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Effect of irrigation systems and deficit irrigation level on the root-zone water status, seed yield and water Productivity of canola under Egypt climatic conditions

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FIELD experiments were conducted during two canola cultivation seasons at the experimental farm of the National Research Centre, El-Nubaria, Al- Buhayrah governorate in northern Egypt. The experimental design and treatments were split plot with three replications. Irrigation systems (Sprinkler Irrigation system and Drip Irrigation system) in main plots and deficit irrigation levels (I100:100% Full Irrigation "FI", I90: 90%FI, I80: 80% FI, I70: 70%FI, I60: 60%FI and I50: 50% FI) were used in sub main plots. The results of the statistical analysis showed that the highest value of moisture content within the root zone of canola plants, corresponding to the lowest water stress, was achieved with sprinkler irrigation at 100% of the full irrigation. It was also clear that the lowest value of soil moisture content was achieved with drip irrigation at 50% of the full irrigation. In addition, the highest crop productivity was achieved with sprinkler irrigation at 100%, then 90%, and then 80% of the full irrigation. There were no significant differences between them. As a result of the above, it is recommended using sprinkler irrigation with 80% of the full irrigation and save 20% of the irrigation water requirements for canola. It was also clear that the lowest productivity was achieved with drip irrigation at 50% of the full irrigation. The best value of water productivity was obtained when irrigating with a sprinkler irrigation system using 80% of the full irrigation. This value had no significant difference against the highest value of productivity when irrigating with sprinkler irrigation at 100% of the full irrigation, Finally, the highest oil content and yield values for canola seeds were achieved with sprinkler irrigation at full irrigation. The lowest canola oil content and yield values were achieved with drip irrigation at 50% of the full irrigation requirement

Keywords: Drip Irrigation, Sprinkler irrigation, Water Productivity, Deficit irrigation strategy, Canola, Water stress.

1. Introduction

Lack of water is one of the main challenges to food production in Egypt. To rationalize and lower the use of irrigation water (IW), it is crucial to use efficient irrigation systems (Okasha et al., 2013; El-Metwally et al., 2015; Eid et al., 2013). Producing more food with less water is Egypt's agricultural challenge. This objective can be attained in part by increasing agricultural yield per unit of water used. Increasing agricultural production per unit of water used, known as water productivity, is crucial to meeting the rising demand for food brought on by population expansion (Dewedar et al., 2023; Bakry et al., 2012; Eid and Negm 2019; Okasha et al., 2016). There is a serious water deficit in Egypt, and competition for the limited available water supplies is intensifying. New irrigation techniques are required to raise the productivity of field crops (Marwa et al., 2017; Hozayn et al., 2016). In Egypt, where average rainfall is rather low, crop yield per unit of water is important (Abdou et al., 2024; Hozayn et al., 2016; Ayman et al., 2023; Abdelraouf, Abuarab 2012; Hozayn et al., 2013). In Egypt

rainfall averages 12 mm per year, with variations ranging from 0 mm in desert regions to 200 mm in northern coastal areas. Water-saving technologies like micro-irrigation and similar methods should be promoted in semi-arid regions like Egypt so that some of the irrigation water (IW) can be saved for the development of new areas (Awad et al., 2024; El-Habbasha et al., 2014; Abdelraouf et al., 2019).

Producing enough high-quality food while limiting adverse environmental effects and lowering external inputs is one of the largest difficulties facing agriculture today. High crop yield can result from intensive conventional agriculture (Ahmed et al., 2024; Abdelraouf et al., 2021; Eid and Negm 2019). Around the world, the production of agricultural products is limited to varied degrees by a lack of high-quality water, especially in arid and semi-arid

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regions. Severe drought stress is a threat to about 1.2 billion hectares of rain-fed agricultural land worldwide (Passioura, 2007 and Haq et al., 2014; Eid et al., 2023; Ramadan 2016). Therefore the is much interest in conducting research on crops that can produce acceptable yield under water deficit (Khan et al., 2009; Ramadan et al., 2020; Sabra et al., 2023; Sinaki et al., 2007; Marwa et al., 2023; Sahar et al., 2021). To establish when a shortage or excess of water may result in a decline in production, it is imperative to comprehend how each crop responds to varying amounts of applied water, this will allow for the proper management of irrigation (Bernardo et al., 2006; Abdelraouf and Ragab 2018 a, b). The primary causes of the decline in the amount and quality of water available are identified as environmental degradation. This underscores the necessity of employing effective irrigation techniques and alternative water resources, particularly in arid and semiarid areas (Rebouças et al., 2010; Abdelraouf et al., 2016; Alhashimi et al., 2023).

The water deficit affects many processes in the crop, although most of the effects are related to the reduction in growth, the most sensitive process, and to stomatal closure.

High oil output is a characteristic of the canola crop. Its seeds have between 30 and 45 percent oil (Oad et al., 2001). Additionally, seed development, oil contents, and grain production were negatively impacted by water stress during the blooming and grain filling periods (Faraji et al., 2009). Irrigation boosted oil content in dry years, while it had no effect in years with above-average precipitation.

An oil-bearing crop with a global appeal, canola (Brassica napus) is significant for diet and nutrition. In response to water deficiency stress during growth stages, the Brassica exhibits significant heterogeneity within the species. Certain spring canola cultivars' blooming to seed and silique ripening duration were adversely affected by water deficiency situations. From anthesis to ten days after seed filling in silique, canola is vulnerable to water shortage. Time and the intensity of stress had a significant impact on the variation of phenology and phenology-related features (Alyari et al., 2000). After palm and soybean, canola (Brassica napus L.), a member of the crucifer family, is the third most widely grown oilseed crop globally (Takashima et al., 2013). Canola can be utilized as green manure, in industry, or as human nourishment (Sprague et al., 2016). Canola is mostly used in Europe for industrial processes like making biodiesel. However, canola is utilized to produce food in Brazil (Milazzo et al., 2013).

Therefore, the objective of this work is to evaluate yield, oil content and oil yield of canola plants subjected to water deficit under sprinkler and drip irrigation systems.

1.Materials and methods

The irrigation system and study site: Field tests were carried out at the National Research Center's experimental farm in El-Nubaria, Al-Buhayrah governorate in northern Egypt over the course of two canola growing seasons (Figure 1). The farm is located at latitude 30° 30'1.4" N, longitude 30° 9' 10.9" E, and its mean elevation above sea level is 21 meters. The climate of the experimental region is semi-arid, with hot, dry summers and mild winters. The local weather station at El-Nubaria Farm provided the maximum and minimum temperature, relative humidity, and wind speed data.

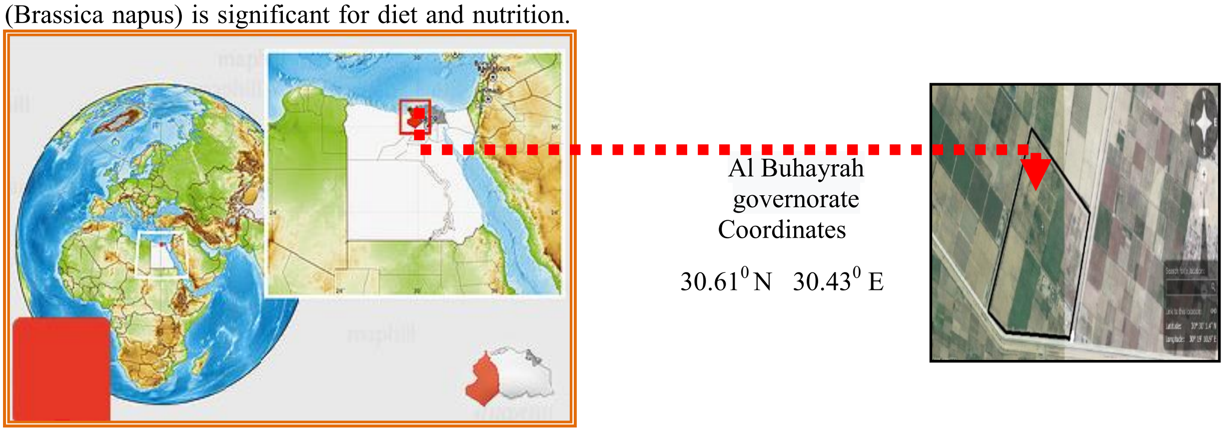

Fig. 1. Location of study region in Al Buhayrah governorate in Egypt.

Irrigation system components: The irrigation system was made up of a pumping system, a filtration unit, and a control pressure head, a 45 m^3/h centrifugal pump, a screen filter, a backflow prevention device, a pressure regulator, pressure gauges, control valves, and a flow meter. The water was transported from the source to the primary control sites in the field via the main line, a 110 mm outer diameter (OD) polyvinyl chloride (PVC) pipe. PVC pipes with a 75 mm OD served as sub-main lines that were connected to the main line. The sub-main line, control valves, and discharge gauges were linked to manifold lines, which are polyethylene (PE) pipes with an OD of 63 mm. The emitters were constructed in 50-meter-long, 16 mm (OD) lateral PE tubes. At 1.0 bar operating pressure, the emitters' discharge rate was 4 l/h, and their distance from one another was 30 cm. The sprinklers in the sprinkler irrigation system had a flow rate of 1.2 m^3/h and were spaced 12 m apart.

The physical and chemical characteristics of irrigation water and soil: 87.4% sand, 7.9% silt, and 4.7% clay make up the sandy soil texture; the pH is 7.8, the salinity is measured by electric conductivity, the EC is 1.68 dS/m, and there is 0.44% organic matter in the top 30 cm of the soil. Extractable Fe, Mn, and Zn levels were 2.98, 1.74, and 0.66 mg/kg soil, respectively, while available soil N, P, and K amounts were 17.1, 4.4, and 26.0 mg/kg soil, respectively. Table (1) displays the chemical properties of irrigation water.

Canola water requirements*:* For 2022/2023 and 2023/2024, the seasonal irrigation needs for canola were determined. Table (2) provides a summary of the seasonal irrigation water applied for the two irrigation systems under investigation, which was derived from Equations 1 and 2. The period between irrigations for both irrigation systems was two days.

Where Kc = the crop coefficient of canola under Egyptian conditions was 0.57 in the middle of the initial growth stage, 1.15 in the middle of the maturity stage, and 0.73 at the end of the final stage, Kr = ground cover reduction factor, IRg = gross irrigation requirements, mm/day, and ETo = reference evapotranspiration, mm/day (calculated from the Central Laboratory for Climate-Agricultural Research Center Egyptian Ministry of Agriculture at El-Nubaryia farm and according to the Penman-Monteith equation (Allen et al., 1998) as shown as Figure 2), Ei =%, irrigation efficiency and it was 85% for sprinkler irrigation and 95% for drip irrigation, R is the amount of water that the plant receives from sources other than irrigation, such as rainfall, millimeters, LR is the amount of water (in millimeters) needed for salt leaching.

Experimental Design: Experimental design and treatments were split plot with three replications. Irrigation systems (Sprinkler Irrigation system and Drip Irrigation system) in main plots and deficit irrigation scheduling (I100:100% Full Irrigation "FI", I90: 90%FI, I80: 80% FI, I70: 70%FI, I60: 60%FI and I50: 50% FI) were used in sub main plots.

Field Measurements:

Water stress the root-zone: Soil moisture in the root zone was measured before each irrigation during the growing season (Figure 3). The difference between the soil moisture content at field capacity and the wilting point is the maximum amount of water that can be used. The ratio of current water availability (the difference between current and wilting point soil moisture) to maximal water availability is used to compute water stress (WS) (Abdelraouf et al., 2020 a,b,c).

Yield and yield component of canola: From every plot, a 100 × 100 cm random section was taken. Before being converted to kg/ha, the canola yield was obtained in kg/m^2.

Water productivity of canola: ″WP_{canola}″*:* The water productivity of canola seed was calculated according to James (1988) as follows:

$$\mathbf{WP_{canola} = Ey/Ir} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where WP_{canola} is water productivity ($kg_{canola}\ m^{-3}_{water}$), Ey is the economical yield (kg_{canola} /ha); Ir is the amount of applied irrigation water (m^3_{water}/ha/season). Seed oil content (%) was used to compute oil yield (kg/ha). Using petroleum ether at 40°C to 60°C b.p., the Soxhlet apparatus calculated the percentage of seed oil in accordance with AOAC, (1970).

Statistical Analysis: In accordance with Snedecor and Cochran (1982), a combined analysis of the data for the two growing seasons under study was conducted. The means of the various treatments were compared using the values of least significant differences (L.S.D. at the 5% level).

Table 1. Chemical characteristics of the irrigation water.

pH	EC (dSm^{-1})	Cations and anions (meq/l)								SAR
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
7.15	0.45	1.43	0.63	2.62	0.33	--	0.12	1.73	1.44	2.7

EC= Electrical Conductivity SAR= Sodium Adsorption Ratio

Table 2. Seasonal irrigation requirements for canola crop under sprinkler and drip irrigation systems.

Irrigation Systems	Equations	m^3/ha/season	
		2022/2023	2023/2024
Sprinkler irrigation system	IRg =[[ET_O x Kc] / Ei] - R + LR …………..(1)	3600	3500
Drip irrigation system	IRg = [[ET_O x Kc x Kr] / Ei] - R + LR ……….(2)	2900	2800

FI: Full Irrigation

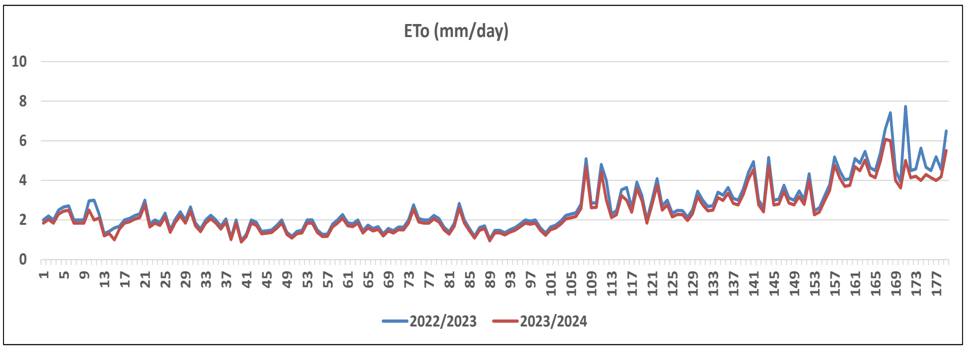

Fig. 2. Evapotranspiration rate in the study area during the canola growth period.

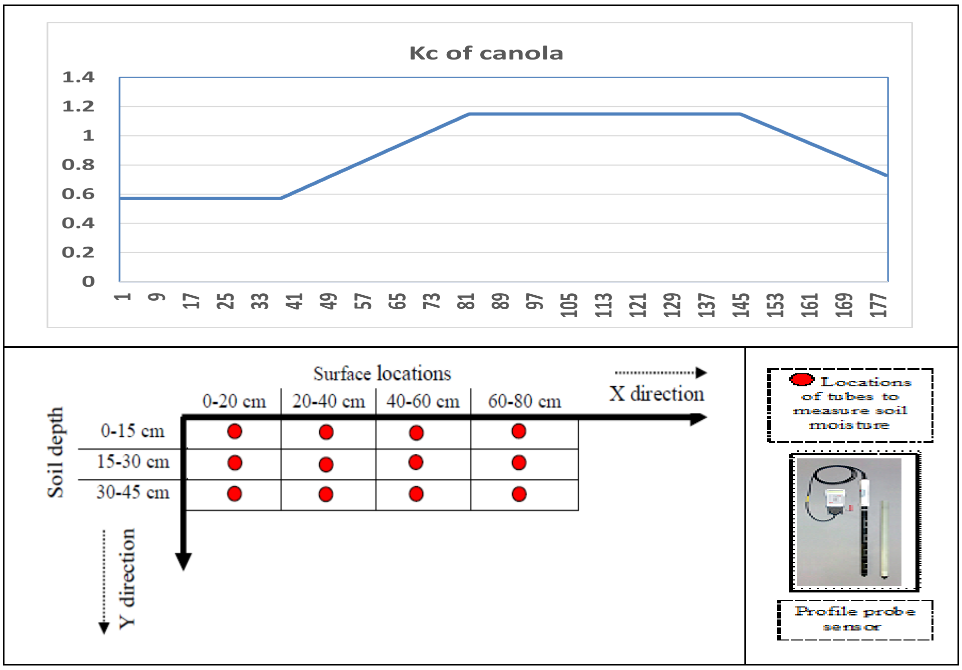

Fig. 3. Measuring average moisture content within the root zone before irrigation during the four stages of canola plant growth (179 day).

Results and Discussion

Water stress of the root-zone

The data presented in Figure (4) demonstrates the significant effect of sprinkler and drip irrigation systems, in addition to the effect of deficit irrigation strategy, on the average soil moisture content within the root zone before each irrigation during the two canola growth seasons.

Figure (4) shows an increase in soil moisture content values under the sprinkler irrigation system compared to the drip irrigation system, resulting in a decrease in water stress within the root zone. This is likely due to the uniformity of the soil moisture content resulting from the uniform downward movement of irrigation water under the sprinkler irrigation system, while the movement of irrigation water differed under the drip irrigation system.

Figure (4) demonstrates a significant increase in moisture stress with a decrease in the amount of irrigation water applied within the root zone of canola plants. The average soil moisture content values before irrigation were highest when the irrigation was 100% of the full irrigation (FI), while the soil moisture content was lowest when the irrigation was 50% FI. This was expected, since increasing the volume of irrigation water applied covered a larger wetted volume within the root zone, which meant a decrease in moisture stress, while decreasing the volume of irrigation water applied resulted in a decrease in soil moisture content and an increase in the degree of stress on the roots of the planted crop.

From Figure (4), it is clear that the highest value of moisture content within the root zone of canola plants, corresponding to the lowest water stress, was achieved with sprinkler irrigation at 100% of the crop water requirement, CWR. It was also clear that the lowest value of soil moisture content was obtained with drip irrigation at 50% of the CWR.

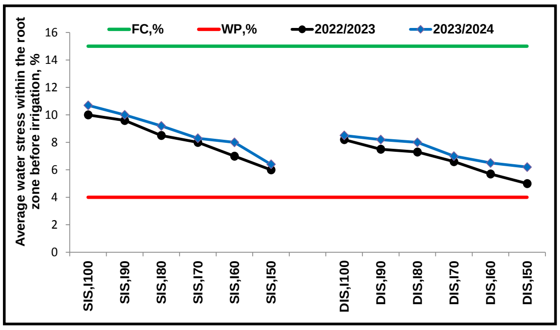

Fig. 4. Effect of irrigation systems and water deficit strategy on the average water stress of root-zone of canola plants before each irrigation process (SIS: Sprinkler. Irrigation System; DIS: Drip Irrigation System; FC: Field Capacity; WP: Welting Point).

Yield and yield component

The data presented in Figure (5) and Table (3) represent the productivity data obtained as a result of the study. They demonstrate the significant effect of sprinkler and drip irrigation systems, as well as the deficit irrigation strategy, on canola seed yields obtained after each harvest.

In Figure (5) and Table (3), canola seed yield values were significantly higher under the sprinkler irrigation system compared to the drip irrigation system. This was due to improved moisture content with the sprinkler irrigation system, which was accompanied by lower water stress values, resulting in increased water and nutrient uptake rates, which positively impacted productivity. Meanwhile, there was significant water stress in the root zone with the drip irrigation system, which reduced water and nutrient uptake rates, resulting in lower productivity values. With further explanation, it can be said that the reason why sprinkler gave a better yield might be achieve better yields may be due to the positive effects of the method of water application to the soil when irrigating crops. Sprinkler irrigation mitigates the dry conditions around the plants (improving microclimate). Sprinkler irrigation also enhances photosynthesis by washing away dust that prevents full sunlight from reaching the leaves. With sprinkler irrigation, water falling on sandy soil moves in a unidirectional downward direction, pushing salts down to the root zone. Sprinkler irrigation generally has a low and almost equal impact on water stress. Although drip irrigation is more efficient in water distribution, it has some drawbacks. Drip irrigation increases salt accumulation in the soil, which has a greater impact on salt stress on the plants. This requires increasing the washing coefficient and increasing the volume of water applied to achieve salt balance in the root zone before planting and irrigation.

In general, crop productivity values decreased with the decrease in the amount of irrigation water applied. The yield data presented in Figure (5) and Table (3) showed a decrease in yield values with the decrease in the amount of irrigation water applied within the root zone of canola plants. This may have been due to increased water stress with the decrease in the amount of irrigation water applied. The highest yield values were achieved when irrigated with 100% of the CWR, while the lowest yield values were achieved when irrigated with 50% of the CWR. Statistical analysis of the yield data revealed no significant differences in yield values at 100%, 90%, and 80% of the CWR. This may have been due to the close and interconnected relationship between water stress and nutrient stress, i.e., the concentration of nutrients in the root zone. When irrigated with 100% of the CWR, the lowest level of water stress was achieved and a decrease in nutrient concentration, i.e., an increase in nutrient stress, while when irrigated with 80% of CWR, a balance between water stress and nutrient stress, i.e., an increase in nutrient concentration with a lower amount of water applied was achieved (Abdelaal et al., 2025; Kassab et al.,2025; Saad et al., 2025).

From Table (3) it is clear that the highest crop productivity was achieved with sprinkler irrigation at 100%, then 90%, and then 80% of the CWR. There were no significant differences between them. As a result of the above, it is recommended to use sprinkler irrigation with 80% of the CWR for saving 20% of irrigation water for canola. It was also clear that the lowest productivity was achieved with drip irrigation at 50% of the CWR.

Water productivity of canola

The data presented in Figure (6) and Table (4) represent the data of canola water productivity. The data demonstrated the effect of sprinkler and drip irrigation systems, as well as the deficit irrigation strategy, on canola seed water productivity. This was obtained by weighing the yield of each season for each treatment and dividing the yield by the total volume of irrigation water applied during the entire growing season from planting to harvest.

In Figure (6) and Table (4), the canola water productivity values were higher under the drip irrigation system compared to the sprinkler system. This is due to the greater total volume of irrigation water applied to canola plants under the sprinkler system compared to the drip irrigation system.

Canola water productivity values fluctuated with decreasing irrigation water application volume. This may be attributed to changes in crop yield values and changes in the amount of irrigation water applied, as water productivity values are related to changes in both yield values and the volume of irrigation water applied.

From Table (4), the best value of productivity was obtained when irrigating with a sprinkler irrigation system with the addition of 80% of the CWR, at which the productivity value has no significant difference between it and the highest value of productivity when irrigating with sprinkler irrigation with the addition of 100% of the CWR,

Oil content and oil yield of canola

The data presented in Figure (7) and Table (5) represent the data on the oil content and yield values . The effect of the sprinkler and drip irrigation systems, as well as the deficit irrigation strategy, on the oil content and yield of the canola seed crop was demonstrated after each season's harvest and the canola seed oil extraction process.

In Figure (7) and Table (5), the oil content and yield values of canola seeds were significantly higher under the sprinkler irrigation system compared to the drip irrigation system. This may be due to the improved moisture content with the sprinkler irrigation system, which was accompanied by less water stress, resulting in increased water and nutrient uptake rates, which positively impacted the increase in canola seed oil content and yield. Meanwhile, the drip irrigation system experienced significant water stress in the root zone, which reduced water and nutrient uptake rates, resulting in lower canola seed oil content and yield values.

In general, the oil content and yield values of canola seeds decreased with decreasing irrigation water volume. Data on oil content and yield values in Figure (7) and Table (5) show a decrease in oil content and yield values with decreasing irrigation water volume. This is due to the increased water stress due to the decrease in the volume of irrigation water applied. The highest yield values were achieved with 100% of the CWR, while the lowest yield values were achieved with 50% of the CWR.

From Table (5) it is clear that the highest oil content and yield values for canola seeds were achieved with sprinkler irrigation at 100% of the CWR. The lowest canola oil content and yield values were achieved with drip irrigation at 50% of the CWR.

Conclusion

Two field experiments were run to evaluate the response of yield, water productivity and oil yield of canola plants grown under sprinkler or drip irrigation systems. The results of the statistical analysis showed that the highest value of moisture content within the root zone, corresponding to the lowest water stress, was achieved with sprinkler irrigation at 100% of the full irrigation. It was also clear that the lowest value of soil moisture content was achieved with drip irrigation at 50% of the full irrigation. In addition, the highest crop productivity was achieved with sprinkler irrigation at 100%, then 90%, and then 80% of the full irrigation. There were no significant differences between them. As a result of the above, it is recommended to use sprinkler irrigation with 80% of the full irrigation for canola. It was also clear that the lowest productivity was achieved with drip irrigation at 50% of the full irrigation. Finally, the highest oil contents and yield values for canola seeds were achieved with sprinkler irrigation at 100% of the full irrigation, while the lowest canola oil contents and yield values were obtained with drip irrigation at 50% of the full irrigation requirement.

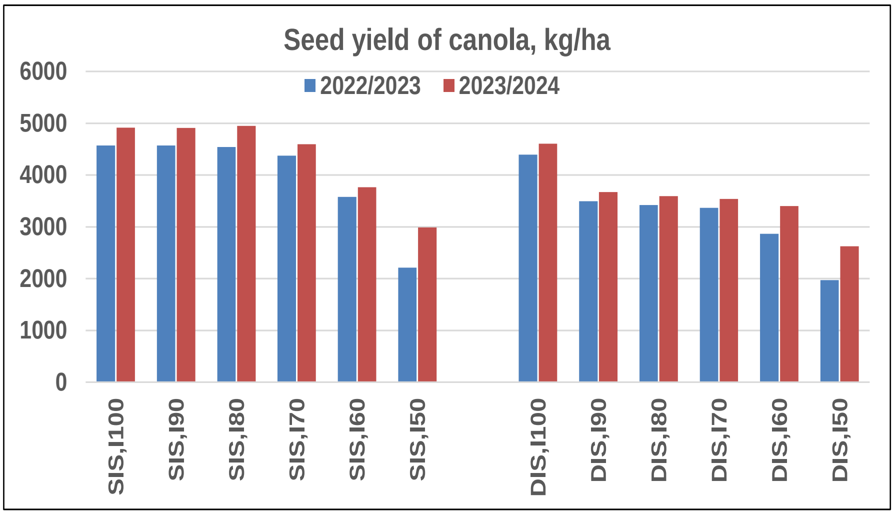

Fig. 5. Effect of irrigation systems and deficit irrigation strategy on the yield of canola (SIS: Sprinkler Irrigation System; DIS: Drip Irrigation System).

Table 3. Effect of irrigation systems and deficit irrigation scheduling on the biological, straw, grain yield and water productivity of canola.

IS	Deficit Irrigation level, %	Biological yield, ton/ha		Straw yield, ton/ha		Grain yield, kg/ha	
		2022/2023	2023/2024	2022/2023	2023/2024	2022/2023	2023/2024
SIS		8563 a	8764 a	4622 a	4537 a	3975 a	4353 a
DIS		7030 b	7272 b	3779 b	3699 b	3251 b	3573 b
LSD at 5%		128.6	167.9	134.8	183	91.23	124
	100	8884 a	9240 a	4370 a	4480 a	4480 a	4760 a
	90	8299 b	8632 b	4299 ab	4435 b	4033 b	4292 b
	80	8074 c	8398 c	4193 b	4352 c	3981 b	4271 b
	70	7883 d	8199 d	4013 c	4191 d	3870 c	4066 c
	60	7166 e	7454 e	3944 c	3871 e	3222 d	3583 d
	50	6475 f	6185 f	4382 a	3380 f	2093 e	2806 e
LSD at 5%		99.92	105	117	42.86	92.48	84.28
SIS	100	9450 a	9830 a	4814 a	4917 a	4569 a	4913 a
	90	9270 b	9643 b	4765 a	4922 a	4572 a	4910 a
	80	9020 c	9382 c	4678 a	4884 a	4542 a	4947 a
	70	8807 d	9161 d	4434 b	4682 b	4373 b	4594 b
	60	7937 f	8255 f	4358 b	4489 c	3579 c	3766 c
	50	6894 i	6314 k	4680 a	3326 i	2214 f	2988 g
DIS	100	8317 e	8651 e	3926 cd	4044 d	4391 b	4607 b
	90	7327 g	7621 g	3833 de	3947 e	3494 cd	3673 cd
	80	7128 h	7414 h	3709 ef	3820 f	3419 d	3594 de
	70	6958 i	7238 i	3591 fg	3699 g	3367 d	3538 e
	60	6396 j	6652 j	3530 g	3253 j	2866 e	3399 f
	50	6055 h	6056 l	4084 c	3433 h	1971 g	2623 h
LSD at 5%		141.3	148.6	165.4	60.62	130.8	119

IS: Irrigation Systems, SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System

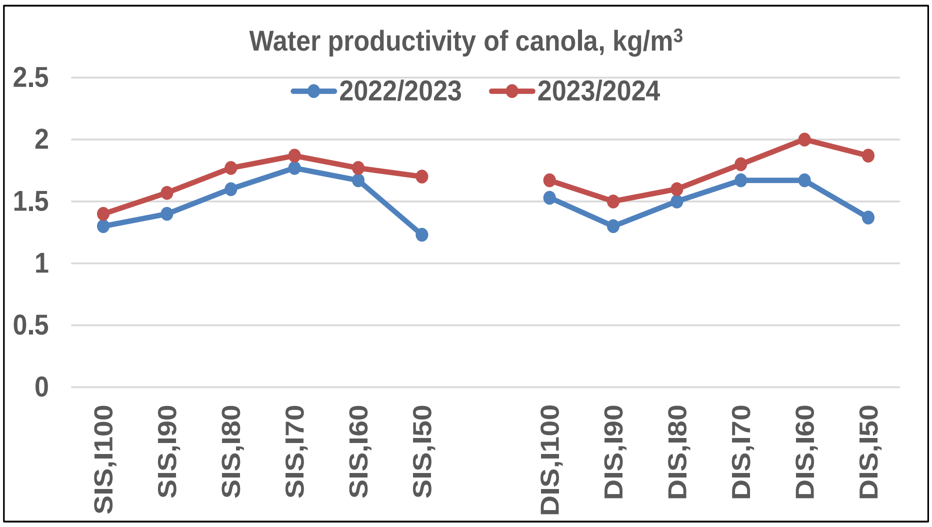

Fig. 6. Effect of irrigation systems and deficit irrigation strategy on the water productivity of canola (SIS: Sprinkler Irrigation System; DIS: Drip Irrigation System).

Table 4. Effect of irrigation systems and deficit irrigation level on the grain yield and water productivity of canola.

IS	Deficit Irrigation level, %	Grain yield, kg/ha		Water productivity of canola, kg/m^3	
		2022/2023	2023/2024	2022/2023	2023/2024
SIS		3975 a	4353 a	1.48	1.68
DIS		3251 b	3573 b	1.50	1.74
		91.23	124		
	100	4480 a	4760 a	1.42	1.53
	90	4033 b	4292 b	1.35	1.53
	80	3981 b	4271 b	1.55	1.68
	70	3870 c	4066 c	1.72	1.83
	60	3222 d	3583 d	1.67	1.88
	50	2093 e	2806 e	1.30	1.78
		92.48	84.28		
SIS	100	4569 a	4913 a	1.30	1.40
	90	4572 a	4910 a	1.40	1.57
	80	**4542 a**	**4947 a**	**1.60**	**1.77**
	70	4373 b	4594 b	1.77	1.87
	60	3579 c	3766 c	1.67	1.77
	50	2214 f	2988 g	1.23	1.70
DIS	100	4391 b	4607 b	1.53	1.67
	90	3494 cd	3673 cd	1.30	1.50
	80	3419 d	3594 de	1.50	1.60
	70	3367 d	3538 e	1.67	1.80
	60	2866 e	3399 f	1.67	2.00
	50	1971 g	2623 h	1.37	1.87
		130.8	119		

IS: Irrigation Systems, SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System

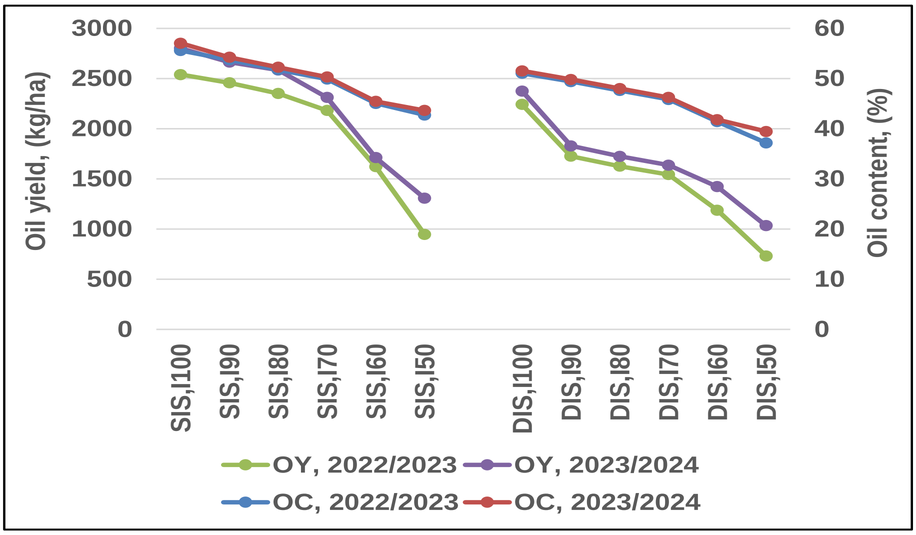

Fig. 7. Effect of irrigation systems and deficit irrigation strategy on the oil content (OC) and oil yield (OY) of canola (SIS: Sprinkler Irrigation System; DIS: Drip Irrigation System).

Table 5. Effect of irrigation systems and deficit irrigation scheduling on the oil content and oil yield of canola.

IS	Deficit Irrigation level, %	Oil content, (%)		Oil yield, (kg/ha)	
		2022/2023	2023/2024	2022/2023	2023/2024
SIS		49.78 a	50.48 a	2014 a	2230 a
DIS		45.41 b	46.13 b	1509 b	1670 b
LSD at 5%		0.62	1.23	30.48	71.35
	100	53.30 a	54.28 a	2390 a	2588 a
	90	51.57 b	52.02 b	2091 b	2246 b
	80	49.67 c	50.12 c	1988 c	2154 c
	70	47.85 d	48.27 d	1862 d	1974 d
	60	43.22 e	43.62 e	1400 e	1567 e
	50	39.95 f	41.53 f	839 f	1170 f
LSD at 5%		1.09	1.23	69	75.08
SIS	100	55.57	57.03	2539 a	2802 a
	90	53.73	54.23	2457 a	2663 b
	80	51.73	52.23	2350 b	2584 b
	70	49.87	50.30	2181 c	2311 c
	60	45.03	45.43	1621 e	1712 e
	50	42.73	43.63	946 g	1306 g
DIS	100	51.03	51.53	2241 c	2375 c
	90	49.40	49.80	1726 d	1829 d
	80	47.60	48.00	1626 e	1724 de
	70	45.83	46.23	1543 e	1636 e
	60	41.40	41.80	1187 f	1422 f
	50	37.17	39.43	732 h	1033 h
LSD at 5%		N.S.	N.S.	97.81	106.2

IS: Irrigation Systems, SIS: Sprinkler Irrigation System, DIS: Drip Irrigation System.

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