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Influence of irrigation deficit and humic acid on soil and canola growth characters and water use efficiency

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Abstract: The objective of the present study was to determine the effect of humic acid (HA0, HA1 and HA2) application on the some soil and canola plant characters to water stress under three different irrigation treatments designated as a percentage from evapo-transpiration as mild (IR 1) and slight (IR 2), full irrigation (IR 3) with no water stress treatments.
The results showed that different irrigation levels applied has statisticallysignificant effect on yield components such as plant height,no of branches./plant,no of leaves/plant, leaves area, root length, fresh and dry weight for root and shoot, weight 100 seeds. Application of HA increased aggregate sizes towards the large one so there was an accumulation in sizes over 2 mm increase and the opposite was true in case of <1mm. Increasing HA by application unite could decrease hydraulic conductivity values by -11.7 and -23.0 % over untreated plot. Seed yield and Oil yield (kg/fed), the increase in oil content was associated with increasing HA and/or IR treatments and increasing IR led to increase oil content by 0.7 and 10.5 % for IR 2 and IR 3 by comparing with IR1. There is an increase occurred at HA_2 over control with 3.2%, but this rate decreased to – 10.4% at HA_3 treatment. The highest values were 2.06 kg seed/m^3 irrigation water (IR1-HA_2) followed by 1.55 kg seed/m^3 (IR2-HA_2). Same trend was attained in case of WUE for oil and could be ranked in the following ascending order IR1-HA_2> IR2-HA_2> IR3-HA_2. Oil WUE percentage of increased were 97, 32 and 159 % in same sequences. But the negative effect of HA application was observed in case of WUE of seed and oil where increase HA from HA_0 till HA_2 decreased WUE of oil by about 26, 55 and 23, 60 % comparing with HA_1 and HA_2 with HA_0, respectively.
Keywords: sandy loam, soil properties, canola, growth characters, oil content, WUE.

Introduction

Canola (*Brassica napus* L.) is an oil seed crop that developed in western Canada from a humble beginning in the mid 1940s to almost 5 million seeded hectares per year by the end of the century[1] and it is now the third most important source of vegetable oil in the world. Egypt is one of the top vegetable oil importers in the world (90 % from its need). So canola could coverage the shortage and contributes to solve not less than 70 % of this gape.

Egypt population will be increasing progressively and to reduce the food insecurity, crop production will have to be not only doubled but also increased productivity from irrigation unite and it can expand cultivable area[2,3]. Crop production is the basis of certain nutrients for human life which depends on amount of available nutrient in the soil. Utilization of organic-mineral fertilizers such as humic substances in agriculture has increased in recent years[4]. Physically, it promotes good soil structure and increases the water holding capacity of the soil; biologically it enhances the growth of useful soil organisms, while chemically it serves as an adsorption plant nutrient. Also, it is hydrophilic groups attract hydration, thus increasing the water retention capacity in soils and they have been shown to stimulate plant growth and consequently yield[5,6]. Improvement of soil conditions and establishing equilibrium among plant nutrients are also important for soil productivity and plant production. Mansour, et al [7]mentioned that humic acid(HA) affect directly and indirectly on soil physical (water constant and water flow) and chemical properties.

Aşik et al.[7] reported that soil application of humus increased the N uptake of wheat and it used as bio-fertigation of microbial inoculums and HA could be used as a complementary for mineral fertilizers to improve yield and quality of cowpea under sandy soil conditions [8]. Karam et al.[9] pointed out that water deficiency significantly reduced dry matter accumulation and grain yield reduced to 37%under water stress conditions. Oktem[10]added that underconditions of water stress, the sweet corn plant decreased its leaf area index, yield and marketable ear number.It has been reported that humic substances have beneficial effects on plant growth, nutrient uptake, root development, yield, seed germination and plant photosynthesis[11, 6]. As a consequence, the use of humic substances is proposed as a method of improvement of crop production.

The purpose of this study was to investigate the influence of humic acid application rates on soil and canola plant characters under water deficit treatments.

Material and Methods

The investigation was carried out in Research and Production Station, National Research Centre, El-Nubaria, El-Behera Governorate, Egypt, during the winter season of 2013 on a sandy loamy soil (23% silt; 8% clay). The experimental design was split –split in three replicatesto assess the effect of different levels of humic acid as follow: HA_0, HA_1; HA_2 at0, 1 and 2 g/liter, respectively under three different irrigation treatments designatedas a percentage from evapo-transpiration as mild (IR1), slight (IR2) and full irrigation (IR3) with no water stress treatmentson canola plants. Humic acid contained carbon, 61.2 %, nitrogen, 3.13 g/kg and phosphorus, 2.89 g/kg dry matter purchased in China. Humic acid was injected weekly through irrigation system 8 times two week after germination. All plants were fertilized twice with 20:20:20 fertilizer (Ever-Grow Co., Egypt) one and two month after sowing at the rate of 50 kg /fed.

Surface drip Irrigation method was used with lateral length 35 m, 0.75 m between laterals and 0.3 m among drippers(q= 4 L/hat 1 bar). Plants were Irrigated every 3 days. Details of water supply, control unite and Irrigation treatment is illustrated in Fig. (1).

Seeds of canola (*Brassica napus* L.) were sown at 1stDecember2013, about five seeds in hills and 30 cm apartin both sides of laterals.The experimental were fertilized by 30kg P_2O_5(single super phosphate15.5% P_2O_5) and 50 kg K_2O, (potassium sulphate 50% K_2O) during soil preparation. Urea at 25 kg N/ fed (46% N) divided on five doses injected weekly to irrigationsystemstarted two weeks aftercompleted germination. During the growing period, weeds were controlled by hand as needed. Irrigation process was stopped completely 12 days before harvesting canola plants.

The main soil properties weremeasured (by Hanna Instruments HI 2550 pH/ORP/EC/TDS/NaCl Benchtop Meter) where soil pH value is 7.8 and electrical conductivity 1.5 dS/m (soil paste extracted). Also, the soil contained 510 ppm N, 25 ppm P and 63 ppm K. Aggregate distribution was determined by dry sieving for set 2.0 and 1.0 mm and classified in >2.0 , 2.0-1.0 and < 1.0 mm after[12]. Hydraulic conductivity (HC) was measured in the laboratory under a constant head technique[13] using the following formula: **$HC = (QL)/(At\ \Delta H)$**

Where: HC: water quantity flowing through saturated soil sample / unit time, Q: volume of water flowing through saturated soil sample per unite time (L^3/t), A: cross sectional flow area (L^2) L: length of the soil sample and ΔH: differences in hydraulic head across the sample (L) and t: time (hr)

The total yield of each treatment was harvested fromone meter along each lateral. The recorded plant characters are plant height (cm), Branches No./plant,Leaves no./plant, Leaves area (cm2), root length (cm), fresh weight (gm/plant) for root and shoot, dry weight (gm/plant) for root and shoot, weight 100 seeds(gm), seeds yield per plant (gm), seeds yield (Kg/fed) and, oil yield (Kg/fed).Seed oil was extracted after [14]using the Soxhlet extraction apparatus and petroleum ether (40–60ºC) as a solvent. The extracted oil was separated from the organic solvent using a rotary vacuum evaporator**.**

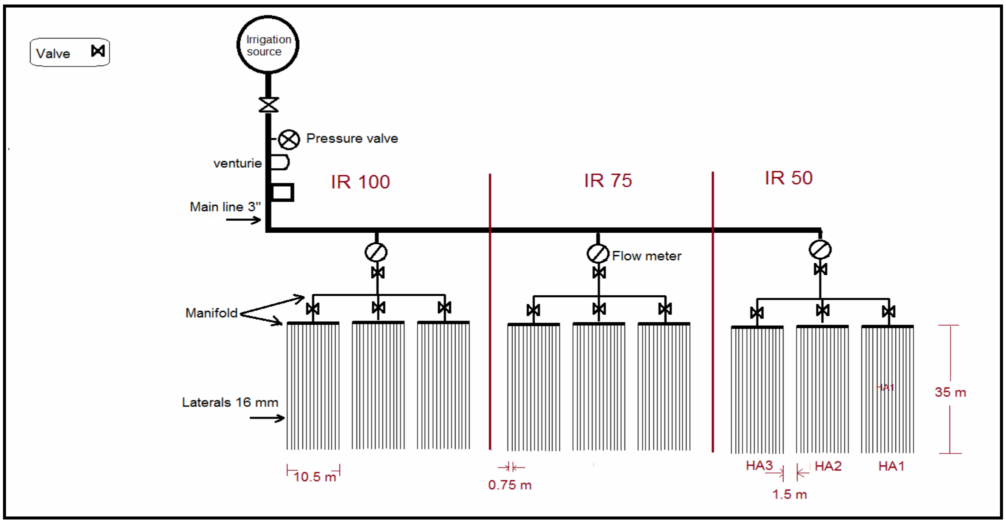

Figure (1) Layout of the experimental treatments

All data were subjected to a one-way analysis of variance (ANOVA), followed by the LSD comparison of means using procedure within the SAS and Statistic systems[15].

Results and Discussion

Soil properties

Regarding to the dry sieving data relative to the humic acid (HA) application under different Irrigation treatment, data pointed out that the highest and the lowest values were attained by increasing HA in all investigated irrigationtreatments. While the ranked of aggregate distribution relative to the IR treatment was arranged in descending order as follows: IR2 > IR1 > IR3 (Table 1 and Fig. 2).Application of HA increased aggregate sizes towards the large one so there was an accumulation in sizes over 2mmand the opposite was true in case of <1mm.Increasing irrigation water treatments from IR2 toIR3 led to decrease in aggregate percentage especially at < 1mm.

According to salt concentration in the soil solute, data indicated that there were increase in EC values with increasing HA and IR treatments. The maximum and minimum values were observed at IR2- HA2 (1.69 dSm^{-1}) and IR3-HA_0 (1.32 dSm^{-1}).An increase in EC value was observed relative to the effect of both investigated factors and the rate of decrease were 1.29and -3.9%for IR2 and IR3 as compared with IR 1 and there wasareduction in EC value by increasing in IR2 to IR3 by about -5.1%.Regarding to HA application to the experimental soil and its effect on the EC values ,the observed data showed that increasing HA by application unite could increase EC values by 13.7 and 18.0 % over control,while the increase in HA by unite from HA_1 to HA_2 lead to increase in EC values by 3.79 %.

Table (1) Effect of humic acid and irrigation treatments on soil dry aggregates %.

Irrigation treatments	Humic treatments	>2 mm	2-1 mm	<1 mm	EC dSm^{-1}	pH	HC cm h^{-1}
IR 1	HA0	26.5	39.3	34.2	1.44	8.03	22.1
	HA1	31.6	42.0	26.4	1.56	8.01	19.7
	HA2	38.9	39.8	21.3	1.64	7.92	17.2
	Mean	**32.3**	**40.4**	**27.3**	**1.55**	**7.99**	**19.7**
IR 2	HA0	25.4	33.1	41.5	1.40	8.03	20.7
	HA1	37.9	26.9	35.2	1.62	7.95	18.3
	HA2	44.6	27.8	27.6	1.69	7.88	15.4
	Mean	**36.0**	**29.3**	**34.8**	**1.57**	**7.95**	**18.1**
IR 3	HA0	25.8	31.9	42.3	1.32	8.02	21.1
	HA1	33.2	29.6	37.2	1.55	7.98	18.4
	HA2	41.2	30.0	28.8	1.60	7.90	16.6
	Mean	**33.4**	**30.5**	**36.1**	**1.49**	**7.97**	**18.7**
LSD 5%	IR or HA	**0.8**	**0.9**	**1.3**	**0.13**	**0.01**	**0.2**
	Interaction	**1.1**	**1.2**	**1.7**	**0.23**	**0.01**	**0.6**

IR1, IR2, IR3: 50, 75 and 100 from ETo, HA0, HA1; HA2 : 0, 1, 2g/liter humic acid

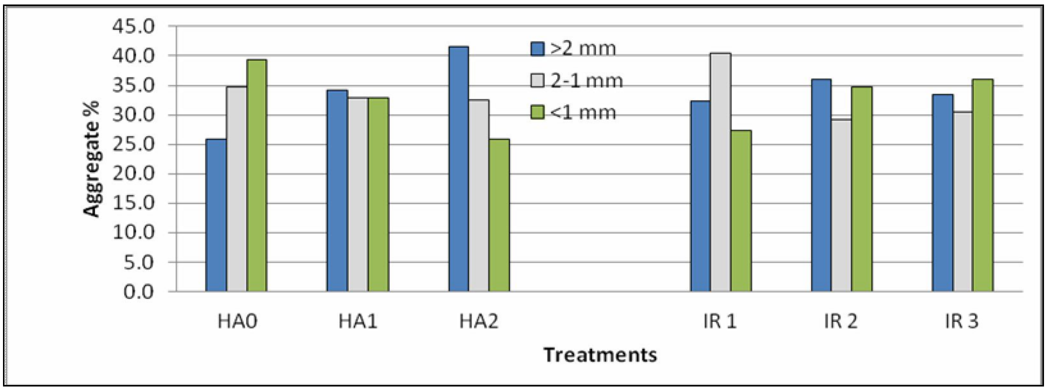

Figure (2) Dry aggregates % as affected by main factors humic acid and irrigation treatments.

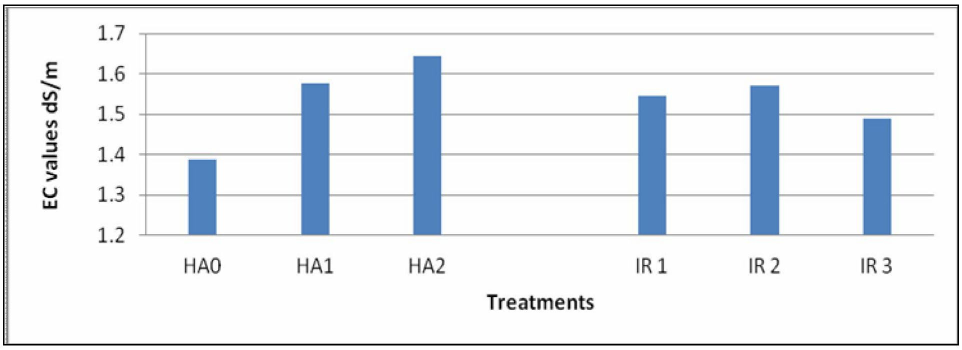

Figure (3) Soil EC as affected by main factors humic acid and irrigation treatments.

In accordance with soil reaction (pH) , data showed that there was aslight decrease in pH values with increasing HA and or IR treatments. The major and the minor values were 8.03 and 7.88, that attained (IR 1 -HA_0)and (IR 2-HA_2), respectively.Regarding to IR treatments, one can notice a small decrease in pH values with the rate of -0.622 and -1.61 for IR2 andIR3 by comparing with untreated plot where the decrease in pH value by increasing in IR2 to IR3 was -1.0. Also, data noticed that by increasing HA per unit, pH values decreased by -0.50 and-0.25 % over control and the increase HA_1 to HA_2 lead to a slight decrease in pH values by about 0.25%.

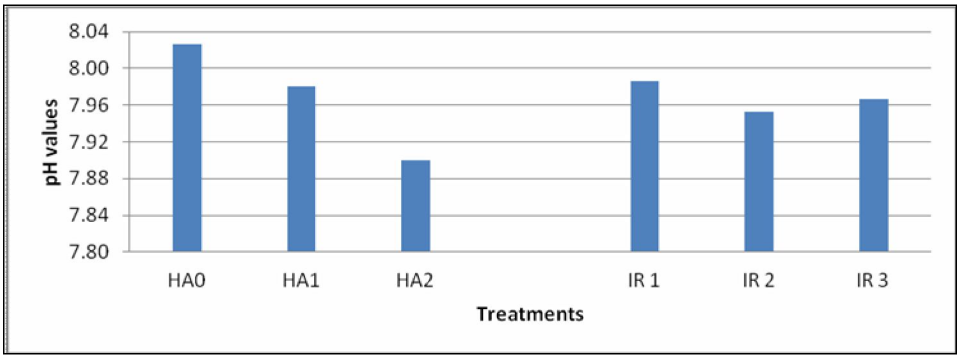

Figure (4) Soil pH Figure as affected by main factors humic acid and irrigation treatments.

According to the water movement in soil under saturated flow (hydraulic conductivity, HC),data in table (1 and Fig. 5) indicated that there were decrease in HC values with increasing HA and IR treatments. The highest and lowest HC values were obtained at IR 1 , HA_0 (22.1 cm/h) and IR3, HA_2 (16.6 cm /h).Regarding to the IR treatments, one can notice that slightly decreases in HC values were attained and the rate of decrease were -8.1 and -5.1 % for IR2 and IR3 as compared with control where as there is increase in HC value by increase in IR2 to IR3 by 3.3 %.The obtained data revealed that increasing HA by application unite (from HA1 to HA2) could decrease HC values by -11.7 and -23% over untreated plot , while the increase HA by unite from HA_1 to HA_2 lead to decrease in HC values by -12.5%. This finding is in harmony with those obtained by [16] who stated that humic substances plays a vital role in make new aggregates through binding fine particles and coagulates soil fine materials.

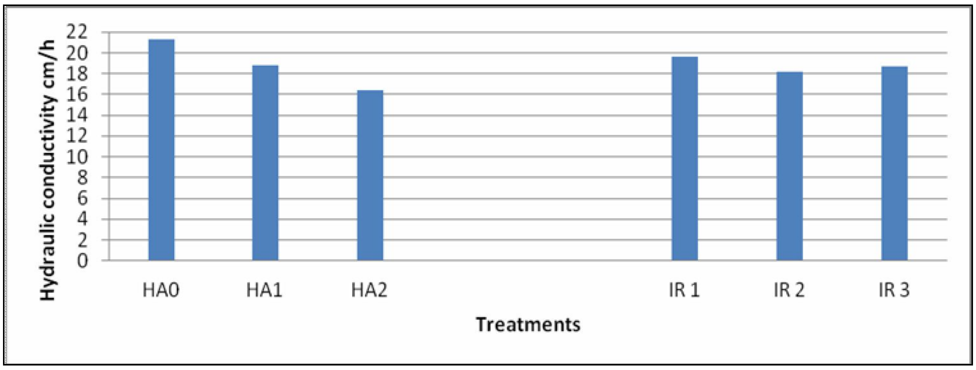

Figure (5) Soil hydraulic conductivity as affected by main factors humic acid and irrigation treatments.

Plant growth characters

According to the obtained plant height (H), it was observed that there was an increase in H values with increasing HA and IR treatments. The highest and lowest values were obtained at IR 2 ,HA_2 (144.4 cm) and IR 1 , HA_0 (82.2 cm).With respect to IR treatment and its effect on plant height, the obtained data revealed that increasing IR by unite could increase H value by 11.3 and 1.2 %over control, while the increase IR by unite from IR 2 to IR 3 lead to decrease in H values by -9 %.Regarding to HA treatments, one can notice that a high increase occurred and the rates of increase were 39 and 50 % for HA_1 and HA_2 by comparison with control. There was an increase in H values by increase in HA_1 to HA_2 by 8%.

Table (2) Effect of humic acid and irrigation treatments on canola plant growth characters.

Irrigation treatments	Humic treatments	Plant height (cm)	No of branch	No of leaves/ plant	Leaf area (cm^2)	Root length (cm)	Fresh weight g/plant		Dry weight g/plant	
							Root	Shoot	Root	Shoot
IR 1	HA0	82.2	8.3	24.3	317.0	12.0	205.3	44.7	58.3	14.3
	HA1	121.4	12.0	35.3	536.3	23.7	265.3	63.5	75.4	23.4
	HA2	134.4	15.0	49.0	756.7	28.0	324.7	76.5	87.5	24.8
	Mean	112.7	11.8	36.2	536.7	21.2	265.1	61.6	73.7	20.9
IR 2	HA0	92.6	10.0	27.0	336.0	15.0	213.7	48.3	60.4	16.2
	HA1	139.2	16.3	39.0	584.0	24.7	294.3	66.5	78.4	25.3
	HA2	144.4	19.3	60.0	783.3	33.3	346.3	79.6	98.4	26.7
	Mean	125.4	15.2	42.0	567.8	24.3	284.8	64.8	79.0	22.8
IR 3	HA0	96.8	9.7	22.3	302.3	8.7	200.7	40.4	53.5	13.3
	HA1	116.5	11.3	30.0	516.7	20.7	244.0	60.5	71.5	20.2
	HA2	128.7	12.7	40.3	723.7	25.0	304.3	70.8	81.5	22.3
	Mean	114.0	11.2	30.9	514.2	18.1	249.7	57.2	68.9	18.6
LSD 5%	IR or HA	1.3	0.8	1.1	4.8	0.9	37.5	14.3	16.5	8.6
	Interaction	4.3	1.7	4.2	15.4	2.1	24.6	11.5	12.7	5.4

IR1, IR2, IR3: 50, 75 and 100 from ETo, HA0, HA1; HA2 : 0, 1, 2g/liter humic acid

According to depth of the root system in the soil and its effect on yield production, data in table (2) indicated that, there was an increase in root length by increasing IR and HA treatments. The maximum and minimum values were at IR 2 -HA_2 (33.3) and IR 3- HA_0 (8.7).The effect of HA treatment on the yield was very significant and there was a highly increase in the root length by increasing HA and the rate of increase were 93.3 and 142.0 % for HA_1 and HA_2 compared with control, while the increase in HA per unite from HA_1 to HA_2 was 25.7%. From the above mentioned, roots allow a plant to absorb water and nutrients from the surrounding soil and its increase depending mainly on the differences in metrics potential which is 0.0 at saturation, so restricted root length and distribution under IR3 is expected.

Same trend was obtained in case of number of branch per plant, number of leaves per plant, and leaf area (Table 2). It is clear that individually the rate of change is great in the irrigation treatments than HA treatments, where HA play an important role in increasing vegetation and related characters

Fresh weight for root and shoot:

According to the root fresh weight (R FW), data indicated that there were an increase in RFW by increasing HA and IR treatments. The highest and lowest values were detected at IR2 - HA_2 (346.3 g/plant) and IR3 -HA_0 (200.7 g/plant). However, a considerable increase in (RFW) values with a rate of 29.7and 57.4 % forIR2 and IR3 as compared with control and also there is increase in RFW value by increase in IR2 to IR3 by 21.4%.

With respect to HA application to the in the investigated yield and its effect on the RFW values, the obtained data revealed that increasing HA lead to an increase in RFW at IR 2 with a rate of 7 % ,but a decrease happened at IR 3 by -6 % over control. There was a decrease in RFW by unite from HA_2 to HA_3 with a rate of -13 %.

According to the obtained the shoot fresh weight (Sh FW), it was observed that there was an increase in Sh FW values with increasing HA and IR treatments. The major and the minor values were 80 and 40at IR 2-HA_2 and IR 3-HA_0 respectively. In accordance with IR treatments and its effect on the shoot fresh weight, by increasing IR, the Sh FW could increase by 42.7 and 69.9 % for IR2 and IR3 by comparing with untreated plot. The increase in IR by unite from IR2 to IR3 lead to an increase in Sh FW values by 19 %.Regarding to HA treatment, one can note that an increase occurred at HA_2 over control with 5.2 %, but this rate decreased to -7 % at HA_3 . There was a decrease in Sh FW values by increasing HA_2 to HA_3 with a rate of -12 %.

Dry weight for root and shoot:

Depending on the previous data, there was a clear increase in the root dry weight by increasing HA and IR treatments. The maximum and minimum values were 98.4 and 53.5 g/plant at IR2-HA_2 and IR3- HA_0, respectively.An increase in root dry weight (RDW) was observed relative to the effect of both investigated factors and the rates of increase were 30.8 and 55.2 % for IR2 and IR3 as compared with control.There was an obvious increase in RDW values by increase in (IR3 -IR2) with a rate of 18.6 %.In other word, HA application to the investigated yield and its effect on RDW values, the obtained data revealed that increasing HA per unit could increase RDW values by 7.8 % for IR2 and decrease RDW values by -6.1 over control. A decrease happened in (DW r)values while the increase in HA by unite from HA_1 to HA_2 with a rate of -12.7%.

According to the shoot dry weight(ShDW), data showed that there was an increase in ShDW values with the increase in HA and IR values. The highest and lowest values were observed at IR 2- HA_2 (26.7 g/plant) and IR 3- HA0 (13.3 g/plant).Also, one can notice that large increasesinSh DW values were obtained at IR2 and IR3 and the rates of increase were 58 and 69 %,respectively above IR1. The increase in HA by unite from HA_1 and HA_2 lead to an increase in Sh DW values by 7.0 %. With respect to HA application to the investigated yield and its effect on the (DW s) values, data showed that increasing HA by unite resulted to an increase in IR2 treatment by 9% and a decrease in IR 3 by -11% over untreated.

This finding is agreed with that obtained by[5] who reported that HA increase root length, root number and root branching. He added that humic substances have a very strong influence on the growth of plant roots. When humic and fulvic acids are applied on the soil, enhancement of root initiation and increased root growth may be observed[17] (Pettit, 2004).

Yield characters

According to the shown data, one can observe that there was an increase in seed index (SI) values by increasing IR and HA treatments. The highest and lowest values were detected at IR2-HA2(5.1 g) and IR3-HA_0(1.8 g). Depending on IR treatment, there were highly increases in SI values by increasing IR treatments with rates of 95and 120% for IR 2 and IR3 comparing with IR1, respectively. With respect to HA treatments, by increasing HA treatments ,an increase in SI values was obtained at HA_1 (14.7%),but there was a decrease at HA_2 with a rate of -8.8%. the transition from HA_1 to HA_2 lead to decrease in SI values by -20.5 %.The obtained results supported by [18]. He mentioned that HA and organically improvement of soil increased the yields of some field crops in several studies and it improved growth, independent of nutrition. Rajpar et al., [19]added that HA efficiently improves crop productivity through increased soil fertility, especially on poorly fertile and alkaline-calcareous soils.

Table (3) Effect of ofhumic acid and irrigation treatments on canola plant yield characters

Oil %	Yield		Seed index	Humic acid treatments	Irrigation treatments
	oil kg/fed	Seed kg/fed			
36.1	242.9	672.5	1.9	HA0	IR 1
38.0	483.0	1271.0	3.9	HA1	
41.3	632.3	1530.0	4.3	HA2	
38.5	452.7	1157.8	3.4	Mean	
36.5	263.0	720.7	2.3	HA0	IR 2
42.3	590.0	1395.3	4.2	HA1	
40.4	698.7	1731.3	5.1	HA2	
39.7	517.2	1282.4	3.9	Mean	
36.0	221.2	614.9	1.8	HA0	IR 3
29.1	326.0	1120.7	3.5	HA1	
38.4	543.7	1416.3	3.8	HA2	
34.5	363.6	1050.6	3.1	Mean	
1.5	13.7	78.1	0.2	IR or HA	LSD 5%
2.6	23.1	121.3	0.3	Interaction	

IR1, IR2, IR3: 50, 75 and 100 from ETo, HA0, HA1; HA2 : 0, 1, 2g/liter humic acid

Data indicated that there were an increase in seed yield (SY) by increasing HA and IR treatments. The highest and lowest values were detected at IR 2 , HA_2 (30.3 kg/fed) and IR 3 , HA_0 (9.2kg/fed). Regarding to IR treatment, one can notice a considerable increase in SY values with a rate of 121 % and 138 % for IR 2 andIR 3 as compared with control and also there is increase in SY value by increase in IR 2 to IR 3 by 8 %.With respect to HA application to the canola yield, the obtained data revealed that increasing HA lead to an increase in SY at IR 2 with a rate of 29 % and at IR 3 by 6 % over control. There was a decrease in SY by unite from HA2 to HA3 with a rate of -17.2%.Al-Omran et al. [20] reported that salt accumulation in the field relative to the deficit irrigation treatments was an important factor in reducing the yield.

Depending on resulted data SY(kg/fed)and Oil (kg/fed), it was observed that there was an increase in oil % values with increasing HA and IR treatments. The major and the minor values were 42.3 and 29.1% at IR 2 - $HA_1$and IR 3 , HA1, respectively. In accordance with IR treatments and its effect on the oil percentage, by increasing IR , the oil % could increase by 0.7% and 10.5% for IR 2 and IR 3 by comparing with untreated plot. The increase in IR by unites from IR 2 to IR 3 lead to an increase in oil% values by 9.7 %. Regarding to HA treatment, one can note that an increase occurred at HA_2 over control with 3.2%, but this rate decreased to – 10.4% at HA_3 . There was a decrease in (%oil) values by increasing HA_2 to HA_3 with a rate of -13%.

Water use efficiency for seed and oil yield.

According to the irrigation treatments that applied relative to ETo, the obtained data at the end of the canola growing season that the total amounts of irrigation water was 177.0, 265.5 and 354.4 mm/fed/growing season which means 743.4, 1115.1 and 1488.5 m^3/fed/growing season for IR 1, IR2 and IR3 %.

Data in Figure (3) illustrated the effect of irrigation water amounts (IR1, IR2 and IR3) and HA application rate (HA_0, HA_1 and HA_2) on the water use efficiency (WUE) for seed and oil content. Data revealed that the highest values were 2.06 kg seed/m^3 irrigation water (IR1-HA_2) followed by 1.55 kg seed/m^3 (IR2-HA_2). Same trend was attained in case of WUE for oil and could be ranked in the following ascending order IR1-HA_2> IR2-HA_2> IR3-HA_2.

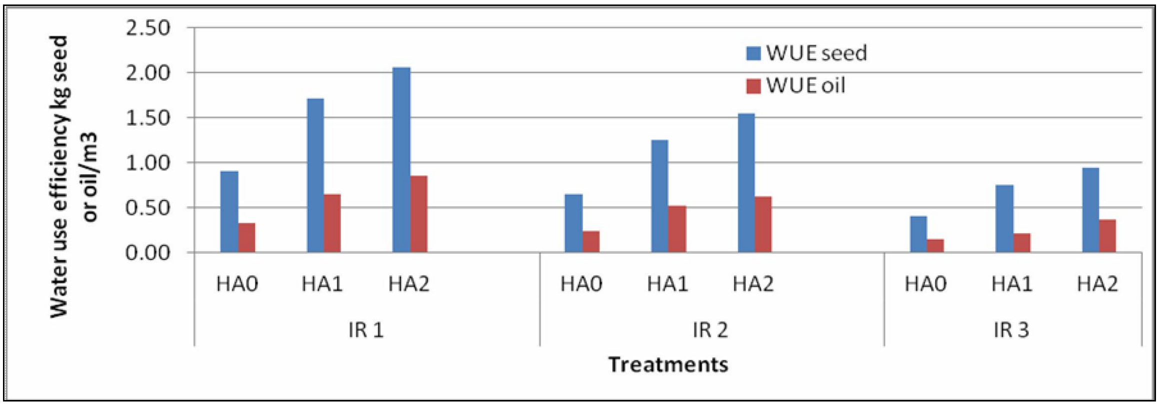

Figure (4) Effect of irrigation and humic acid (HA) treatments on water use efficiency for seed and oil.

Regarding to WUE of canola seed and oil % as influenced by the studied main factors, one can notice that increasing irrigation water from IR1 till IR3 (from 50 to 100 % from ETo) increased seed WUE values by about 89% comparing IR2with IR1 and 132 and 23 % comparing IR3 with IR1 and IR2, respectively. Whereas, oil WUE percentage of increased were 97, 32 and 159 % in same sequences. But the negative effect of HA application was observed in case of WUE of seed and oil where increase HA from HA_0 till HA_2 decreased WUE of oil by about 26, 55 and 23, 60 % comparing HA_1 and HA_2 with HA_0, respectively.

These results ensure the importance of irrigation water requirements for canola to maximize yield of both seed and oil content that support healthy plant growth, increasing HA application lead to decrease WUE due to canola plant growth going forward vegetative one. This finding is in harmony with those obtained by[21,22].

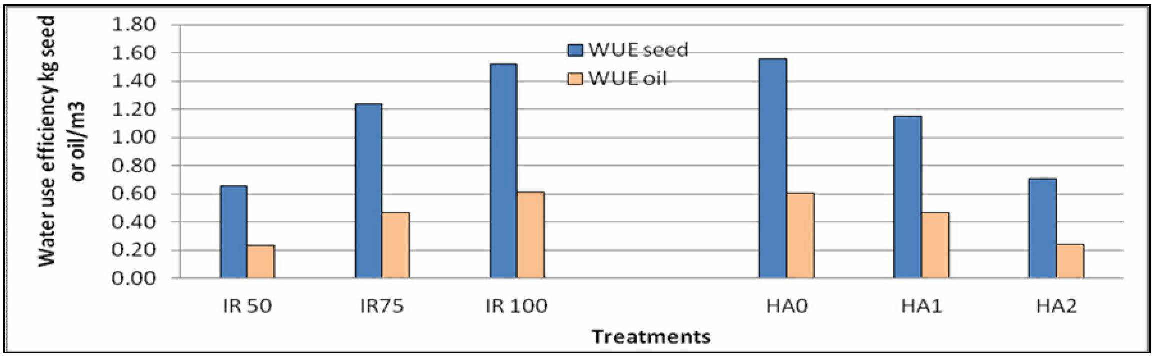

Figure (5) Effect of irrigation and humic acid (HA) treatments on water use efficiency for seed and oil.

Conclusion

Irrigation water is more influence than humic acid on most canola plant characters especially seed and oil yield and hence water use efficiency. However, the second rate of HA used is more effective under deficit used irrigation amounts. Alsothe study confirms present recommendations that the best seed yield potential for canola is achieved by irrigation at 75 % of ETo and/or enriched by humic acid at 2g/liter was more conducive to achieving higher seed yield, especially in good growing conditions, and resulted in heavier mature seeds with higher oil content. With progressive work it could develop a greater understanding of the best way to apply humic and study its impact the plant and soil, which will allow effective integrate humic substances into fertilizer application.

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