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Canola Response to Alternate Furrow and cut-off Irrigation Combined with Bio-Mineral Fertilizer Applications at North Delta Region

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ABSTRACT

Two consecutive winter seasons field experiments were held at Sakha Agricultural Research Station, Kafr El-sheikh Governorate.The productivity of canola, some water relations, and economic returns were the subjects of the study and evaluation of four irrigation regimes: cut-off irrigation at 100% (I_1), 90% (I_2), and 85% (I_3) of furrow length and alternative furrow irrigation (I_4); and four fertilization treatments: F_1 (recommended dose of NP (100% RNP as control)), F_2 (75% RN+100% RP+ rhizobactrien (BioI), F_3 (100% RN + 65% RP+ phosphorien (BioII), and F_4 (50% RNP+ the mixture of Bio1+ BioII). The findings demonstrated that, in both seasons, the sequence of seasonal water application and water consumptive usage was $I_1 > I_2 > I_3 > I_4$. Comparing the I_2, I_3, and I_4 treatments to the I_1 treatment, the water savings were 6.98, 10.47, and 20.11%, respectively. In all seasons, the (I_3) and (F_3) treatments are superior in raising canola seeds&, oil yield and most of its characteristics. Crop water and irrigation efficiencies as well as groundwater contribution, I4 had the best outcomes over the two seasons. Combining I_3 and F_3 treatments produced the maximum revenue and profitability of canola seed production; in contrast, I_4 and F_3 or F_4 treatments produced the highest net revenue from the water unit in the two seasons. In conclusion, the most effective treatments for increasing canola production at a lower cost, generating a profit, and conserving water and mineral fertilizers were I_3 or I_4 treatments in conjunction with F_4 treatment.

Keywords: Alternative furrow irrigation, Bio-mineral fertilizers, cut-off irrigation, Canola plant, economic revenue

INTRODUCTION

Producing as much as 14.7% of the world's total vegetable edible oil, canola (*Brassica napus* L.) is the third-largest oil seed crop after soybean and palm (Yasari etal., 2008 and Rosillo-calle etal., 2009). Monounsaturated and polyunsaturated fatty acids are abundant in it (Flakelar et al., 2015). It is used for a number of purposes besides human consumption, including the manufacturing of biodiesel and canola seed meal for animal feed (Abshar and Sami, 2016). Furthermore, canola is a major oil crop in several nations, particularly the USA, Canada, and the EU. In particular, canola could be grown successfully during the winter on recently reclaimed land outside the old Nile valley to avoid competition with other crops occupied the old cultivated area, which could help Egypt overcome some of its local deficit of vegetable edible oil production (Sharran et al., 2002 and Megawer and Mahfouz, 2010).

The requirement for water has significantly increased due to the growing global population as well as the growing need for food and fibre (Asseng et al., 2018). Egypt's water deficit is predicted to fall below 500 m^3 per capita year, a level that is predicted to be reached in 1988 (EL-Quosy). A good water management plan is required to achieve the highest level of water and land use efficiency in the Northern Nile Delta region given the current restricted water supply resources and Egypt's agricultural conditions. In order to accomplish the appropriate and cost-effective use of water, numerous researches were conducted to increase irrigation efficiency (Abo Soliman etal., 2008; Abdel Reheem, 2017 and Khalifa, 2019&2020).

According to EL-Hadidi et al. (2008), EL-Arqan et al. (2008), Khalifa (2016), and EL-Sayed et al. (2022) the primary factors directly affecting the irrigation efficiency of surface irrigation systems are border irrigation, surge flow, and alternate furrow irrigation. In the subsequent cut-off irrigation event, the water front relocates to irrigate more land that has been planted. According to Kassab (2012), EL-Hadidi etal. (2016), Miao etal. (2015), Khalifa (2019), and Fayed etal. (2021) this method is regarded as a straightforward, simple, and successful means of conserving water. Due to its cheap cost and energy requirements, furrow irrigation is widely used (Holzapfel etal.,2010). However, because the wet surface area of the furrows was smaller, there were less deep percolation losses, which led to water savings in alternate furrow irrigation. Field research conducted by Hamzie (2011); Ahmadi and Bahrani (2009); Hamzie and Soltani (2012):, Reddy etal., (2013), Xiao-bo etal.,(2017), and Katuwal etal., (2018), concluded that there was no significant different of canola seed yield and its attributes between irrigation with 50 % and 80% ETm, and the best oil output and seed value for canola were recorded with80% ETm, meanwhile, the lowest ones were detected with 100% ETm.

Scientists in recent years tried to introduce biological fertilizers instead of chemical fertilizers. Increasing denitrification, which raises the amount of N2O released into the atmosphere and may have an effect on global warming, along with increasing groundwater and soil acidification are some of the potential environmental problems associated with greater use of mineral fertilizers (Kavyani et al., 2008). Finding alternatives was therefore essential. The use of such N2-fixing (Azotobacter and Azospirillum) and phosphate-

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solubilizing microorganisms bacteria may be able to help plants grow faster and generate large amounts of physiologically active compounds that can encourage the development of reproductive organs and boost plant yield (Omran and Azzam (2007); Ebrahimi etal,2007; Yasari etal,2009; Morteza and Javad (2013) and Khalifa, (2022). To enhance water use and reduce water resources pollution, integrated nutrient management by the combination of chemical and Biofertilizers may be a useful tool as mentioned by several investigators (Awad etal., 2005; Mishra etal., 2010; Khalifa etal., 2013; Morteza; Javad, 2013 and Khalifa,2020). Furthermore, in this context, it has been suggested that using arbuscular mycorrhizal fungus (Amf) as microbial fertilizer could be a useful tool for food security and sustainable agriculture (Thirkell etal., 2017). An increasing number of studies have shown that Amf inoculation can mitigate the detrimental impacts of abiotic stressors, like drought (Bernado etal., 2019; Kamali and Mehraban, 2020). Finding substitute uses for mineral fertilisers that would lessen their negative impacts without sacrificing canola's high yield production became imperative.

Thus, the current study's goal is to examine and assess the effects of different irrigation water treatments for canola plants, including the use of the cut-off irrigation technique and potential biofertilizers as a partial substitute for mineral fertilizers, on the productivity of canola (cultivar serw4), some water relationships, and financial return.

MATERIALS AND METHODS

In the winter seasons of 2015/2016 and 2016/2017, two field experiments were carried out at the Sakha Agricultural Research Station in the Kafr EL-Sheikh Governorate. The purpose of this research is to examine the effects of irrigation schedules, the partial replacement of NP-Mineral fertilizer levels by biofertilizer applications (phosphorien and rhizobacterien alone or in combination) on canola crop yield and yield components (C.V. Serw 4), some water relations, and the groundwater table's contribution to canola's water needs and economic return. The groundwater table depth (87cm) in the current study is considered a shallow water table and can contribute to the irrigation water needs of the canola crop. The water table depth, plant salt tolerance and root characteristics, soil hydraulic properties, groundwater salinity level, and the presence of irrigation and drainage systems all influence the relationship between canola root depth and water table depth. In the case of shallow water depth, the roots can extract water and plant water uptake (Kahlown etal., 2005 and EL-Hadidi etal., 2016). Table (1) displays the physical and chemical characteristics of the soil at the experimental location, whereas Table (2) shows the agro-meteorological data collected over the two growing seasons in the Kafr EL-Sheikh region. The procedures outlined by Page etal. (1982) and Klute (1986) were followed in order to determine the qualities of the soil. Tables (1a and 1b) contain the experimental site's soil characteristics. According to the data in the tables, the soil has a clayey texture, an EC of 3.96 dS/m, a pH range of 8.01 to 8.11, and Na^+ (22.36 mmoLe L^{-1}) as the main cation and CL^{-} (19.73 mmole L^{-1}) as the dominating anion. Three replications and a split-plot design were used to set up the experiment. The following irrigation treatments were applied to the main plots:

I1= stop watering when the furrow is 100% full (verify treatment)
I2 = stop irrigation at 90% of the length of the furrow
I3 = stop irrigation at 85% of the length of the furrow
I4 = Alternative irrigation in furrows.

Each cut-off irrigation treatment had dimensions of 100 m for length and 7 m for width (10 ridges × 0.7 m width). Therefore, 700 m^2 was the area covered by each irrigation treatment. Since a 4L sec-1 m^{-1} width irrigation discharge rate was being employed, water was turned off at the waterfront when the furrow length and alternative irrigation reached 100%, 90%, and 85%. In order to prevent irrigation water from lateral movement to other plots, ditches of 1.5 meters in width isolated each cut-off irrigation. Stalking was done at intervals of 10 meters along each farmed furrow irrigation system until the planned irrigation run was completed. When the watering event started, the amount of time it took to get to the waterfront at each station and at the conclusion was noted. As a result, starting at the beginning of irrigation, the corresponding time for the water to disappear at each station was also noted. The opportunity time of irrigation water at each station is the expression used to represent the difference between the water advance and recession times.

Subplots were categorized into four groups based on how much NP-mineral fertilizer was partially replaced by bio-fertilizer application:

F1= Using the prescribed dosage of mineral-NP (100% RNP) as a reference
F2= Applying 100% of the required dose of mineral-P (100% RP) + rhizobacterien (BioI) + 75% of the recommended dose of mineral-N (75% RN).
F3= Applying phosphorien (BioII) at 100% RN+ 65% RP+
F4= 50% RNP+ combination BioI+Bio II is applied.

Ten ridges of 8.3 meters in length and 0.7 meters apart made up each sub-plot area, which measured 58.1 square meters. The phosphorien (Bacillus megatherium var. phosphaticum) and rhizobactrien (Azotobacter chroococum and Azospirillumbraensesil) bacteria that were used as inoculants were adsorbed on peat-moss power as carriers and registered to the Biofertilizers unit, Ministry of Agriculture, Egypt, from which it was obtained. A 300 g fed^{-1} application rate was used for each biofertilizer. Just before seeding, canola seeds were mixed to initiate the inoculation process. Each treatment's inoculated seeds were manually placed on ridges, 15 cm apart from each other on two sides of the hills, and both seasons' irrigation was done immediately. The dates of planting were November 25, 2015, and November 24, 2016, respectively, for both seasons, the dates of harvesting were April 20, 2016, and April 19, 2017.

Three weeks after sowing, plants were thinned in one plant per hill to give 20 plants/m^2. In each season, rice was the previous crop. Ammonium nitrate (33.5%N), a nitrogen fertilizer, was added at a rate of 60 kgN fed-1. The fertilizer was applied in two equal doses as directed; the first dose was administered before to post-planting irrigation, and the second dose was administered prior to the third watering. Before line setup, phosphorus fertilizer was given to the bottom of each furrow at the prescribed quantity of 6.56 kg P fed-1 in the form of calcium superphosphate (15.5%P2O5). The recommended dose for each fertilization treatment was 19.92 kg K fed-1 in the form of potassium sulphate (48% K2O). Plough work, land levelling, agronomic methods, and a 0.1%

ground surface slope were all done in accordance with standard agricultural procedures used by canola producers, with the exception of the treatments under study.

When it came time to harvest, ten plants were sampled from each of the three central ridges in the subplot, and measurements were made of the average plant height (cm), number of branches (plant-1), seed yield (g), seed yield (kg fed-1), oil yield (kg fed-1) and seed oil percentage. (Oil %) in seed was calculated using the methodology outlined by A.O.A.C (1995).

Table 1. Mean of the two seasons' soil chemical and physical characteristics at the experimental location prior to canola crop planting

1a- Physical properties

Soil depth, Cm	Distribution of Particle Size, % Clay	Silt	sand	Class of Texture	Infilt.Rate, cm hr^{-1}	Bulk density, Mg m^{-3}	Total porosity,%	*Soil moisture characteristics, % FC	PWP	AW
0-15	55.26	26.9٤	17.80	clayey		1.271	52.04	45.18	24.12	21.06
15-30	53.40	28.10	18.5	Clayey		1.363	48.57	44.10	23.16	20.94
30-45	52.20	29.50	18.3	Clayey		1.372	48.23	40.43	21.33	19.10
45-60	51.10	30.15	18.75	Clayey		1.391	47.51	37.25	21.10	16.15
Mean	52.99	28.68	18.34	Clayey		1.350	49.09	41.74	22.43	19.31

1b- Chemical properties

Soil depth, cm	pH @	EC@@ dSm^{-1}	SAR	S. C. mmolc L^{-1} Ca^{+2}	Mg^{+2}	Na^{+1}	K^{+1}	S. A. mmolc L^{-1} CO_3^{-2}	HCO_3^{-1}	CL^{-1}	SO_4^{-2}
0-15	8.11	3.66	7.97	6.85	7.88	21.62	0.25	N.D	5.27	18.10	13.23
15-30	8.03	3.81	7.34	7.66	9.01	21.18	0.25	N.D	5.62	18.36	14.12
30-45	8.01	4.16	7.89	8.10	9.64	23.51	0.35	N.D	6.24	21.10	14.26
45-60	8.03	4.22	8.01	7.78	8.89	23.13	0.40	N.D	6.51	21.35	14.34
Mean	-	3.96	7.8	7.85	8.86	22.36	0.31	N.D	5.91	19.73	13.99

FC=soil field capacity PWP= soil permanent wilting point AW= soil Available water * as gravimetric water content
@= In soil water suspension (1:2.5), it was determined. @@= In saturated soil paste extract, it was determined.
S.C.= Soluble cations, S. A= Soluble anions

Table 2. Average of a few climatic variables for the Kafr El-Sheikh region during the course of the two canola crop growth seasons**

Months of growth for the crop.	Air temperature, (co) Max.	Min.	Mean	Relative humidity, % Max.	Min.	Mean	Wind velocity Km $24hr^{-1}$	Pan evaporation mm/month	*Rainfall mm/month
				First grwing season					
November 2015	24. 4	14. 4	19. 4	87. 0	64. 2	75. 6	57. 2	244. 6	-
December 2015	19. 7	8. 4	14. 0	88. 6	67. 2	77. 9	57. 9	250. 4	25. 0
January .2016	18. 4	6. 4	12. 4	85. 6	62. 5	74. 1	69. 2	252. 4	43. 2
February 2016	22. 6	9. 4	15. 9	85. 0	53. 1	69. 1	58. 8	251. 9	-
March 2016	24. 5	11. 6	18. 1	81. 5	58. 3	69. 9	63. 2	359. 2	13. 2
April 2016	30. 0	18. 6	24. 3	81. 6	41. 8	61. 7	87. 1	593. 8	-
				Second growing season					
November 2016	24. 9	17. 9	21. 4	77. 9	56. 8	67. 4	56. 0	198. 1	-
December 2016	19. 3	10. 8	15. 1	85. 4	65. 1	75. 3	64. 7	156. 4	21. 3
January 2017	18. 2	5. 7	12. 0	87. 3	62. 9	74. 7	51. 9	136. 2	16. 7
February 2017	19. 7	10. 2	15. 0	85. 8	60. 1	73. 0	59. 3	214. 4	16. 3
March .2017	21. 7	17. 9	19. 8	84. 9	60. 4	72. 7	83. 8	295. 4	-
April 2017	26. 5	21. 6	24. 1	79. 4	50. 8	65. 1	89. 3	263. 4	10. 6

*** (Novica, 1970) Effective rainfall (ER) = incident rainfall×0.7**
****At an elevation of roughly 6 metres above mean sea level, the meteorological station at Sakha Agriculture Research Station is located at 310 07-N latitude and 300 57-E longitude.**

Collecting data

- **applied of irrigation water (IWA)**

Soil moisture samples were taken at regular intervals until they reached the target amount of permissible moisture (50 percent depletion of accessible water). The amount of water applied at each irrigation treatment was established by elevating the soil moisture content to its field capacity + 10% for leaching purposes.

Water for irrigation was pumped through a weir at a rate of 4L sec-1 m-1 width at 10cm as the effective head over the crest. The volume of water was determined using the formula $Q= 1.84\ L\ H^{1.5}$, where Q is the discharge rate in millilitres per minute, L is the weir's length in centimetres, and H is the height of water above the weir crest in centimetres. Only four irrigations were used throughout the entire canola crop growing season, including planting irrigation for every treatment in each season.

Seasonal water application was computed using the formula provided by Giriappa (1983) as follows: AW stands for applied water; IW for irrigation water applied by squaring the discharge rate by the amount of time needed for furrow irrigation; ER stands for effective rainfall; and GWC stands for shallow ground water table contribution.

- **Water consumption (WC)**

The percentage of moisture in the soil was calculated (based on weight) prior to, 48 hours following, and during harvest. In the effective root zone, soil samples were taken from progressively deeper strata (0–15, 15–30, 30-45, and 45–60 cm). The actual crop water consumed (ETc), or soil moisture depletion (SMD), is the basis for this method of measuring consumed water; Hansen et al. (1979) reported that the amount of water consumption was estimated in the 60-cm effective root zone.

$$CU = \sum_{i=i}^{i=N} \frac{\theta 2-\theta 1}{100} * Dbi * Di ,$$

where

In the effective root zone (60 cm), CU stands for water consumption (cm). Soil moisture percentage 48 hours post-irrigation = θ 2, Dbi is the bulk density of the particular layer (Mg m-3), θ 1 is the percentage of soil moisture before the next irrigation and Di = depth (15 cm) of soil layer.

- **Productivity of consumptive water (PCW)**

It was determined using (Ali et al., 2007).

$$PCW = Y/ETc \approx cu$$

PCW stands for water productivity (kg m-3 of water consumed), Y represents canola seed yields (kg fed^{-1}) and ETc denotes the seasonal water consumption during the growth season (m^3 fed^{-1}).

- **Irrigation water productivity (IWP)**

As per Ali et al. (2007), the calculation was as follows: IWP = Y/WA, where Y is the seed yield measured in kilograms fed^{-1}, WA is the seasonal water applied (m^3 fed^{-1}), and IWP is the irrigation water productivity (kg m^{-3} WA).

- **Efficiency of Consumptive Use (ECU)**

In accordance with Doorenbos and Pruitt (1975), the following computation was made:

ECU is equal to the efficiency of consumptive use (%) equals CU/IWA ×100.

CU= seasonal water consumption (m3 fed^{-1}),
IWA = applied irrigation water (m3 fed-1).

- **Groundwater table's contribution to the water requirement for canola (GWC)**

The computation was done in this manner: GWC = ETc - SMD/ETc ×100, where ETc = crop evapotranspiration = ET0*Kc, SMD = soil moisture depletion = cu, and ETo = was calculated using three methods: FAO Penman Montieth (Allen et al., 1998), Pan evaporation and Blaney & Criddle (Doorrenbos and Pruitt, 1975). Average values were computed and taken into consideration in the calculation.

- **Efficiency of Water Application (EWA):** EWA= (Da – (Dp+ R0)/Da ×100 was calculated by dividing the volume of water held in the effective root zone by the applied irrigation water (Downy, 1970). Here, Da stands for applied water (cm), Dp for deep percolation (cm), R0 for runoff (cm), and EWA for water application efficiency.
- **Efficiency of Water distribution (EWD):** The following formula was used to determine it, per James (1988): Ewd= (1- y/d) ×100, where d is the average depth of soil water held along the furrow length during irrigation, y is the average numerical deviation from d.
- **Economic analysis (Profitability from an economic perspective):** • It was computed using the formula provided by the FAO in 2000. The price of the Egyptian local market was used to compute the cash inflows and outflows for different treatments. A number of economic variables were also assessed, including:

***Net revenue (L.E /fed) = seasonal total revenue (L.E/fed) – seasonal total cost (L.E/fed).**

*** Economic efficiency = net revenue (L.E /fed)/ total cost (L.E/ fed)**

*** Net revenue from water unit (L.E m^{-3}) = net revenue (L.E /fed) / water applied (m3 /fed)**

- **Analytical statistics:** A portion of the data (canola yield and its constituent parts) were statistically analyzed, and Duncan's multiple range test was used to determine mean value differences (Gomez and Gomez, 1984). SAS software was used to perform all statistical analyses.

RESULTS AND DISCUSSION

Water seasonal application and conservation

Three factors determine the quantity of seasonal water applied (WA) for canola crops: groundwater contribution to crop water need (GWC), effective rainfall (ER), and irrigation water (IW). When compared to other irrigation treatments, Table 3's data indicate that the I_1¬ treatment received the most applied water during the first and second seasons, respectively, at 2177.7 m3 fed-1 (51.58 cm) and 2191.98 m3 fed-1 (52.19 cm). The total of 45.46 cm for irrigation water, 5.7 cm for effective rainfall, and 0.69 cm for groundwater contribution in the first season (refer to Table 3) equals the amount of water applied. In the second season, the corresponding values were 47.36 cm for irrigation water, 4.54 cm for effective rainfall, and 0.29 cm for groundwater contribution. Meanwhile, the least amount of water was applied to the alternative furrow irrigation treatment (I_4), which was 1737.96 m^3 fed^{-1} (41.38 cm) and 1753.08 m^3 fed^{-1} (41.47 cm) in each of the two growing seasons. This includes (1.45 and 0.77 cm) as ground water contribution, 5.57 and 4.54 cm as effective rainfall, and 34.23 and 36.43 cm as irrigation water in the first and second seasons, respectively. With increasing cut-off irrigation of furrow length and alternating furrow irrigation during the two growth seasons, it was observed that the quantity of seasonal water applied was reduced. I_1 (2184.84) > I_2 (2038.26) > I_3 (1955.73) > I_4 (1745.52) m^3 fed^{-1} are the averages of the applied water for the two seasons, presented in descending order.

Table 3. The impact of irrigation treatments on the seasonal amount of water provided to canola crops throughout the two growing seasons

Irrig. Treatment (I)	Components of water						Total of water applied (WA)		Water saving	
	IW		ER		GWC					
	m^{3}fed^{-1}	cm	m^{3}fed^{-1}	cm	m^{3}fed^{-1}	cm	m^{3}fed^{-1}	cm	m^{3}fed^{-1}	%
					1st season					
I_1	1909.32	45.46	239.40	5.7	28.98	0.69	2177.7	51.85	-	-
I_2	1751.82	41.71	239.40	5.7	31.92	0.76	2022.72	48.16	154.98	7.12
I_3	1674.12	39.86	239.40	5.7	34.44	0.82	1947.96	46.38	229.74	10.55
I_4	1437.66	34.23	239.40	5.7	60.90	1.45	1737.96	41.38	439.74	20.19
					2nd season					
I_1	1989.12	47.35	190.68	4.54	12.18	0.29	2191.98	52.19	-	-
I_2	1849.26	44.03	190.68	4.54	13.86	0.33	2053.80	48.90	138.18	6.83
I_3	1757.70	41.85	190.68	4.54	15.96	0.38	1964.34	46.77	227.64	10.39
I_4	1530.06	36.43	190.68	4.54	32.34	0.77	1753.08	41.74	438.90	20.02
					mean of the two seasons					
I_1	1949.22	46.41	215.04	5.12	20.58	0.49	2184.84	52.02	-	-
I_2	1800.54	42.83	215.04	5.12	22.89	0.55	2038.26	48.53	146.58	6.98
I_3	1715.91	40.86	215.04	5.12	25.20	0.60	1955.73	46.56	228.69	10.47
I_4	1483.86	35.33	215.04	5.12	46.62	1.11	1745.52	41.56	439.32	20.11

FL stands for furrow length. Irrigation water (IW) and effective rainfall (ER), Groundwater Contribution (GWC),I_1 denotes irrigation that is stopped at 100%FL, I_2 at 90%FL, I_3 at 85%FL, and I_4 denotes alternative furrow irrigation.

In contrast to the standard treatment (I_1), the average water savings in the two seasons were 146.58, 228.69, and 439.32 m^3 fed^{-1} or 6.98, 10.47 and 20.11% for I_2, I_3 and I_4- treatments, respectively. In a parallel study, Ibrahim and Emara (2009) and Kassab (2012) have found a similar result to our study in water saving (9.23-11.0%) by irrigating 85%

of sugar beet and maize furrow respectively, also Khalifa (2019) discovered that, under cut-off at 85% of furrow length and alternate furrow irrigation of faba bean, water savings ranged from 10.92 to 22.55%, respectively. The greatest crop output would determine how much water could be saved for irrigation of further crops and horizontal agricultural growth. Correspondingly, Liang etal., (2013); Yang etal., (2015); Xiao-bo etal., (2017), and Katuwal etal., (2020), reported that both cutoff irrigation at 85% of furrow distance and alternate furrow irrigation maintains a reasonable crop yield and save irrigation water.

Water consumptive use (CU)

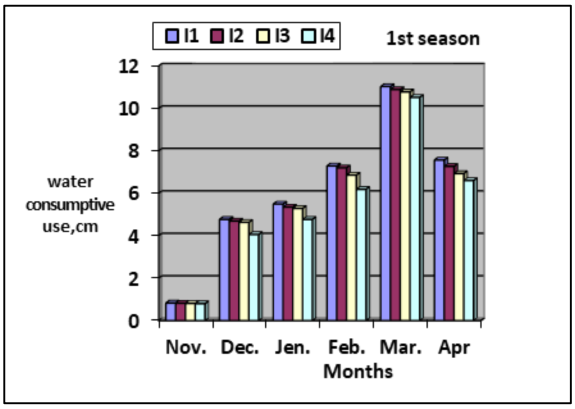
Canola crop water consumption follows the same pattern as applied seasonal water. The amount of irrigation water applied already has an impact on the soil water status, which directly affects water consumption. Table (4) and Fig. 1 show the monthly and seasonal values of water consumption were clearly affected by irrigation and fertilization treatments. It is observed that the monthly water consumptive use by Canola crop was Low during Nov., and Dec., and increase with to reach the highest values during March in both seasons, under all treatments. The highest seasonal mean values of water consumptive use for canola crop were 1552.95 m^3fed^{-1} (36.98 cm) and 1554.42 m^3fed^{-1} (37.01 cm) were recorded with (I_1) during the 1st and 2nd seasons, respectively, comparison to the other irrigation treatments. Also, data indicate that the over mean values of crop water consumption for canola, in the two seasons were I_1 (1553.69)> I_2 (1522.71)> I_3 (1490.58)> I_4 (1389.78) m^3fed^{-1}. CU was the highest (36.99 cm) for I_1- treatment, it was the consequence of watering the entire farmed furrow. This is because (I_1) receiving the maximum amount of applied water. Conversely, the minimum value 1389.78 m^3fed^{-1} (33.09cm) was achieved with alternative furrow irrigation (I_4). Also, data show that decreasing NP-mineral addition rates and using biofertilizers (rhizobacterien and phosphorien) alone or mixture resulting in a slight increment of CU of canola in both growing seasons compared with recommended of NP-mineral (F_1). Consequently, the CU mean values that were greatest overall were noted under the combination of I_1-treatment and applying 50% RNP + mixture of rhizobacterien+ phosphorien (F_4) and the values are 1573.53 m^3 fed^{-1} (37.46 cm). Conversely, the CU mean values that were the lowest overall were noted under the combining of I_4 (alternate furrow irrigation) and applying 100% RNP (F_1) and the value is 1365 m^3 fed^{-1} (32.5cm). It was observed that water consumptive use was decreased with increasing cut-off irrigation of furrow length and alternative irrigation during both growing seasons. Therefore, raising the seasonal water consumption values under F_2, F_3, and F_4 treatments compared with F_1- treatment, might be because of the biofertilizers application (rhizobacterien and phosphorien) which encourage plants to grow well and form healthy plants which consume a large amount of water to compensate the water losses by transpiration, consequently, the amount of water consumed by plants will increase. The findings obtained by Kassab and Ibrahim (2007), Kassab (2012), EL-Mowelhi et al., (1999b), EL-Nagdy et al., (2010), Megawer and Mahfoz (2010), and Khalifa (2019) are consistent with these results.

Efficiencies of crop water

Efficiency of crop water is a metric that shows how productive the water unit is. Two terms could be used to evaluate this function: water productivity (WP), which links yield to water used, and irrigation water productivity (IWP), which relates yield to the water applied.

Regarding irrigation water productivity (IWP), the overall mean values of the two seasons for treatments I_1, I_2, I_3, and I_4 were 0.62, 0.66, 0.72, and 0.80 kg m^{-3}, respectively (Table 4). Therefore, I_4- treatment (alternative furrow irrigation) cleared the highest average of IWP (0.80 kg m^{-3}). While the lowest (0.62 kg m^{-3}) was associated with I_1-treatment (cut-off at 100% FL). The current study's results are nearly identical to those published by Caihong et al., (2015) and Khalifa, (2019) they stated that Alternate irrigation under faba bean gave high values of water use efficiency compared with continuous furrow irrigation.

Concerning water productivity (WP), the over-mean values of WP in the two growing seasons for treatments I_1, I_2, I_3, and I_4 were 0.86, 0.90, 0.94, and 1.01 kg m^{-3}, respectively (Table 4). The highest value (1.01 kg m^{-3}) was obtained under the I_4- treatment, while the lowest value (0.86 kg m^{-3}) resulted from the I_1 treatment. In addition, data clearly show that the combination of I_4F_3 achieved the highest values of WP, followed by the combination of I_4F_4 in comparison with the other treatments. Increasing the overall mean values of IWP and WP under both I_3 and I_4 treatments might be because of decreasing both seasonal applied water and water consumptive use (CU) compared to (I_1 and I_2) treatments. These results show a strong correlation with those found by Ibrahim and Emara (2009&2010); Kassab (2012); Xiao-bo et al., (2017), Khalifa (2019), and Wu et al., 2021



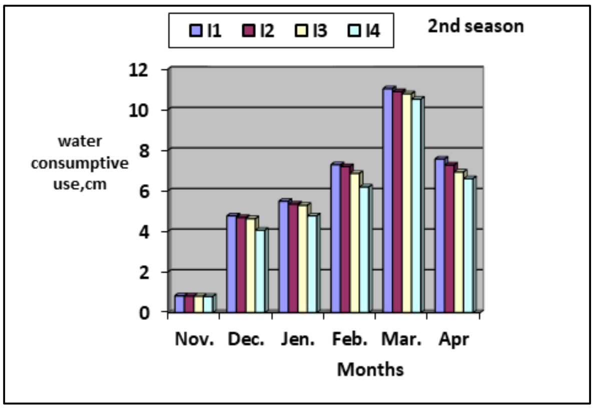


Fig. 1. Monthly water consumptive use as affected by irrigation treatment in the two seasons

Table 4. Water Consumptive Use (CU); Water Productivity (WP) and Irrigation Water Productivity (IWP) for seed yield of canola crop in the two seasons

Treatments		1st season			2nd season			The two seasons' over-average values		
Irrigation(I)	Fertilization(F)	CU, m^3 fed^{-1}	WP, (kg/m^3wc)	IWP, (kg/m^3wa)	CU, m^3 fed^{-1}	WP, (kg/m^3wc)	IWP, (kg/m^3wa)	CU, m^3 fed^{-1}	WP, (kg/m^3wc)	IWP, (kg/m^3wa)
I_1	F_1	1530.48	0.82	0.58	1531.32	0.82	0.57	1530.9	0.82	0.58
	F_2	1548.12	0.82	0.60	1544.76	0.85	0.60	1546.44	0.84	0.60
	F_3	1559.88	0.90	0.64	1567.44	0.90	0.64	1563.66	0.90	0.64
	F_4	1573.32	0.87	0.63	1573.74	0.89	0.64	1573.53	0.88	0.64
mean		1552.95	0.85	0.61	1554.42	0.87	0.63	1553.69	0.86	0.62
I_2	F_1	1503.18	0.84	0.63	1504.02	0.86	0.56	1503.60	0.85	0.60
	F_2	1516.62	0.87	0.65	1527.12	0.88	0.62	1521.87	0.88	0.64
	F_3	1529.22	0.94	0.71	1533.0	0.93	0.65	1531.11	0.94	0.64
	F_4	1537.20	0.92	0.70	1533.84	0.92	0.71	1535.52	0.92	0.71
mean		1521.24	0.89	0.67	1524.18	0.90	0.64	1522.71	0.90	0.66
I_3	F_1	1467.06	0.87	0.66	1485.96	0.86	0.65	1476.51	0.87	0.66
	F_2	1477.56	0.93	0.70	1499.40	0.92	0.70	1488.48	0.93	0.70
	F_3	1486.38	1.01	0.77	1502.76	1.03	0.78	1494.57	1.02	0.78
	F_4	1499.40	0.95	0.74	1504.86	0.96	0.74	1502.08	0.96	0.74
mean		1482.60	0.94	0.72	1498.56	0.94	0.71	1490.58	0.94	0.72
I_4	F_1	1348.20	0.95	0.74	1381.80	0.93	0.73	1365	0.94	0.74
	F_2	1380.24	0.98	0.78	1393.98	0.98	0.78	1387.11	0.98	0.78
	F_3	1388.52	1.03	0.83	1402.80	1.06	0.85	1395.66	1.06	0.84
	F_4	1393.56	1.02	0.82	1406.16	1.04	0.84	1399.86	1.03	0.83
Mean		1383.48	1.00	0.79	1396.08	1.01	0.80	1389.78	1.01	0.80

F_1= Applying recommended dose of mineral-NP (100% of R_{NP}) as control $F_{2=}$ Applying 75% of R_N + 100% of R_P+ rhizobactrien (BioI)
$F_{3=}$ Applying 100% of R_N+ 65% of R_P+ phosphorien (BioII) F_4= Applying 50% of R_{NP}+ mixture of BioI+Bio II
I_1=cut-off irrigation at 100%of FL I_2= cut-off irrigation at 90%of FL I_3= cut-off irrigation at 85%of FL I_4= Alternative Furrow irrigation

Irrigation Efficiencies

Efficiency of water application (EwA)

Table 5 and Fig. 2 demonstrate that EWA, % is impacted by irrigation treatments in the two growing seasons. The maximum values of EWA (81.81 and 81.29%) were achieved from alternative furrow irrigation (I_4), while, the lowest ones of EWA (65.59 and 65.41%) resulted from cut-off irrigation at 100% FL(I_1) in the 1st and 2nd seasons, respectively. Meanwhile, the overall average values of EWA of the two seasons were 65.51, 69.08, 75.17, and 81.55% for I_1, I_2, I_3, and I_4 treatments, respectively. In general, the overall average values of EWA, % descending in a certain order I_4> I_3> I_2> I_1. These findings somewhat concur with those published by EL-Arqan etal., (2008), Amer (2011), and Khalifa (2016&2019).

Efficiency of water distribution (Ewd)

The obtained data from Table 5 and Fig 2 indicate that the efficiency of water distribution is impacted by irrigation treatments in the two growing seasons. The maximum values of Ewd (76.23 and 76.08%) were noted with alternative furrow irrigation (I_4) in the 1st and 2nd seasons, respectively, followed by cutoff irrigation at 100% FL (I_1) in both growing seasons, while, the minimum values of Ewd (71.37 and 73.75 %) resulted from cutoff at 90% FL (I_2) in the 1st season and cut-off at 85% FL(I_3) in the 2nd season. Moreover, the overall mean values of Ewd of the two growing seasons were 75.06, 72.88, 73.03, and 76.16% for I_1, I_2, I_3, and I_4 treatments, respectively. In general, the overall average values of Ewd, % descending in a certain order I_4> I_1 > I_3> I_2. The results achieved here are consistent with those obtained by Chen etal., (2013), Amer (2011), and Khalifa (2019).

Table 5. Impact of irrigation treatments and use of biochemical fertilisers on efficiency of water application (EwA), efficiency of water distribution (Ewd), and efficiency of consumptive usage (Ecu) over the two growing seasons

Treatments		1st season			2nd season			The overall average values of the two growing seasons		
Irrigation(I)	Fertilization(F)	Ecu,%	EwA,%	Ewd,%	Ecu,%	EwA,%	Ewd,%	Ecu,%	EwA,%	Ewd,%
I_1	F_1	70.20	65.59	74.56	69.83	65.43	75.56	70.07	65.51	75.06
	F_2	71.06	65.59	74.56	70.47	65.43	75.56	70.77	65.51	75.06
	F_3	71.66	65.59	74.56	71.52	65.43	75.56	71.59	65.51	75.06
	F_4	72.33	65.59	74.56	71.84	65.43	75.56	72.09	65.51	75.06
mean		71.31	65.59	74.56	70.92	65.43	75.56	71.12	65.51	75.06
I_2	F_1	74.21	69.73	71.37	73.16	68.43	74.39	73.69	69.08	72.88
	F_2	74.96	69.73	71.37	74.34	68.43	74.39	74.65	69.08	72.88
	F_3	75.65	69.73	71.37	74.67	68.43	74.39	75.16	69.08	72.88
	F_4	76.11	69.73	71.37	74.74	68.43	74.39	75.43	69.08	72.88
mean		75.23	69.73	71.37	74.23	68.43	74.39	74.73	69.08	72..88
I_3	F_1	75.22	75.44	72.48	75.60	74.90	73.57	75.44	75.17	73.03
	F_2	75.82	75.44	72.48	76.30	74.90	73.57	76.06	75.17	73.03
	F_3	76.30	75.44	72.48	76.52	74.90	73.57	76.41	75.17	73.03
	F_4	77.09	75.44	72.48	76.68	74.90	73.57	76.89	75.17	73.03
Mean		76.11	75.44	72.48	76.28	74.90	73.57	76.20	75.17	73.03
I_4	F_1	77.50	81.81	76.23	78.73	81.29	76.08	78.12	81.55	76.16
	F_2	79.40	81.81	76.23	79.52	81.29	76.08	79.46	81.55	76.16
	F_3	79.93	81.81	76.23	80.06	81.29	76.08	80.00	81.55	76.16
	F_4	80.26	81.81	76.23	80.30	81.29	76.08	80.28	81.55	76.16
Mean		79.27	81.81	76.23	79.65	81.29	76.08	79.47	81.55	76.16

F_1= Using 100% of RNP, the recommended dosage of mineral-NP, as a control, F_2= Using 100% of RP+ rhizobactrien (BioI) + 75% of RN
F_3 = Using 100% of RN+ 65% of RP+ phosphorien (BioII); F_4 = Using 50% of RNP+ mixture of BioI+Bio II; I_1 denotes irrigation that is stopped at 100% of FL, I_2 at 90% of FL, I_3 at 85% of FL, and I_4 denotes alternative furrow irrigation.

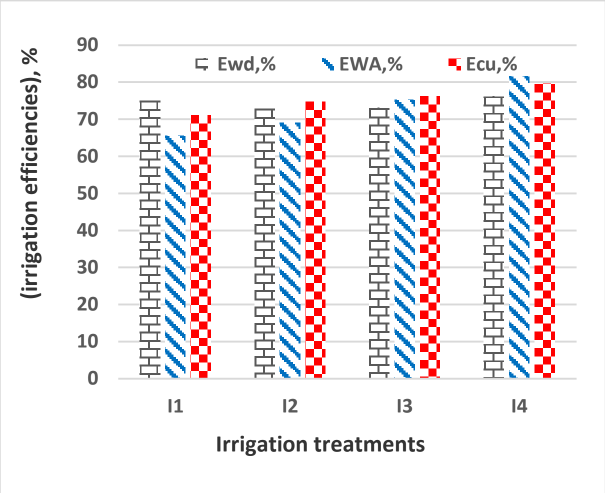


Fig. 2. Effect of irrigation treatments on consumptive use efficiency (Ecu), irrigation application efficiency (EIA) and water distribution efficiency (Ewd) under canola crop as an average of the two growing seasons

I_1=cut-off irrigation at 100%of FL I_2= cut-off irrigation at 90%of FL
I_3= cut-off irrigation at 85%of FL I_4= Alternative Furrow irrigation

Efficiency of consumptive use (Ecu)

A measure that shows how well plants can use the soil water held in the effective root zone is called efficiency of consumptive use. Table 5 and Fig.2 show the maximum overall mean values (79.47%) were recorded from alternative furrow irrigation (I_4), followed by cutoff irrigation at 85% FL (I_3). Consequently, by reducing the amount of water provided, more irrigation water might be usefully utilised by developing plants, reducing water losses. Conversely, though, the minimum overall mean values of Ecu (71.12%) were attained from cutoff irrigation at 100%FL (I_1). Also, the obtained data indicate that the combination of $I_4 F_4$ gave the highest values of Ecu (80.26 and 80.30%) in both growing seasons, respectively. In general, the overall average values of Ecu, % can be descending in the following order $I_4 > I_3 > I_2 > I_1$. These findings are largely concurred with the results obtained by Kassab and Ibrahim (2007), Kassab (2012), Ibrahim and Emara (2009&2010), and Khalifa (2019).

Canola yield and its components

Data from Table 6 and Fig. 3 reveal that canola yield of seed and its constituents were insignificantly impacted by irrigation treatments, except plant height which was significantly affected in both seasons. On the other hand, all the mentioned traits in Table 7 were increased with cutoff irrigation at 85% FL (I_3) and alternative furrow irrigation (I_4) in both growing seasons. The maximum values of canola seed yields (1395.58 and 1410 kg fed^{-1}), oil yield (638.77 and 644.51 kg fed^{-1}), No. of branches plant^{-1} (8.35 and 8.27) and seed yield plant^{-1} (27.91 and 28.21 g) resulted from I_3-treatment for the 1st and 2nd seasons, correspondingly, whereas, the minimum ones of the previously listed variables were met with I_1-treatment, in both growing seasons. Moreover, I_4-treatment produced the tallest height of canola and higher oil content in both seasons, compared with the I_1-treatment. The obtained results in the present study are close to those reported by (Hamzie, 2011, Xiao-bo etal, 2017 and Katuwal etal., 2020) according to what they said no significant difference in seed yield and oil percent in the seed of canola between irrigation 50% and 80% Etm, and the maximum values of the previously mentioned parameters were noted with 80% ETm, meanwhile, the minimum ones were recorded with 110 ETm. In comparison with I_1-treatment, seed yield fed^{-1} increased by (4.88 and 3.15%), and oil yield fed^{-1} by (5.62 and 4.22%) were recorded for I_3 and I_4 treatments, respectively, in the 1st season. The corresponding values of seed yield fed^{-1} (4.78 and 4.21%), and oil yield fed^{-1} (5.09 and 4.84%) were detected in the 2nd season. These outcomes somewhat correspond with the findings of Hamzie and Soltani (2012), Abd EL-Wahed and Ali (2013), and Thirkell etal., (2017).

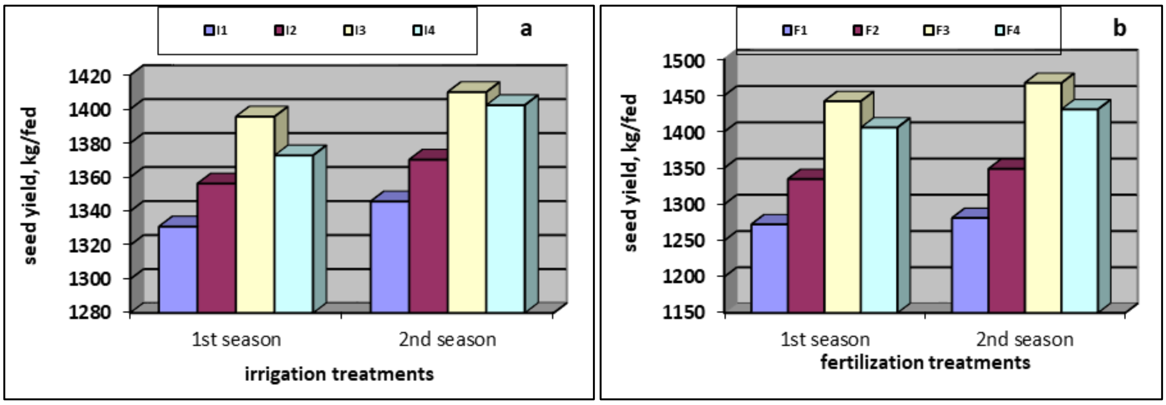


Fig. 3. Canola seed yield during the two growing seasons as a result of fertilisation treatments (b) and irrigation treatments (a).

Concerning the impact of different fertilizer combinations on canola yield and its constituents, data presented in Table 6 and Fig. 3 demonstrate that, with the exception of seed yield plant^{-1} in the first season, all yield and quality traits were highly significantly impacted by the various fertiliser combinations treatments in both seasons. The maximum values of plant height (156.87 and 156.82 cm), No. of branches/plant (8.69 and 8.78); oil content in seeds (46.62 and 46.61%) were recorded with F_4 treatment. Meanwhile, the maximum ones for seed yield /plant (28.84 and 29.35 g); seed yield (1442.23 and 1467.42 kg/ fed); oil yield (638.77 and 672.73 kg /fed) resulted from F_3-Treatment in both seasons, respectively. Also, data indicate that there is no significant differences between F_3 and F_4 treatments on most traits in both seasons.

Table 6. Canola crop yield and its constituent as influenced by fertilisation and irrigation treatments over the two seasons of growth.

Treatments	plant height, cm	no. of branches/plant	seed yield/ plant(g)	seed yield, kg fed^{-1}	Oil, % In seed	Oil yield, kg fed^{-1}
			1st season			
			Irrigation (I)			
I_1	138.35^{c}	8.17	26.61	1330.88	45.42	604.77
I_2	145.76^{b}	8.32	28.87	1356.15	45.64	619.31
I_3	145.66^{b}	8.35	27.91	1395.58	45.75	638.77
I_4	148.95^{a}	8.15	27.46	1372.75	45.90	630.31
F-Test	**	Ns	Ns	Ns	Ns	NS
			fertilization (F)			
F_1	135.08^{d}	7.38^{c}	27.19	1272.33^{c}	44.93^{d}	571.62^{c}
F_2	140.78^{c}	8.30^{b}	26.70	1334.83^{b}	45.30^{c}	604.79^{b}
F_3	145.99^{b}	8.61^{ab}	28.84	1442.25^{a}	45.85^{b}	661.28^{a}
F_4	156.87^{a}	8.69^{a}	28.19	1405.94^{a}	46.62^{a}	655.46^{a}
F-Test	**	**	Ns	**	**	**
			Interaction (I×F)			
$I_1 \times F_1$	132.60^{d}	6.80^{d}	25.08	1255.33	44.76	561.77
$I_1 \times F_2$	136.63^{d}	8.73^{a}	26.01	1300.67	45.03	585.72
$I_1 \times F_3$	140.43^{c}	8.70^{a}	28.04	1402.17	45.41	636.72
$I_1 \times F_4$	143.73^{cd}	8.43^{b}	27.31	1365.33	46.50	634.87
$I_2 \times F_1$	134.67^{d}	7.40^{c}	32.39	1269.33	44.90	569.81
$I_2 \times F_2$	138.90^{d}	8.20^{b}	26.28	1314.00	45.29	595.10
$I_2 \times F_3$	149.47^{b}	8.73^{a}	28.70	1435.17	45.77	656.99
$I_2 \times F_4$	160.00^{a}	8.93^{a}	28.12	1406.10	46.60	655.33
$I_3 \times F_1$	136.70^{d}	7.73^{c}	25.67	1283.33	45.00	577.41
$I_3 \times F_2$	140.87^{c}	8.27^{b}	27.43	1371.33	45.41	622.73
$I_3 \times F_3$	143.60^{c}	8.67^{a}	29.92	1496.00	45.89	686.62
$I_3 \times F_4$	161.47^{a}	8.73^{a}	28.63	1431.67	46.69	668.31
$I_4 \times F_1$	136.33^{d}	7.60^{c}	25.63	1281.33	45.08	577.48
$I_4 \times F_2$	146.73^{bc}	8.00^{b}	27.09	1353.33	45.49	615.61
$I_4 \times F_3$	150.47^{b}	8.33^{b}	28.71	1435.67	46.33	664.81
$I_4 \times F_4$	162.27^{a}	8.67^{a}	28.41	1420.67	46.70	663.33
F-TEST	**	*	Ns	Ns	Ns	Ns
			2nd season			
			Irrigation (I)			
I_1	138.13^{c}	8.13	26.91	1345.67	45.56	613.32
I_2	145.60^{b}	8.12	27.41	1370.25	45.67	626.05
I_3	146.20^{b}	8.27	28.21	1410.00	45.68	644.51
I_4	148.98^{a}	8.05	28.05	1402.33	45.82	643.02
F-Test	**	Ns	Ns	Ns	Ns	Ns
			Fertilization (F)			
F_1	135.40^{d}	7.18^{c}	25.62^{c}	1281.00^{c}	44.94^{d}	575.76^{c}
F_2	140.90^{c}	8.12^{b}	26.98^{b}	1348.85^{b}	45.33^{c}	611.42^{b}
F_3	145.79^{b}	8.58^{a}	29.35^{a}	1467.42^{a}	45.84^{b}	672.73^{a}
F_4	156.82^{a}	8.78^{a}	28.63^{a}	1431.00^{a}	46.61^{a}	667.00^{a}
F-Test	**	**	**	**	**	**
			Interaction (I×F)			
$I_1 \times F_1$	132.93^{d}	6.75^{d}	25.08	1254.00	44.69	561.57
$I_1 \times F_2$	135.93^{d}	8.53^{a}	26.27	1313.33	45.10	591.99
$I_1 \times F_3$	139.37^{cd}	8.93^{a}	28.24	1412.00	45.78	646.44
$I_1 \times F_4$	144.27^{cb}	8.67^{a}	28.07	1403.33	46.56	653.27
$I_2 \times F_1$	134.80^{d}	7.13^{d}	25.92	1296.00	44.90	582.08
$I_2 \times F_2$	139.47^{cd}	7.87^{c}	26.86	1343.00	45.35	609.05
$I_2 \times F_3$	149.27^{b}	8.40^{ab}	28.66	1432.32	45.84	656.42
$I_2 \times F_4$	158.87^{ab}	9.07^{a}	28.19	1409.67	46.59	656.66
$I_3 \times F_1$	137.47^{cd}	7.40^{c}	25.68	1284.00	44.45	577.08
$I_3 \times F_2$	141.13^{cb}	8.13^{ab}	27.37	1368.67	45.33	620.40
$I_3 \times F_3$	143.93^{cb}	8.77^{a}	30.83	1541.00	45.82	706.31
$I_3 \times F_4$	162.27^{a}	8.77^{a}	28.95	1446.33	46.62	674.26
$I_4 \times F_1$	136.40^{d}	7.47^{c}	25.80	1290.00	45.13	582.30
$I_4 \times F_2$	147.07^{b}	7.93^{c}	27.41	1370.33	45.55	624.24
$I_4 \times F_3$	150.60^{b}	8.20^{ab}	29.69	1484.33	45.92	681.74
$I_4 \times F_4$	161.87^{a}	8.60^{ab}	29.30	1464.67	46.68	685.81
F-TEST	**	*	Ns	Ns	Ns	Ns

NS, *, ** insignificant, significant at 0.5 and 0.01 level of probability, respectively. Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test. BioI=Rhizobacterien, BioII=phosphorien

I_1=cut-off 100%FL I_2=cut-off 90%FL I_3=cut-off 85% FL F_1=100% RNP

F_2=75%RN+ 100%RP+BioI F_3=100%RN+65%RP+BioII F_4=50%RNP+ BioI+BioII

In comparison with F_1 (recommended dose of NP) as control, seed yield /fed increased by (13.36 and 10.5%) and (14.53 and 11.71%) and oil yield fed^{-1} by (15.69 and 14.67%) and (16.84 and 15.85%) for F_3 and F_4 in both seasons, respectively. Because biofertilizers use atmospheric nitrogen and water as well as free solar energy, they have the potential to reduce the extensive use of mineral fertilisers and increase the efficiency of these fertilisers. This could explain the increase in canola seed yield and its associated qualities. (Abbas etal., (2006); Mahato etal., (2009), Megawer and Mahfouz (2010) and Soltan et al., 2018). Additionally, as N2-fixing bacteria, soil microorganisms like Azotobacter and Azosprillum may be able to help plants grow faster, produce more biological and reproductive organs, and have more productive organs overall (Awad etal., 2005; Ebrahimi etal., 2007, Yasari etal., 2008, and Omran etal., 2009). Thus, due to their relative benefits, low cost of fertilisation, and decreased soil pollution, the above-mentioned fertiliser treatments—especially F4 (which got half of the recommended amount of NP plus a blend of BioI + Bio II)—were desirable. With the exception of plant height (cm) and number of branches, plant-1 was extremely substantially affected by the interaction effect between watering treatments and the administration of biochemical fertilisers (Figs. 4 and 5). The outcomes aligned with the research conducted by Poraas EL-Din etal. (2008), Yasari etal. (2008), Megawer and Mahfouz (2010), Mahboobeh and Jahanfur (2012), Morteza and Javad (2013), Sharifi et al. (2011), Xiao-bo et al., (2017), and Khalifa (2020).

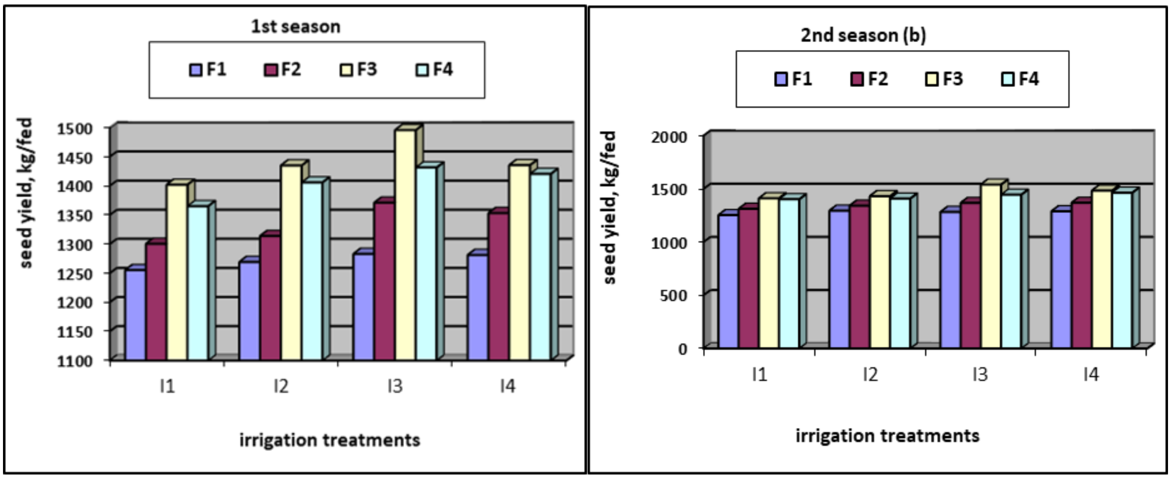


Fig. 4. Seed yield of canola crop as impacted by interaction between fertilization and irrigation treatments in both seasons

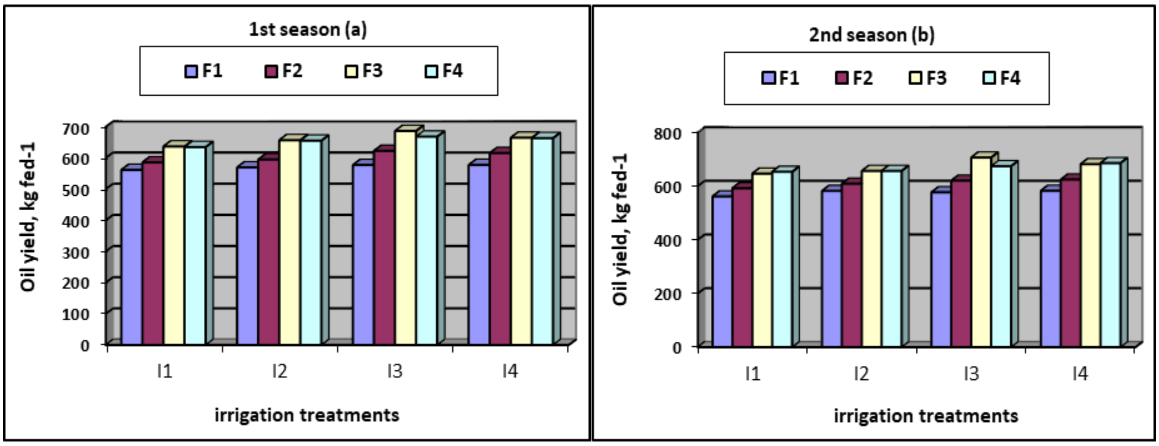


Fig. 5. Oil yield in seed of canola crop as impacted by interaction between fertilization and irrigation treatments in both seasons

I_1=cut-off 100%FL **I_2=cut-off 90%FL** **I_3=cut-off 85% FL** **F_1=100% RNP**

F_2=75%RN+ 100%RP+BioI **F_3=100%RN+65%RP+BioII** **F_4=50%RNP+ BioI+BioII**

Contribution of groundwater to Etc-canola crop (GWC)

Table 7 data indicate that as cut-off irrigation at 85% treatment and alternative irrigation rose during both growing seasons, the groundwater table's contribution to canola water requirements increased. The GWC's seasonal average values were (0.69 and 0.29 cm); (0.76 and 0.33cm), (0.82 and 0.38cm) and (1.45 and 0.77cm) for treatments I_1, I_2, I_3, and I_4 in both growing seasons, correspondingly. During both growing seasons, it was observed that I_4 (Alternative Furrow irrigation) produced the greatest values of GWC. The most plausible explanation for these findings is that throughout both seasons, the highest values of groundwater contribution % were attained as a result of the water table's contribution decreasing as the amount of applied water grew. Also, data shows that seasonal average values of GWC were slightly impacted by different combination treatments of biochemical fertilizers implementation in both growing seasons. Whereas, the average values were (0.99 and 0.48cm), (0.95 and 0.45cm), (0.91 and 0.43cm), and (0.87 and 0.41cm) for F_1, F_2, F_3, and F_4 respectively during both growing seasons. These findings are somewhat in accompanied with that recorded by Karimove etal., (2014), EL-Hadidi etal., (2016), and Khalifa (2019).

Table 7. The impact of irrigation and fertilisation treatments on groundwater contribution to ETc of canola crops throughout the two seasons

Fertilization (F)	F_1		F_2		F_3		F_4		Seasonal mean of irrigation regimes	
	GWC		GWC		GWC		GWC		GWC	GWC
Irrigation treatments (I)	cm	%	cm	%	cm	%	cm	%	cm	%
					1st season					
I_1	0.75	25.04	0.71	23.79	0.67	22.28	0.63	21.04	0.69	23.04
I_2	0.83	27.88	0.77	25.79	0.73	24.25	0.69	22.70	0.76	25.16
I_3	0.89	29.73	0.84	28.04	0.80	26.64	0.75	24.96	0.82	27.34
I_4	1.49	52.61	1.47	51.77	1.43	50.17	1.41	49.42	1.45	50.99
Seasonal mean of fertilization	0.99	33.82	0.95	32.35	0.91	30.84	0.87	29.53		
					2nd season					
I_1	0.31	12.66	0.29	11.54	0.28	11.41	0.26	10.62	0.29	11.56
I_2	0.38	15.58	0.34	13.91	0.31	12.66	0.29	11.54	0.33	13.24
I_3	0.41	16.83	0.40	16.15	0.37	15.03	0.34	13.91	0.38	15.48
I_4	0.82	33.92	0.77	31.78	0.75	31.07	0.73	30.08	0.77	31.71
Seasonal mean of fertilization	0.48	19.75	0.45	18.35	0.43	17.54	0.41	16.54		

F_1=100% of R_{NP}, F_2= 75% of R_N+ 100% of $R_{.P}$ +Rhizobacterien (BioI), F_3= 100% of R_N+ 65% of R_P+ Phosphorien (BioII), F_4= 50% of R_{NP} + mixture of BioI + Bio II
I_1=cut-off irrigation at 100%of FL I_2= cut-off irrigation at 90%of FL I_3= cut-off irrigation at 85%of FL I_4= Alternative Furrow irrigation

- **Economic analysis:**

Table (8) presents the entire cost of canola production, which includes both fixed and variable costs, for the two growing seasons based on the Egyptian local market price (L.E). Total cost differed among studied treatments according to different amount of bio and mineral fertilizers in both seasons. Certain components must be included in the economic assessment process in order for it to be carried out in both seasons (Table 9). Collected data indicates that the mixture of I_3-treatment (cutoff irrigation at 85% F L) and F_3-treat. (using 100% of R_N +65% of R_P +phosphorien) gave the maximum values of seasonal total revenue (22436.6 and 23115.45 L. E fed.$^{-1}$) ,net revenue (14296.6 and 14950.5 L.E/ fed.) and eonomic efficiency (1.76 and 1.83) in both seasons, respectively.M, net income from water unit for canola seed yield (7.72 and 8.06 L.E m^{-3}) were achieved with the combination between I_4-treatment (alternative furrow irrigation) and F_3-treatment (applying 100% of R_N+ 65% of R_P+ phosphorien) in both growing seasons, correspondingly. The lowest values of the aforementioned parameters were recorded with the combination of I_1 and F_1 treatments in both seasons. Therefore, based on an economical evaluation, the effects of irrigation schedules with F3 or F4 treatments on canola crops can be arranged in declining order; $I_3 > I_4 > I_2 > I_1$.

Table 8. Values of production cost components of canola seed yield / fed. for various treatments (L.E/ fed/) throughout both seasons

Cost items	Cost values for various agronomic operations (L.E)															
	I_1				I_2				I_3				I_4			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
Seeds	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
P, P_2O_5	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
K, K_2O	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
N,NH_4NO_3(33.5%)	425	318.75	425	212.5	425	318.75	425	212.5	425	318.75	425	212.5	425	318.75	425	212.5
Biofertilizers	-	15	15	30	-	15	15	30	-	15	15	30	-	15	15	30
Land rent	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
								Machinery cost, L.E								
Plowing	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170	170
Leveling	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230
Furrowing	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Irrigation	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
								Wages, L.E								
Planting	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Hoeing	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
Fertilizer broadcast	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Irrigation	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Spraying with trace element	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Harvesting	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Pesticide and manual weed control	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Total (cost 1st season)	8225	8133.8	8170	7945.5	8225	8133.8	8170	7942.5	8195	8103.8	8140	7912.5	8175	8083.8	8120	7892.5
Total cost (2nd season)	8250	8152.5	8195	7953.8	8230	8152.5	8195	7955	8220	8122.5	8165	7923.8	8200	8102.5	8145	7903.8

***Increasing seasonal total cost for the 2nd season belonged to increment the price of mineral fertilizers**
F1=100% of RNP, F2=75% of RN+ 100% of R.P + Rhizobacterien (BioI), F3= 100% of RN+65% of RP+ Phosphorien (BioII), F4=50% of RNP + mixture of BioI +Bio II
I1=cut-off irrigation at 100%of FL I2= cut-off irrigation at 90%of FL I3= cut-off irrigation at 85%of FL I4= Alternative Furrow irrigation
***Marketable price for 1kg canola seed = 15L.E**

Table 9. Economic analysis of canola seed yield as impacted by fertilization and irrigation treatments throughout the two growth seasons

Treatments Irrigation (I)	Fertilization (F)	Seed yield, kg fed^{-1}	Total revenue $LE.fed^{-1}$	Total* cost $LE.fed^{-1}$	Net revenue $LE.fed^{-1}$	Applied water m^3fed^{-1}	Net revenue from water unit, LE. m^{-3}	Economic efficiency
				1st season				
I_1	F_1	1255.3	18829.5	8225	10604.5	2180.22	4.86	1.29
	F_2	1300.7	19510.5	8133.8	11376.7	2178.54	5.22	1.40
	F_3	1402.2	21033.0	8170	12863	2176.86	5.91	1.57
	F_4	1365.3	20479.5	7945.5	12534	2175.18	5.76	1.58
I_2	F_1	1269.3	19039.5	8225	10814.5	2025.66	5.34	1.31
	F_2	1314.0	19710	8133.5	11576.5	2023.14	5.72	1.42
	F_3	1435.2	21528	8170	13358	2021.46	6.61	1.64
	F_4	1406.1	21091.5	7942.5	13149	2019.78	6.51	1.66
I_3	F_1	1283.3	19249.5	8195	11054.5	1950.48	5.67	1.35
	F_2	1371.3	20569.5	8103.8	12465.7	1948.80	6.40	1.54
	F_3	1495.8	22436.6	8140	14296.6	1948.12	7.33	1.76
	F_4	1431.5	21472.5	7912.5	13560	1945.02	6.97	1.71
I_4	F_1	1281.3	19219.5	8175	11044.5	1739.64	6.34	1.35
	F_2	1353.3	20299.5	8083.8	12215.7	1738.80	7.03	1.51
	F_3	1435.6	21534	8120	13414	1737.12	7.72	1.65
	F_4	1420.7	21310.5	7892.5	13418	1736.28	7.72	1.70
				2nd season				
I_1	F_1	1254.0	18810	8250	10560	2192.82	4.82	1.28
	F_2	1313.3	19699.5	8152.5	11547	2191.98	5.27	1.42
	F_3	1412.0	21180.5	8195	12985.5	2191.56	5.93	1.58
	F_4	1403.3	21049.5	7953.8	13095.7	2190.72	5.98	1.65
I_2	F_1	1296.0	19440	8230	11210	2055.9	5.45	1.36
	F_2	1343	20145	8152.5	11992.5	2054.22	5.83	1.47
	F_3	1432.7	21490.5	8195	13295.5	2052.96	6.48	1.62
	F_4	1409.6	21144	7955	13189	2052.12	6.43	1.66
I_3	F_1	1284.0	19260	8220	11040	1965.60	5.62	1.34
	F_2	1368.5	20527.5	8122.5	12405	1965.18	6.31	1.53
	F_3	1541.0	23115.5	8165	14950.5	1963.92	7.61	1.83
	F_4	1446.4	21696	7923.8	13772.2	1962.66	7.02	1.74
I_4	F_1	1290	19350	8200	11150	1755.18	6.35	1.36
	F_2	1370.3	20554.5	8102.5	12452	1753.08	7.10	1.54
	F_3	1484.3	22264.5	8145	14119.5	1752.24	8.06	1.73
	F_4	1464.8	21972	7903.8	14068.2	1751.14	8.03	1.78

marketable price for 1kg canola seed= 15 LE

F1=100% of R_{NP}, F2=75%of R_N+ 100% of R_P+ Rhizobacterien (BioI), F3= 100% of R_N+65% of R_P+ Phosphorien (BioII), F4=50% of R_{NP} + mixture of BioI +Bio II

I_1= cut-off irrigation at 100% of furrow length (check treatment), I_2= cut-off irrigation at 90% of furrow length, I_3= cut-off irrigation at 85% of furrow length, I_4= Alternative furrow irrigation.

*** Includes the cost of all agricultural operations (fixed and variables) such as: price of mineral fertilizers, bio-fertilizers addition and seeds. Machinery costs (plowing, scraping, land leveling, furrowing), labour wages for (planting, Hoeing, fertilizer broadcast, irrigation, pesticide and manual weed control and harvesting) and land rent, in both seasons.**

CONCLUSION

The current study's findings showed that One of the most effective strategies to increase canola crop productivity and create a better environment is to use biofertilizers in part place of NP-mineral fertilisers. Inoculation of canola seed with the combined use of Biofertilizers (Phosphorien + Rhizobactrien) and half recommended dose of mineral NP (F_4) and cutoff irrigation at 85% of FL (I_3) or Alternative furrow irrigation (I_4) were superior to other treatments, whereas achieved the maximum canola yield and its components additionally oil content in seeds and oil yield kg fed^{-1} and water saving. In addition, the benefit of ground water contribution for crops, which considered as a supplementary supply of irrigation water, particularly in light of Egypt's current water scarcity.

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استجابة نبات الكانولا لوقف جبهة الري والري التبادلي في خطوط بالتداخل مع استخدام الأسمدة الحيوية -المعدنية في أراضي شمال دلتا النيل

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الملخص

أجريت تجربة حقلية خلال الموسم الشتوي لموسمي ٢٠١٦/٢٠١٥ & ٢٠١٧/٢٠١٦ بمحطة البحوث الزراعية بسخا بمحافظة كفر الشيخ .والهدف من الدراسة هو دراسة وتقييم أربع نظم للري وهي إيقاف سريان مياه الري عند ١٠٠% (I_1) ، ٩٠% (I_2)، ٨٥% (I_3) من طول الخط والري التبادلي (I_4) (كمعاملات رئيسية)، اربع معاملات للتسميد الحيوي - المعدني كالتالي المعاملة الأولى F_1 (إضافة ١٠٠% من الجرعة الموصي بها من NP كنترول)، المعاملة الثانية F_2 (إضافة ٧٥% من الجرعة الموصي بها من N +١٠٠% من الجرعة الموصي بها من P+ ريزوباكتيرين كسماد حيوي)، المعاملة الثالثة F_3 (إضافة ١٠٠% من الجرعة الموصي بها من N +٦٥% من الجرعة الموصي بها من P + فوسفوريين)، المعاملة الرابعة F_4 (إضافة ٥٠% من الجرعة الموصي بها من NP+ خليط من الفوسفوريين +ريزوباكتيرين) علي إنتاجية الكانولا وبعض العلاقات المائية ، توفير مياه الري والعائد الاقتصادي. وأوضحت النتائج المتحصل عليها: يمكن ترتيب كلا من معاملات الري طبقا لكمية مياه الري المضافة والاستهلاك المائي الموسمي تنازليا كالتالي المعاملة الاولي > المعاملة الثانية > المعاملة الثالثة > المعاملة الرابعة. نسبة كمية المياه المتوفرة بواسطة المعاملة الثانية، الثالثة، الرابعة كانت ٦,٩٨، ١٠,٤٧، ٢٠,١١ % على الترتيب مقارنة بالمعاملة الاولي. كلا من معاملة الري الثالثة (I_3) ومعاملة التسميد الثالثة (F_3) تفوقا في زيادة إنتاج البذور والزيت لنبات الكانولا ومعظم مكوناته في كلا الموسمين. معاملة الري الرابعة (I_4) حققت اعلي القيم للإنتاجية المائية من الماء المستهلك (WP)، الإنتاجية المائية من مياه الري (IWP) لإنتاج البذور للكانولا، كفاءة كلا من مياه الري المضافة (WEA,%)، الاستهلاك المائي (Ecu,%) وتوزيع المياه (Ewd,%) وكذلك مساهمة الماء الأرضي للاحتياجات المائية لنبات الكانولا في كلا الموسمين. أوضحت النتائج ان التداخل بين معاملة الري الثالثة (I_3) ومعاملة التسميد الثالثة (F_3) أعطت اعلي القيم لكلا من العائد الموسمي الكلي، العائد الصافي والكفاءة الاقتصادية، بينما صافي العائد من وحدة المياه لإنتاج البذور قد تحصل عليه من الخليط بين معاملة الري الرابعة (I_4) ومعاملة التسميد الثالثة (F_3) في كلا الموسمين. لذلك يتضح من النتائج المتحصل عليها من هذه الدراسة انها ذات أهمية في تحسين و تطوير نظام الري السطحي في الأراضي الطينية في منطقة شمال الدلتا من خلال ري نبات الكانولا بالمعاملة الثالثة (وقف مياه الري عند ٨٥% من طول الخط أو الري بالمعاملة الرابعة (الري التبادلي) بالتداخل مع معاملة التسميد الرابعة (إضافة ٥٠% من الجرعة الموصي بها من النتروجين والفوسفور + الخليط من ريزوباكتيرين+ الفوسفورين) كأسمدة حيوية للحصول علي اعلي إنتاجية اقتصادية للكانولا وتوفير كلا من مياه الري والتسميد المعدني، كذلك العائد الاقتصادي . بالإضافة الي المساهمة الفعالة للماء الأرضي في الاحتياجات المائية لمحصول الكانولا والتي لها أهمية عظمي كمصدر إضافي لمياه الري خاصة تحت ظروف نقص المياه في مصر.