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SCHEDULING IRRIGATION OF CANOLA UNDER NITROGEN SOURCES IN MIDDLE EGYPT

By

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ABSTRACT

Two field experiments were carried out at Giza Agricultural Research Station, ARC, Egypt, during 2000- 2001 and 2001- 2002 seasons to identify the effective pan coefficient (selected from 1.4, 1.2, 1.0, and 0.8 treatments) needed for scheduling irrigation of canola plants (using pan evaporation records) under three nitrogen sources N_1 (ammonium nitrate), N_2 (50% ammonium nitrate + azotobacter) and N_3 (50% ammonium nitrate + azospirillum). The effects of the two selected factors on water relations, seed and oil yields, yield components, oil%, protein% and fatty acids composition were studied.

Results of the two growing seasons indicated that plant height, number of branches/ plant, 100- seed weight and seed yield/fed were significantly increased with the treatment of 1.0 pan evaporation coefficient. Also, all studied growth characters were superior when the ammonium nitrate was applied.

Seed oil percent was increased with I_3 (1.0 pan evaporation coefficient) and N_2 (50% ammonium nitrate + azotobacter). Meanwhile, protein percent was increased for I_3 irrigation treatment with N_3 (50% ammonium nitrate + azospirillum). Oil yield was increased for I_3 with N_1. However, the differences between N_1 and N_2 didnot reach the level of significance. Predominant fatty acids comprised palmitic, stearic, arachidic, behenic, oleic, linoleic, linolenic, gadoleic and erucic acids.

Major fatty acids comprised oleic, linoleic, linolenic.The minor acids were palmitic, stearic, gadoleic and erucic. Oleic, lenoleic and lenolenic acids ranged from 56.68 to 56.74%, 18.72 to 18.79% and 8.55 to 8.76%, respectively.

Seasonal water consumptive use values were 1637 and 1601 m^3/fed in 2000- 2001 and 2001- 2002 seasons, respectively. The maximum water use efficiency value was obtained when the evaporation pan coefficient of 1.0 together with N_2 (50% ammonium nitrate + azotobacter) were applied in both seasons.

Results indicated also that the most efficient method for calculating canola crop evapotranspiration (ETc) in Middle Egypt was Penman Monteith formula.

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In general, the 1.0 pan evaporation coefficient and 50% ammonium nitrate + azotobacter could be recommended to obtain the best results for canola crop yield, quality and also saving irrigation water.

I-INTRODUCTION

Canola is one of the important oil crops in Egypt. It grows in winter, while most of oil crops are grown in summer and compete with other major summer crops such as cotton, maize and rice on the limited cultivated area. Canola seed contains more than 45% of an excellent edible oil.

Canola oil is characterized by a low level of saturated fatty acids, a relatively high level of the monounsaturated fatty acid, oleic acid, and an intermediate level of the poly unsaturated fatty acids, linoleic and linolenic acids. Canola oil is appreciably
higher in polyunsaturated fatty acids than palm or olive oil but it is lower in polyunsaturated fatty acids than sunflower, corn or cotton seed oil. It contains an appreciable amount of linolenic acid compared to other common vegetable oils. (Canola Council of Canada, 1988)

The most important factors affecting canola production are time amount of irrigation water, fertilization treatments, sowing date, weeds control and harvesting date.

The distribution of vegetation over the surface of the earth is more controlled by the availability of water than by any other single factor. Decreasing water content is accompanied by loss of turgor and wilting, cessation of cell enlargement, closure of stomata, reduction in photosynthesis, and interference with many basic metabolic processes. Continued dehydration causes distribution of the protoplasm and death of most organisms .Water is as important quantitatively as qualitatively, constituting 80 to 90 percent of the fresh weight of most herbaceous plant parts and over 50 percent of the fresh weight of woody plants. Water in plants is as the solvent in which gases, minerals, and other solvents enter plant cells and move from cell to cell and organ to organ. The permeability of most cell walls and membranes to water results in a continuous liquid phase extending through the plant in which translocation of solutes of all kinds occurs (Kramer, 1983).

Fertilizer efficiency can be reduced by as much as 10 to 50 percent for instance by each of the following causes: poor seedbed preparation (10-25%), improper seeding (5-20%), delay in sowing (20-40%), unsuitable crop variety (20-40%), inadequate plant density (10-25%), improper fertilizer placement (5-10%), insufficient irrigation or drainage (10-20%), weed infection (15-50%), attack of pests and diseases (5-50%), and last but not least imbalanced fertilizer application (20-50%). Only the whole "package" of agronomic skills will result in the highest effectiveness of fertilizers in food production (FAO, 1981).

Nitrogen is very important for all plants. It promotes the vegetative growth and increases the protein content in grains.

In this connection, Jensen and Middleton (1965) applied the accumulative pan evaporation in scheduling irrigation in USA. In Egypt, as early as (1976) Awady et al. used open pan evaporation to estimate optimum water requirement for pea-crop by means of a pioneer trickle-irrigation.

Eid et al. (1982) used the evaporation pan method for scheduling irrigation of two field crops (namely corn and Egyptian clover) at two agroclimatological regions (i.e. Sakha in Kafr El- Sheikh Governorate and Giza in Giza one). El- Marsafawy (1995) in Giza identified the effective evaporation pan coefficient through two field experiments. More studies on determination of effective the evaporation coefficients were made in Egypt on soybean and wheat in Middle Egypt (El- Marsafawy, 2000 and Yousef 1989, respectively), faba been in Middle Egypt (Foad, 1995) and cotton in Upper Egypt (Rayan et al, 2000) and maney others are being carried out for the same purpose.

Ibrahim et al. (1988) indicated that water consumptive use for rapeseed ranged from 2072 to 1678 m^3/fed in Fayoum and Mallawi, respectively. The highest water use efficiency was obtained when the treatment of 40 % depletion was applied. They also found that seed yield, number of seeds/ pod, 1000 seed weight and seed oil content were increased by increasing irrigation water. Bhagat et al. (1989) found that sowing rapeseed on 20 Sep., sowing in lines, irrigation, NP fertilization and insecticide and fungicide applications, seed yield was 0.75 t/ha and oil content was 29.27 % compared with 0.12 t/ha and 31.17 % with late dates, broadcast sowing and no irrigation, fertilizers, insecticide or fungicides. Harbir- Singh et al. (1990) studied the effect of 60 mm irrigation at 50 % flowering + 50 % siliqyae development or at irrigation depth: cumulative pan evaporation ratios of 0.3 or 0.6 or no post- sowing irrigation on yield and water use of rapeseed. They found that the highest seed yield of 1.25 t/ha was obtained with irrigation at an irrigation depth: cumulative pan evaporation ratio of 0.6 compared with 0.17 t from the unirrigated crop. Also, water- use efficiency was increased with irrigation frequency. El-Emam (1993) showed that the highest yield of rapeseed and oil content were obtained by drill sowing and applying 75 kg N/fed. El-Kafoury et al. (1997) studied the effect of four levels of nitrogen fertilizer (30, 45, 60 and 75 kg N/fed) on some agronomic characters of rapeseed. They found that the yield/fed increased significantly by increasing the nitrogen levels up to 60 kg/fed, but the yield/plant, weight of pods/plant, weight of 1000 seeds, number of branches/plant and number of pods/plant were highly significant increased up to 75 kg/fed. Meanwhile, there were no significant differences among nitrogen levels on plant height in both seasons. Oil content was significantly decreased as nitrogen levels increased. Abbas et al. (1999) found that prolonged irrigation intervals decreases significantly plant height, number of branches/plant, number of pods/plant, 1000 seed weight, seed yield/plant, seed yield/fed and seed oil content. El-Mowelhi et al. (1999b) found that actual water consumptive use for canola crop (Pactol cv.) was 1478.5, 1244.5 and 1172.1 m3/fed for 40, 60 and 80% depletion from the available soil moisture.

respectively at Sakha region (Kafr Elsheikh Governorate). Ahmed (2001) found that seed yield of rapeseed was significantly increased by adding N and P fertilizers at 60 kg N and 31 kg P/ha. Chema et al. (2001) indicated that seed yield/ ha was increased with increasing N and P fertilizers up to 60 and 90 kg N and P, respectively.

Yoshida et al.(1992) reported that the fatty acids composition of rapeseed oil were $C_{16:0}$ (3.6%), $C_{18:0}$ (1.5%), $C_{18:1}$ (58.7%), $C_{18:2}$ (23.4%), $C_{18:3}$ (12.3%) and $C_{22:1}$ (0.2%). Mahmoud (1995) indicated that the fatty acids composition of rapeseed oil were palmetic $C_{16:0}$ (4.52%), stearic $C_{18:0}$ (1.43%), oleic $C_{18:1}$ (60.45%), linoleic $C_{18:2}$ (17.96%), linolenic $C_{18:3}$ (6.17%), arachidic $C_{20:0}$ (0.58%), gadoleic $C_{20:1}$ (93.78%), behenic $C_{22:0}$ (1.10%) and erucic $C_{22:1}$ (1.84%).

The aim of the present investigation was to schedule irrigation of canola crop using the pan evaporation method, optimize nitrogen fertilizer utilization in clean environment and save water and nitrogen fertilizer resources. Application of the pan evaporation method is built on the identification of the effective pan coefficient (needed for the maximum canola yield) in advance and then applying the coefficient later on the farmers forms. The present study aimed at identifying the effective pan coefficient.

II-MATERIALS AND METHODS

The present investigation was carried out at Giza Agric. Res. Station Farm, ARC, Egypt, on canola (Pactol cv. Brassica napus L.) during the two successive growing seasons of 2000/ 2001 and 2001/ 2002 to study the effect of different times of irrigation and nitrogen sources on water relations, seed yield and yield components, percent of oil, protein and fatty acids composition of canola plants. The different times of irrigation were determined through the application of different Class-A pan evaporation coefficients. The irrigation treatments included the evaporation pan coefficients to select the effective one, which can be used on the farm level to identify the suitable time to add irrigation water.

Irrigation was applied according to the daily records of the evaporation pan. Irrigation treatments were applied after life irrigation. The irrigation application through growing season was applied when the accumulative pan records reached about 100% from the total available soil moisture, or when the water balance reached zero.

A spilt plots design with four replicates was used. The plot area was 21 m^2 (1/200 fed). The main plots were devoted to irrigation treatments and the sub plots were assigned for different nitogen sources. Sowing dates were Nov. 21st and Nov. 1st in 2000/ 2001 and 2001/ 2002 seasons, respectively.

The description of the experimental treatments was as follows:

A- Irrigation treatments: (pan evaporation coefficients)

I_1- Irrigation at 1.4 evaporation pan coefficient.
I_2 - Irrigation at 1.2 evaporation pan coefficient.
I_3 - Irrigation at 1.0 evaporation pan coefficient.
I_4 - Irrigation at 0.8 evaporation pan coefficient.

B- Nitrogen sources:

N_1 - 100% ammonium nitrate.
N_2 - 50% ammonium nitrate + azotobacter.
N_3 - 50% ammonium nitrate + azospirillum.

The nitrogen was added into two equal doses. The first one was added before the life irrigation and the other one was added before the second irrigation. The seeds of canola were treated by azotobacter and azospirillum before sowing for N_2 and N_3 treatments. Phosphorus fertilizer was added in the form of calcium super phosphate (15.5% P_2O_5) with the first dose of nitrogen. Potassium fertilizer was added in the form of potassium sulphate (48% K_2O) into two equal doses with the same times of the nitrogen fertilizer. The nitrogen, phosphorus and potassium fertilizers were applied at the rates recommended for the area under study. The preceding crop to canola was sunflower in the two studied seasons.

The mechanical analysis results of soil (according to Piper, 1950) are shown in Table (1). The soil moisture constants and meteorological data of Giza agricultural research station are shown in Tables (2) and (3), respectively

Table (1): Particle size distribution of the experimental field soil at Giza region.

Soil fractions	Content (%)
Coarse sand	2.91
Fine sand	13.04
Silt	30.51
Clay	53.18
Textural class	Clay

Table (2): Soil moisture constants (% by weight) and bulk density (g/cm^3) of the experimental field in the 0-60 cm depth.

The constants depth (cm)	Field capacity (%)	Wilting point (%)	Available water (%)	Bulk density (g/m^3)
00-15	41.85	18.61	23.24	1.015
15-30	33.68	17.05	16.18	1.24
30-45	28.38	16.92	11.46	1.20
45-60	28.05	16.54	11.51	1.28

Table (3): Meteorological data at Giza Agricultural Research Station in 2000-2001 and 2001-2002 seasons.

Month	2000-2001 season							
	T.max	T.min	W.S	R.H.	S.S	S.R	R.F	E.pan
Nov.	26.1	14.9	2.0	58	8.1	326	7.5	3.00
Dec.	21.4	11.1	1.2	62	7.1	268	10.0	2.80
Jan.	21.0	8.7	1.3	57	7.0	280	0.1	2.40
Feb.	21.9	8.6	1.3	50	7.9	354	0.6	2.70
Mar.	27.7	14.0	2.3	50	8.6	441	8.8	3.20
Apr.	30.1	16.9	2.7	43	9.6	519	0.0	4.40
	2001-2002 season							
	T.max	T.min	W.S	R.H.	S.S	S.R	R.F	E.pan
Nov.	25.4	13.9	1.6	53	8.1	326	0.0	2.60
Dec.	21.0	9.7	1.6	55	7.1	268	1.4	2.10
Jan.	18.0	7.5	1.6	63	7.0	280	7.0	1.70
Feb.	22.6	11.3	2.2	56	7.9	354	9.7	2.80
Mar.	25.9	13.5	2.4	48	8.6	441	0.0	3.10
Apr.	28.4	14.8	2.6	44	9.6	519	0.0	4.20

where:

T.max., T.min. = maximum and minimum temperatures °C;
W.S = wind speed (m/ sec); R.H. = relative humidity (%);
S.S = actual sun shine (hour); S.R = solar radiation (cal/ cm^2/ day);
R.F = rain full (mm/ month) and E pan = evaporation pan (mm/ day).
Source: Weather data were obtained from the Agrometeorological Station at Giza.

Characteristics studied:

I- Growth, yield and yield component parameters:

1- Plant height (cm).
2- Number of branches/plant.
3- 100- seed mass (g).
4- Seed yield (kg/fed).
5- Oil yield (kg/fed).

Data were statistically analyzed according to Sendecor and Cocheran(1980).

II- Chemical analyses:

1- Seed oil percentage.
2- Protein percentage.
3- Fatty acids composition.

Oil and protein percentages were determined according to the Standard Methods of A.O.A.C.(1990).

Determination of fatty acids:

Methylation of the triglycerieds content of the crude extracted oils was carried out using methanolic base (0.5 N) in iso-octane at room temperature as reported by Daun et al (1983).

The methylated fatty acids samples were analyzed by GLC technique using Hewlett Packard, HP-5890 Plus 11 with flame ionization detector (FID) supplied with integrator and computer control under the following conditions:-

- Column HP 20 M (Carbowax), 25 M length, 0.3 mm inside diameters, 0.3 μm film thickness.
- Column temperature 170 °C and head pressure 3.5 psi (0.24bar). Carrier gas N, 30 ml and flow rate 2.0 mL/min. Injection port temperature 220 °C and detector temperature 250 °C.

Standard methyl ester of the fatty acids was used for identification of the unknown fatty acid and calculated as area percent under scale.

III- Water relations parameters of canola:

1- Actual water consumptive use (evapotranspiration):

Actual evapotranspiration (ET) was estimated from the sampling method and calculated according to the equation of Israelson and Hansen (1962):

$$\mathbf{CU = D \times Bd \times (Q_2 - Q_1) / 100}$$

where:

CU = actual evapotranspiration.
D = the irrigation soil depth (cm).
Bd = bulk density of soil (g/cm^3).
Q_2 = the percentage of soil moisture two days after irrigation.
Q_1 = the percentage of soil moisture before next irrigation.

1.1- Seasonal water consumptive use:

Seasonal water consumptive use or seasonal evapotranspiration value was obtained from the sum of water consumptive use for all irrigations and for all treatments, from sowing until harvesting.

1.2- Water use efficiency (WUE):

W.U.E value was calculated in kg of seed yield of canola per m^3 of water consumed according to the following equation (Vites, 1965):

$$\text{WUE (kg/m3)} = \frac{\text{Seed yield (kg/ fed)}}{\text{Seasonal ET (m3/ fed)}}$$

2- Canola evapotranspiration estimated by some ET formulae (Potential evapotranspiration or ET_{crop}):

The ET_{crop} values were estimated from the general formula:

$$\mathbf{ET_{crop} = ET_0 \times Kc}$$

where:

ET_{crop} = crop evapotranspiration (mm/month).
ET_0 = reference evapotranspiration (mm/month).

Kc = crop coefficient.

Evapotranspiration values (ET_{crop}) were estimated by three formulae viz. Modified Penman, Penman Monteith and Doorenbos-Pruitt. The "WATER" model (Zazueta and Smajstrla, 1984) was used to calculate potential evapotranspiration by the Modified Penman and Doorenbos- Pruitt methods, while, "CROPWAT" model (Smith, 1991) was used for Penman Monteith

2.1- Penman method:

In the model, the Penman equation was derived from the energy balance equation at the soil surface (Jones et al., 1984):

$$\mathbf{R_n = ET + H + G + P}$$

where:

Rn = net radiation .

ET = evapotranspiration latent heat flux density.

H = sensible heat flux density .

G = soil heat flux density.

P = density of solar radiation stored as photo chemical energy.

The potential ET for each day can be expressed as:

$$ET_p = \frac{d\,R_n / L + g\,E_a}{d + g}$$

where:

ET_p = daily potential evapotranspiration, mm/day.

d = slope of saturated vapor pressure curve of air, mb/°C.

R_n = net radiation, cal/cm^2/day.

L = latent heat of vaporization of water, (59.59-0.055) Tavg cal/cm^2. mm or about 58 cal/cm^2 . mm at 29 °C.

E_a = $0.263\ (e_a - e_d)\ (0.5 + 0.0062\ u)$

e_a = vapor pressure of air = $(e_{max} + e_{min})/2$, mb

e_d = vapor pressure at dew point temperature Td (for practical purposes).

Td is equal to T_{min}.

u = wind speed at a height of 2 meters, km/day.

g = psychometric const. = 0.66 mb/°C.

T_{avg} = $(T_{max} + T_{min})/2$,°C.

e_{max} = maximum daily vapor pressure of air, mb.

e_{min} = minimum daily vapor pressure of air, mb.

T_{max} = maximum daily temperature, °C.

T_{min} = minimum daily temperature, °C.

2.2- Penman Monteith method:

Penman Monteith method was used to calculate ETcrop for wheat at Giza using CROPWAT model (Smith 1991).

$$ETo = ET_{rad} + ET_{aero}$$

where:

ET_o =Reference evapotranspiration of standard crop canopy(mmd^{-1})

ET_{rad} = Radiation term (mmd^{-1})

ET_{aero} = Aerodynamic term (mmd^{-1})

$$ET_{rad} = \frac{\delta(Rn - G)L/\lambda}{\delta + y}$$

where:

ET_{rad} = Radiation term (mmd^{-1})

Rn = Net Radiation ($MJm^{-2}d^{-1}$)

G = Soil heat flux ($MJm^{-2}d^{-1}$)

λ = Latent heat of evaporation ($MJ\ kg^{-1}$)

$$ET_{aero} = \frac{y}{\delta + y^*} \times \frac{900}{(T + 275)} U_2 (ea - ed)$$

where :

ET_{aero} = Aerodynamic term of ETo (mmd^{-1}).

y = psychrometric constant ($kPa\ ^oC^{-1}$).

U_2 = Wind speed (ms^{-1}).

ea-ed = Vapour pressure deficit (kPa).

T = Air temperature (^oC).

y^* = Modified psychrometric constant ($kPa\ ^oC^{-1}$).

2.3- Doorenbos and Pruitt method:

Doorenbos and Pruitt (1977) adapted the Makkink (1957) radiation formula to predict potential ET as follows:

$$ET_p = b\ w\ R_s / L - 0.3$$

where:

ET_p= daily potential evapotranspiration in mm/day.

b = adjustment factor based on wind and mean relative humidity.

W = weighting factor based on temperature and elevation above sea level.

R_S = daily total incoming solar radiation for the period of consideration in cal/cm^2/day

L = latent heat of vaporization of water in cal/cm^2/day

The factors b and w were obtained from Tables (Doorenbos and Pruitt, 1977). The Table used in this software assumes that the elevation above sea level is not significant. This assumption is adequate for Egypt.

3- Comparison with the actual ET:

ET crop values estimated by Modified Penman, Penman Monteith and Doorenbos- Pruitt methods were compared using the actual ET to clarify the efficiency of the methods in calculating the ET crop values.

III-RESULTS AND DISCUSSION

3.1- Growth, yield and yield component parameters:

Averages of plant height, number of branches/ plant, 100- seed weight and seed yield were significantly affected by different irrigation treatments, see Table (4). The maximum value was obtained when the treatment of 1.0 pan evaporation coefficient was applied in the two seasons, while the minimum one was recorded with 0.8 pan coefficient treatment. This may be due to that reducing available soil moisture as a result of long irrigation intervals (i.e. 0.8 pan coefficient) resulted in reducing absorption of soil solution (water and food elements), so, growth, yield and yield components were decreased accordingly.

Seed yield increased by about 36 and 43% for 1.0 pan coefficient as compared with irrigation at short intervals (1.4 pan coefficient) in 2000- 2001 and 2001- 2002, respectively. Also, they increased as compared with the irrigation at long intervals (0.8 pan coefficient), where the increase reached about 53 and 57 % for the same respective seasons. These results are in agreement with those obtained by Ibrahim et al. (1988) and Shawky et al. (1999), fig.(1).

As for N- sources, it is clear that they significantly affected seed yield. The maximum values of all characters under study were obtained for N_1. Increase in seed yield in 2000/ 2001 reached about 9 and 5% for N_1 treatment as compared with N_2 and N_3, respectively. Howevere in 2001/ 2002, the increase in N_1 reached about 10 and 7% compared with the treatments of N_2 and N_3 respectively. This may be due to that the biofertilizer in this case couldnot compensate the reduction of nitrogen.

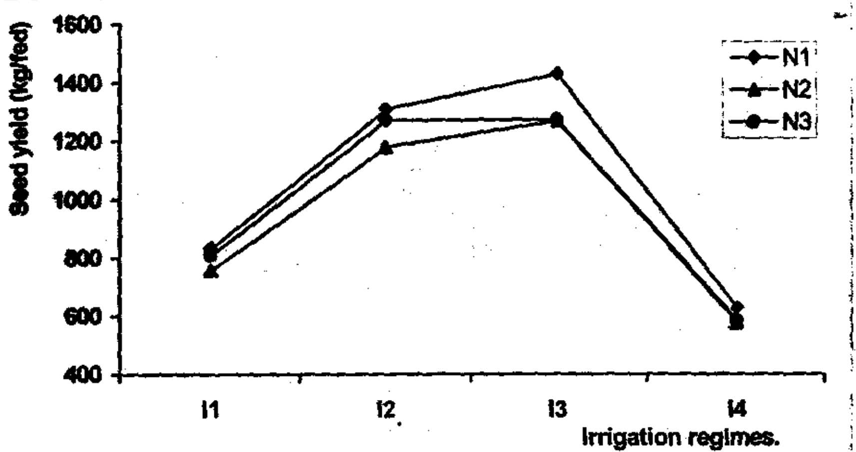

Fig.(1): Seed yield (kg/fed) for canola plants as affected by different treatments.

Table (4): Yield and its components of canola for different treatments in two seasons.

Treatments	Plant height (cm)	No. of branches / plant	100-seed mass (g)	Seed yield (kg/fed)	Seed oil (%)	Protein (%)	Oil yield (kg/fed)
	2000/2001 season						
Irri.-Regimes							
I_1	129.1	6.89	0.20	880	45.2	18.95	397.5
I_2	138.4	7.20	0.22	1299	48.9	19.29	628.6
I_3	140.6	7.26	0.25	1388	49.3	19.29	676.6
I_4	119.6	5.92	0.22	558	48.1	18.63	309.1
LSD 5%	2.8	0.28	0.03	116.00	0.23	0.17	32.2
N-sources							
N_1	131.5	6.88	0.23	1101	47.1	18.89	522.2
N_2	131.2	6.77	0.23	998	51.5	18.88	513.6
N_3	133.0	6.80	0.22	1043	45.0	19.19	473.2
LSD 5%	N.S	N.S	N.S	100.0	N.S	0.14	27.9
	2001-2002 season						
Irri.-Regimes							
I_1	109.1	6.98	0.20	724	46.0	18.94	333.1
I_2	125.8	6.74	0.22	1221	46.7	19.23	568.4
I_3	130.9	7.64	0.24	1269	47.0	19.29	596.1
I_4	83.2	5.42	0.20	546	44.0	18.39	240.1
LSD 5%	6.5	0.29	0.03	81.00	0.22	0.25	38.8
N-sources							
N_1	113.1	6.81	0.22	999	44.7	18.87	451.6
N_2	111.9	6.68	0.22	895	48.1	18.95	434.1
N_3	111.8	6.60	0.21	927	45.0	19.07	417.6
LSD 5%	N.S	N.S	N.S	70.0	N.S	N.S	33.0

No interaction was found between irrigation regimes and N- sources. The best interaction of all characters (except plant height) was obtained when the treatment of 1.0 pan evaporation coefficient with N1 treatment was applied.

In this connection, El-Mowelhi et al. (1999b) found that the highest seed yield of canola crop (1270.61 kg/fed) resulted from the treatment of 40% depletion from the available soil moisture, followed by 60% depletion from the available soil moisture (1167.63 kg/fed). Meanwhile, the treatment of 80% depletion from the available soil moisture gave the lowest one (1024.73 kg/fed). They added that increasing nitrogen fertilizer up to the highest level (65 kg N/fed) led to a significant increase in plant height, number of branches/ plant and seed yield when compared to the lower rate of nitrogen (35 kg N/fed). Generally, they concluded that the maximum values were obtained from the plants irrigated at depletion of 40% A.S.M. and fertilization by 65 kg N/fed. Meanwhile, the lowest one was found for the plant irrigated at 80% depletion of A.S.M. and received 35 kg N/fed.

3.1.1-Seed oil percentage

Averages of seed oil percent as affected by irrigation regimes and different N- sources are shown in Table (4). They were significantly affected by irrigation regimes in the two seasons. Application of 1.0 pan evaporation coefficient treatment produced the highest oil percentages in the two seasons. Meanwhile the application of 0.8 pan evaporation coefficient treatment gave the lowest ones. Increasing available soil moisture before irrigation as a result of short irrigation intervals (I_3) compared to long irrigation intervals (I_4) caused increase in seed oil percent by 2.4 and 6.4 % in the first and second seasons, respectively. This may be due to exposing canola plants to water stress especially during translocation of the sugars from the leaves to seeds and reducing seed oil content. These results are in agreement with that obtained by Rana et al. (1991) who found that oil content was much higher under irrigation than non irrigation condition. Similar results were found by El-Wakil et al. (1992) and El-Saidi et al. (1992) who indicated that seed oil content was increased with decreasing of water depletion.

Although no significant effect of N- sources on seed oil percent, the treatment of N_2 (50% ammonium nitrate + azotobacter) was superior as compared with the two others. Increasing oil percent as arsult of N_2 reached about 8.5 and 12.6% in the first season as compared with N_1 and N_3, respectively. Meanwhile, the increase in oil percent in the second season reached about 7.1 and 6.4%, respectively.

In this connection, Mekki (1990) indicated that seed oil content was not affected significantly by the application of N, P and K fertilizers. While, Bali *et al.* (2000), Brennan et al. (2000) and Cheema et al. (2001) found that increasing of nitrogen fertilizer applied decreased seed oil content significantly

The interaction between irrigation regimes and N- sources significantly affected seed oil percent in the second season. The best interaction was recorded for I_3 (1.0 evaporation pan coefficient) with the addition of N_2 in both seasons, Table(5).

Table (5): Summary of significant interaction effects between the two experimental factors (Irri.-Reimges and N-Sources).

Season	2000-2001			2001-2002					
Irri.-Regimes	Characters								
	Protein %			Seed oil %			Protein %		
	N- Sources								
	N_1	N_2	N_3	N_1	N_2	N_3	N_1	N_2	N_3
I_1	18.87	18.77	19.21	42.6	48.0	47.5	18.73	19.22	18.87
I_2	18.11	18.76	19.37	46.6	50.9	42.5	19.31	18.96	19.43
I_3	19.17	19.27	19.42	45.8	48.1	47.2	19.27	19.05	19.55
I_4	18.42	18.71	18.76	43.9	45.2	42.9	18.18	18.58	18.42
LSD.5%	0.29			0.40			0.40		

3.1.2-Protein percentage

Averages of protein percentages as affected by irrigation regimes and different N- sources are shown in Table (4). They were significantly affected by irrigation regimes in the two seasons. The highest protein percentage value was obtained for I_3 irrigation treatment. Meanwhile, the lowest one was obtained for I_4 irrigation treatment. Protein percentage was increased by 3.4 and 4.7% when the treatment of I_3 was applied as compared with the treatment of I_4 in the first and second seasons, respectively.

With respect to N- sources, they significantly affected protein percent in the first season only. The maximum value was obtained by N_3 nitrogen treatment (50% ammonium nitrate + azospirillium) in both seasons.

The interaction between irrigation regimes and N- sources was found to be significant in affecting protein percentage in the two seasons. The best interaction was recorded for I_3 with adding N_3 in both seasons. The increase in protein percentage for I_3*N_3 compared with I_4*N_1 reached about 5 and 7% in the first and second seasons, respectively, Table (5).

3.1.3-Oil yield, (kg/ fed):

Averages of oil yield as affected by irrigation regimes and different N-sources are shown in Table (4). They were significantly affected by irrigation regimes in the two seasons. Application of 1.0 pan evaporation coefficient treatment produces the highest oil yield in the two seasons. Meanwhile the application of 0.8 pan evaporation coefficient treatment gave the lowest ones. The highest oil yield was obtained for I_3 treatment in the two seasons, which was higher by 41, 7 and 54% as compared with I_1, I_2 and I_4 treatments, respectively in the first season. Meanwhile, in the second season the increased values reached about 44, 5 and 60%, respectively. This trend is in a general accordance with those obtained by Rana et al.(1991) and Nour El-Din et al. (1993), who found that increasing irrigation frequency increased oil yield of rapeseed, fig(2).

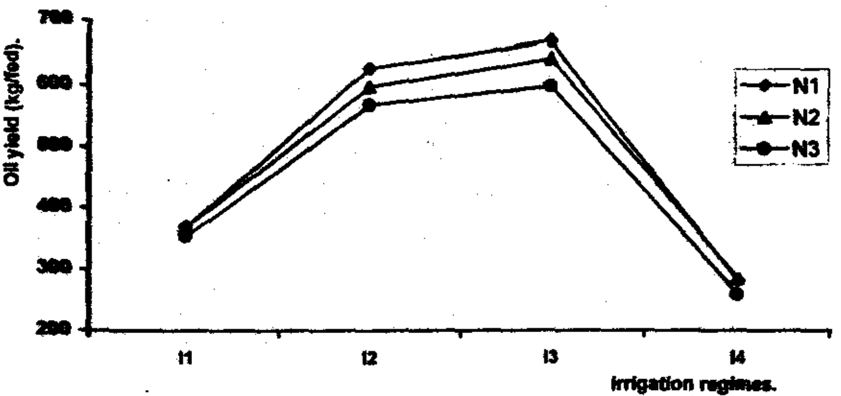

Fig.(2): Oil yield (kg/fed) for canola plants as affected by different treatments.

There was significant effect of N- sources on oil yield in the two seasons. The treatment of N_1 was superior as compared with the two others. At the same time, the differences between N_1 and N_2 didn't reach the level of significant. The same trend was detected by Ali (2002), who found that oil yield was increased by increasing N, P and K (i.e. 45, 30 and 48 kg/fed, respectively) as compared with low doses of nutrients (i.e. 25, 15 and 24 kg/fed, respectively). These results are in disagreement with those obtained by Ahmed (2001), who indicated that oil yield was not affected significantly by nitrogen fertilizer application.

The interaction between irrigation regimes and N- sources did not significantly affect oil yield. The best interaction was recorded for I_3 (1.0 evaporation pan coefficient) with the adding of N_1 in both seasons.

3.1.4-Fatty acids composition:

The GLC of the methyl esters of canola fatty acids showed that the total saturated fatty acids represented 6.54% (I_3N_3 in 2002) to 6.86% (I_3N_3 in 2001), while the total unsaturated one were 93.15% (I_3N_3 in 2001) to 93.39% (I_2N_2 in 2001) as shown in Table (6).

The predominant saturated fatty acid was palmitic acid ($C_{16:0}$). Its amount ranged from 4.45% (I_1N_3 in 2001) to 4.61% (I_3N_1 in 2002).Stearic acid ($C_{18:0}$) was the second constituent of saturated fatty acids and ranged from 1.65 to 1.77%, while other saturated fatty acids, arachidic acid ($C_{20:0}$) and behenic acid ($C_{22:0}$) were found in small amounts.

Concerning to the unsaturaterd fatty acids data in Table (6) it is clear that the major constituents of unsaturated fatty acids were oleic acid ($C_{18:1}$), linoleic acid ($C_{18:2}$) and linolenic acid ($C_{18:3}$). It is clear that oleic acid ($C_{18:1}$) was the most prevalent unsaturated fatty acid, its content ranged from 56.68% (I_3N_3 in 2001) to 56.74% ([illegible]N_1 in 2002).

Table (6): Fatty acids composition (%) for canola plants as affected by irrigation regimes and nitrogen sources in 2000/ 2001 and 2001/ 2002 seasons.

Season	Irrigation treatments	Nitrogen sources	fatty acids composition %									Total saturated acids (TS)	Total unsaturated acids (TU)	TU/TS
			Saturated acids				Unsaturated acids							
			palmitic $C_{16:0}$	stearic $C_{18:0}$	arachidic $C_{20:0}$	behenic $C_{22:0}$	oleic $C_{18:1}$	linoleic $C_{18:2}$	linolenic $C_{18:3}$	gadoleic $C_{20:1}$	erucic $C_{22:1}$			
2000/ 2001	I1	N1	4.48	1.75	0.18	0.28	56.72	18.77	8.59	5.32	3.86	6.69	93.26	13.94
		N2	4.46	1.71	0.19	0.27	56.73	18.78	8.61	5.34	3.87	6.63	93.33	14.08
		N3	4.45	1.68	0.22	0.28	56.69	18.75	8.58	5.40	3.86	6.63	93.28	14.07
	I2	N1	4.48	1.72	0.18	0.26	56.69	18.73	8.66	5.37	3.85	6.64	93.30	14.05
		N2	4.47	1.65	0.19	0.26	56.71	18.75	8.76	5.32	3.85	6.57	93.39	14.21
		N3	4.49	1.68	0.21	0.27	56.71	18.76	8.63	5.35	3.86	6.65	93.31	14.03
	I3	N1	4.54	1.73	0.18	0.27	56.75	18.74	8.65	5.29	3.84	6.72	93.27	13.88
		N2	4.48	1.65	0.23	0.25	56.72	18.79	8.68	5.31	3.84	6.61	93.34	14.12
		N3	4.56	1.77	0.28	0.25	56.68	18.75	8.55	5.31	3.86	6.86	93.15	13.58
	I4	N1	4.51	1.69	0.20	0.29	56.74	18.75	8.66	5.32	3.85	6.69	93.32	13.95
		N2	4.47	1.76	0.19	0.24	56.72	18.73	8.72	5.30	3.85	6.66	93.32	14.01
		N3	4.55	1.65	0.22	0.26	56.69	18.72	8.74	5.30	3.86	6.68	93.31	13.97
2001/ 2002	I1	N1	4.52	1.76	0.18	0.27	56.71	18.76	8.59	5.34	3.86	6.73	93.26	13.86
		N2	4.51	1.73	0.18	0.28	56.73	18.75	8.67	5.31	3.85	6.7	93.31	13.93
		N3	4.56	1.76	0.19	0.25	56.73	18.76	8.56	5.31	3.86	6.76	93.22	13.79
	I2	N1	4.55	1.75	0.18	0.25	56.71	18.72	8.74	5.33	3.85	6.73	93.35	13.87
		N2	4.51	1.71	0.18	0.26	56.70	18.77	8.66	5.32	3.85	6.66	93.30	14.01
		N3	4.58	1.74	0.22	0.26	56.71	18.73	8.56	5.33	3.86	6.8	93.19	13.70
	I3	N1	4.61	1.68	0.19	0.25	56.74	18.75	8.57	5.31	3.85	6.73	93.22	13.85
		N2	4.56	1.65	0.18	0.25	56.73	18.75	8.63	5.31	3.84	6.64	93.26	14.05
		N3	4.46	1.67	0.17	0.24	56.72	18.74	8.56	5.32	3.86	6.54	93.20	14.25
	I4	N1	4.52	1.74	0.23	0.26	56.73	18.75	8.63	5.30	3.85	6.75	93.26	13.82
		N2	4.53	1.69	0.22	0.25	56.71	18.74	8.68	5.33	3.86	6.69	93.32	13.95
		N3	4.55	1.65	0.18	0.25	56.71	18.76	8.73	5.30	3.86	6.63	93.36	14.08

The interest of polyunsaturated fatty acid systems is due to their role as essential fatty acids and the evidance that linking them to coronary heart disease.

Linoleic acid is generally recognized as the essential fatty acid .It is required in the diets of animals and humans, because they are unable to produce it, they are able, however, to convert linoleic acid to arachidonic acid and other members of the linoleic acid or omega-6 family of fatty acids. These long-chain, highly unsaturated fatty acids are important in membrane structures and as starting materials for the synthesis of hormon-like substances, such as prostaglandins and thromboxanes, (Canola Council of Canada, 1988).

Linoleic acid ($C_{18:2}$) was the second major unsaturated acid, its content ranged from 18.72% (I_4N_3 in 2001) to 18.79% (I_3N_2 in 2001).

Recent studies suggest that linolenic acid (viz., α -linolenic acid) is an essential fatty acid. Fatty acids of the linolenic acid or omega-3 family are constituents of lipids in the brain and retina of the eye, for example, and act as precursors for the synthesis of an analogous but different series of prostaglandins and related compounds, (Canola Council of Canada, 1988).

The third major unsaturated acid, linolenic acid $_{18:3}$), its content ranged from 8.55% (I_3N_3 in 2001) to 8.76% (I_2N_2 in 2001).

The gadoleic acid ($C_{20:1}$) and erucic acid ($C_{22:1}$) contents ranged from 5.29% (I_3N_1 in 2001) to 5.40% (I_1N_3 in 2001) and from 3.84 to 3.87%, respectively. These results are in good agreement with that obtained by Fadia Hussein (2004), who studied the fatty acids composition of different canola varieties. She found in Pactol variety that the percentages of fatty acids composition were 2.84% ($C_{16:0}$), 2.57% ($C_{18:0}$), 60.44% ($C_{18:1}$), 23.72% ($C_{18:2}$), 9.06% ($C_{18:3}$), 1.14% ($C_{20:0}$) and 0.67% ($C_{22:1}$).

Similar results were found by El- Samanody (1998) who studied the fatty acids compositions of different rapeseed oil varieties. He found that ($C_{16:0}$) ranged between 4.0 to 5.6%, ($C_{18:0}$) ranged between 1.30 to 1.70%, ($C_{18:1}$) ranged between 36.30 to 60.3, ($C_{18:2}$) ranged from 16.00 to 21.20%, ($C_{18:3}$) ranged from 7.80 to 10.50%, ($C_{20:0}$) ranged from 0.50 to 0.61%, ($C_{20:1}$)ranged from 1.90 to 11.75%, ($C_{22:0}$) ranged from 0.30 to 0.60% and (C $_{22:1}$) ranged from 2.9 to 11.6%. Nahed Atta (2000) found that fatty acids composition of rapeseed varieties ranged from 0.27 to 3.06% myristic ($C_{14:0}$), 3.21 to 29.59% palmitic ($C_{16:0}$), 0.14 to 1.48% stearic ($C_{18:0}$), 29.46 to 58.45% oleic($C_{18:1}$), 1.5 to 22.27% linoleic($C_{18:2}$), 1.96 to 12.54% linolenic ($C_{18:3}$) and zero to 3.08% erucic ($C_{22:1}$).

3.2- Water relations parameter:

3.2.1- Actual water consumptive use :

3.2.1.1- Seasonal water consumptive use (evapotranspiration):

Seasonal actual evapotranspirations (ETa), as affected by different irrigation regimes and nitrogen sources and their interactions, are recorded in fig.(3). The values of irrespective to irrigation regimes and nitrogen sources together were 1637 and 1601 m^3/fed in 2000/ 2001 and 2001/ 2002 seasons, respectively.

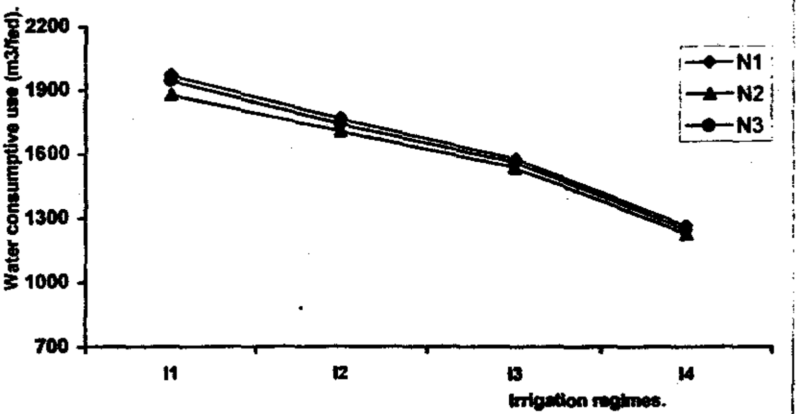

Fig.(3): Water consumptive use (m3/fed) for canola plants as affected by different treatments.

With respect to irrigation regimes, ETa values in 2000/ 2001 were 1957, 1759, 1572 and 1258 m^3/fed for 1.4, 1.2, 1.0 and 0.8 pan evaporation coefficients, respectively. The same respective values in 2001/ 2002 were 1909, 1718, 1543 and 1235 m^3/fed. These results indicate that ETa gradually increased as the available soil moisture increased in the root zone of plants (i.e. irrigation canola plants at short irrigation intervals increased ETa values), while, subjecting canola plants to water deficit caused decrease in ETa values. These results are in full agreement with those obtained by Singh et al. (1990) and Abbas et al. (1999).

For different nitrogen sources, ETa values in 2000/ 2001 were 1662, 1607 and 1641 m^3/fed for N_1, N_2 and N_3, respectively. Values in 2001/ 2002 were 1629, 1568 and 1607 m^3/ fed for the same respective nitrogen sources. It is clear that ETa values slightly increased with the use of ammonium nitrate only as compared with the use of ammonium nitrate + azotobacter or ammonium nitrate + azospirillum. These results are in agreement with those obtained by Garia et al. (1989) ; Katole and Sharma (1991) and Rana et al. (1991), who found that increasing nitrogen fertilizer rate increased water consumptive use.

The interaction between irrigation regimes and N- sources shows that the highest interaction was obtained for I_1 (1.4 pan evaporation coefficient) with N_1 nitrogen source treatment. Meanwhile, the lowest one was recorded for I_4 (0.8 pan evaporation coefficient) with N_2 trteatment.

3.2.1.2- Water use efficiency (WUE):

Seasonal WUE values in 2000/ 2001 were 0.45, 0.73, 0.88 and 0.51 kg seed yield/ m^3 water consumption for 1.4, 1.2, 1.0 and 0.8 pan evaporation coefficients, respectively. Values in 2001/ 2002 were 0.38, 0.71, 0.82 and 0.44

kg seed yield/ m^3 water consumption for the same respective treatments, fig.(4). It is clear that the superior of this character was obtained with the treatment of I_3 (1.0 pan evaporation coefficient) in the two seasons.

In this connection, El- Mowelhi et al. (1999a) indicated that WUE increased by decreasing the amount of irrigation water. The highest value was recorded for I1 irrigation treatment (adding 40% of available water) compared with I_2 (adding 60% of available water) or I_3 (adding 120% of available water).

With respect to N- sources, seasonal W.U.E values in 2000/ 2001 were 0.63, **0.69** and 0.61 kg seed yield/m^3 water consumption for N_1, N_2 and N_3 treatments, respectively. However, in 2001/ 2002 the respective values were 0.57, **0.64** and 0.56 kg seed yield/m^3 water consumption. From these results it is clear that WUE was increased for the treatment of N_2 (50% ammonium nitrate + azotobacter).

In this connection, Patel et al. (1989) reported that increasing nitrogen fertilizer rate up to 75 kg/ha increased water use efficiency. Similar results were found by Garia et al. (1989) when nitrogen was applied up to 40 kg/ha, Taylor et al. (1991) when nitrogen was applied at the rate 200 kg/ha and Katole and Sharma (1991) when nitrogen was applied at the rate 90 kg/ha.

Generally, the best interaction for the maximum WUE is 1.0 pan evaporation coefficient with N_2 nitrogen source treatment.

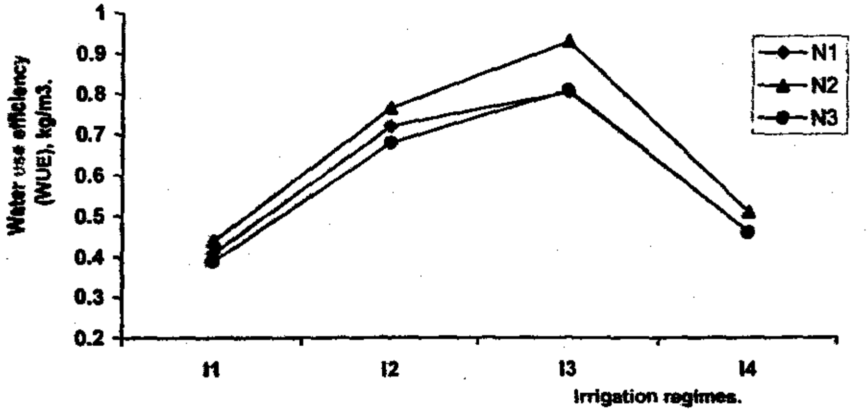

Fig.(4): The average crop water use efficiency as affected by different treatments.

3.2.2- Canola evapotranspiration estimated by some ET formulae (ET crop):

Values of ETo and ETcrop (mm/month) estimated by Modified Penman, Penman Monteith and Doorenbos- Pruitt for the optimum treatment (1.0 pan evaporation coefficient with the ammonium nitrate treatment) and crop coefficient (Kc) values are shown in figures (5 and 6).

In 2000/ 2001, seasonal ETcrop values were 453.82, 383.93 and 332.87

mm for Modified Penman, Penman Monteith and Doorenbos- Pruitt formulae, respectively. In 2001/ 2002, ETcrop values were 425.75, 362.79 and 302.00 mm for the same respective formulae. It is clear that Modified Penman gave the maximum value, in the two seasons. Meanwhile, Doorenbos- Pruitt formula recorded the lowest one.

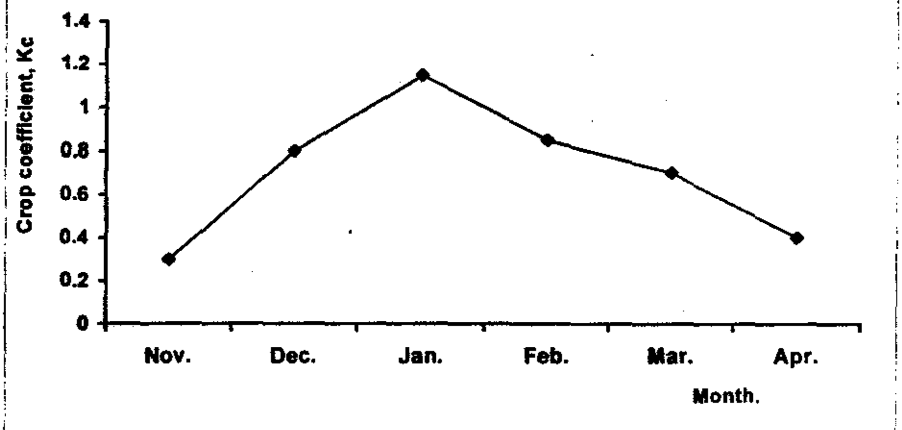

Fig.(5): Crop coefficient for canola during crop season.

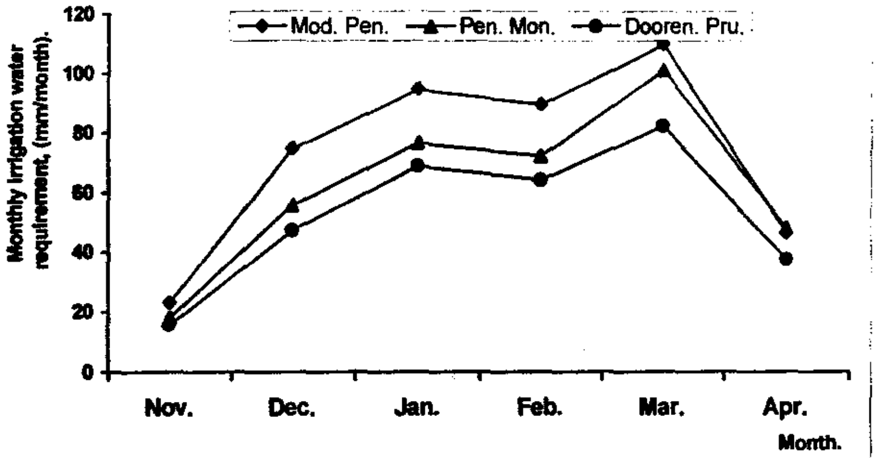

Fig.(6): Monthly irrigation water requirements under different ET formulae of canola.

3.3- Comparison with the actual ET:

Ratios between ETcrop / Actual ET values are shown in Table (7) and fig.(7). Ratios of 1.17, 0.99 and 0.85 were recorded with Modified Penman, Penman Monteith and Doorenbos- Pruitt, respectively. It is clear that Penman Monteith formula was superior in calculating ETcrop for canola in Middle Egypt (i.e. Giza region) due to its least difference from the actual ET value compared with the values of the others formulae.

Table (7): ET crop values calculated by different ET formulae ratio to the ETa of canola plants in 2000-2001 and 2001-2002 seasons.

Formulae	2000-2001		2001-2002		Average	
	ET crop	Ratio	ET crop	Ratio	ET crop	Ratio
Mod. Pen	453.82	1.20	425.75	1.14	439.79	1.17
Pen. Mon.	383.93	1.01	362.79	0.97	373.36	0.99
Dooren. Pru.	332.87	0.88	302.00	0.81	317.44	0.85
Actual ET	378.80	.....	372.10	.....	375.45	.....

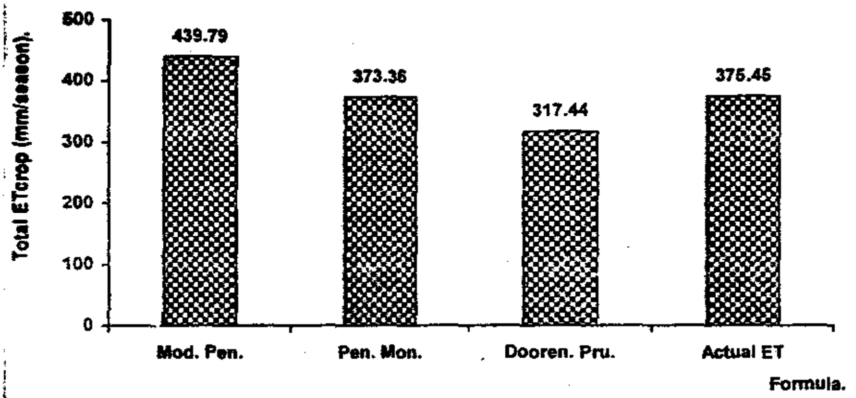

Fig.(7): Total ETcrop(mm/season) under different ET formulae of canola.

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الملخص العربي

جدولة رى الكانولا تحت مصادر نيتروجينية فى منطقة مصر الوسطى

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اقيمت تجربتان حقليتان بمحطة البحوث الزراعية بالجيزة خلال موسمي ٢٠٠٠-٢٠٠١ ، ٢٠٠١-٢٠٠٢ وذلك بهدف دراسة جدولة رى محصول الكانولا فى منطقة مصر الوسطى باستخدام البخر من الوعاء القياسى تحت مصادر نيتروجين مختلفة وأثر ذلك على كل من العلاقات المائية والنمو والمحصول ومكونات المحصول ونسبة الزيت والبروتين ومحصول الزيت والأحماض الدهنية. وقد استخدم لهذا الغرض أربع معاملات للبخر (١,٤ ، ١,٢ ، ١,٠ ، ٠,٨) وثلاثة مصادر للسماد النيتروجينى (١٠٠ % نترات أمونيوم ، ٥٠% نترات أمونيوم + ازوتوباكتر ، ٥٠% نترات أمونيوم + ازوسبيريللم).

وتهدف الدراسة الى تحديد معامل البخر الفعال اللازم لجدولة رى محصول الكانولا بالإضافة الى رفع كفاءة استعمال مياه الرى والتسميد بمصادر نيتروجينية ترفع كفاءة التسميد مع المحافظة على البيئة.

أظهرت النتائج تفوق طول النبات ، عدد أفرع النبات ، وزن ١٠٠ بذرة ، محصول البذور للفدان مع معامل بخر الوعاء ١,٠، كما تفوقت هذه الصفات مع المصدر النيتروجيني ١٠٠% نترات أمونيوم.

أظهرت النتائج تفوق نسبة الزيت فى البذور مع تفاعل معامل بخر الوعاء ١,٠ مع المصدر النيتروجيني ٥٠% نترات أمونيوم + ازوتوباكتر. بينما تفوقت نسبة البروتين مع تفاعل معامل بخر الوعاء ١,٠ مع المصدر النيتروجيني ٥٠% نترات أمونيوم + أزوسبيريللم فى الموسمين.

وقد أوضحت النتائج أن الاستهلاك المائي لمحصول الكانولا (صنف باكتول) فى منطقة الجيزة (مصر الوسطى) ١٦٣٧ & ١٦٠١ م^3/ ف فى الموسم الأول والثانى على الترتيب. وقد زاد الاستهلاك السنوى بزيادة عدد الريات (أى مع معاملة ١,٤ معامل بخر الوعاء). كما زاد الاستهلاك المائى مع المصدر النيتروجينى (١٠٠ % نترات أمونيوم) مقارنا بالمصادر النيتروجينية الأخرى. وقد أعطى معامل بخر الوعاء ١,٠ مع المصدر النيتروجينى (٥٠% نترات أمونيوم + ازوتوباكتر) أعلى كفاءة لاستخدام المياه فى الموسمين.

أوضحت النتائج تفوق معادلة بنمان مونتيث فى حساب الاستهلاك المائى النظرى لمحصول الكانولا فى منطقة مصر الوسطى بفرق قدره -١% فقط وذلك عند مقارنتها بالاستهلاك المائى الحقيقى.

وللحصول على أفضل النتائج من حيث إنتاجية الزيت / فدان وكفاءة استعمال المياه والتركيب الكيميائى للبذور فانه يوصى بتطبيق معاملة جدولة الرى عند معامل بخر ١,٠ وإضافة اللقاح ازوتوباكتر الى نصف كمية النيتروجين المطبقة حاليا (٥٠% نترات أمونيوم + ازوتوباكتر).

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