., 155: 153-160.
24. Bakhashwain, A. and F. El-Nakhlawy, 2009. Performance of canola (*Brassica napus* L.) seed yield, yield components and seed quality under the effects of four genotypes and nitrogen fertiliser rates. J. King Abdulaziz Uni. Meteorol. Environ. Arid Land Agri. Sci., 20: 33-47.
25. Battikhi, A.M. and A.H. Abu-Hammad, 1994. Comparison between the efficiencies of surface and pressurized irrigation systems in Jordan. Irrig. Drainage Syst., 8: 109-121.
26. Ahmad, G., J. Amanullah Inamullah and A. Muhammad, 2006. Phenology and physiology of canola as affected by nitrogen and sulfur fertilization. J. Agron., 5: 555-562.
27. Karlberg, L. and F.W.T.P. de Vries, 2004. Exploring potentials and constraints of low-cost drip irrigation with saline water in sub-Saharan Africa. Phys. Chem. Earth, Parts A/B/C, 29: 1035-1042.
28. Sawa, A.P. and K. Frenken, 2002. Planning, development monitoring and evaluation of irrigated agriculture with farmer participation. Food and Agriculture Organization of the United Nations, SAFR, Harare, Zimbabwe, ISBN: 0-7974-2315-X.
29. Howell, T.A., 2001. Enhancing water use efficiency in irrigated agriculture. Agron. J., 93: 281-289.
30. Gan, Y., S.S. Malhi, S. Brandt, F. Katepa-Mupondwa and C. Stevenson, 2008. Nitrogen use efficiency and nitrogen uptake of *Juncea* Canola under diverse environments. Agron. J., 100: 285-295.
31. AOAC., 1990. Official Methods of Analysis. 15th Edn., Association of Official Analytical Chemists, Washington, DC., USA., pp: 200-210.
32. Snedecor, G.W. and W.G. Cochran, 1990. Statistical Methods. 8th Edn., Iowa State Univ. Press, U.S.A., Pages: 609.
33. Gomez, K.A. and A.A. Gomes, 1984. Statistical Procedures for Agriculture Research. 2nd Edn., John Wiley and Sons, New York, pp: 113-129.
34. Tan, C.S., 1995. Effect of drip and sprinkle irrigation on yield and quality of five tomato cultivars in southwestern Ontario. Can. J. Plant Sci., 75: 225-230.
35. Marouelli, W.A., D.A. Lage, C.S. Gravina, M.M. Filho and R.B. Souza, 2013. Sprinkler and drip irrigation in the organic tomato for single crops and when intercropped with coriander. Revista Ciência Agronômica, 44: 825-833.
36. J. Uddin, N.H. Hancock, R.J. Smith and J.P. Foley, 2013. Measurement of evapotranspiration during sprinkler irrigation using a precision energy budget (Bowen ratio, eddy covariance) methodology. Agric. Water Manage., 116: 89-100.
37. Uzen, N. and O. Cetin, 2016. Effects of nitrogen fertigation frequency on yield and nitrogen retention in drip-irrigated cotton. J. Plant Nutr., 39: 2126-2135.

38. Ramos, T.B., J. Šimůnek, M.C. Gonçalves, J.C. Martins, A. Prazeres and L.S. Pereira, 2012. Two-dimensional modeling of water and nitrogen fate from sweet sorghum irrigated with fresh and blended saline waters. Agric. Water Manage., 111: 87-104.
39. Farneselli, M., P. Benincasa, G. Tosti, E. Simonne, M. Guiducci and F. Tei, 2015. High fertigation frequency improves nitrogen uptake and crop performance in processing tomato grown with high nitrogen and water supply. Agric. Water Manage., 154: 52-58.
40. Kumar, M., T.B.S. Rajput, R. Kumar and N. Patel, 2016. Water and nitrate dynamics in baby corn (*Zea mays* L.) under different fertigation frequencies and operating pressures in semi-arid region of India. Agric. Water Manage., 163: 263-274.