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# EFFECT OF IRRIGATION AND NITROGEN FERTILIZATION ON PRODUCTIVITY, SEED QUALITY, AND WATER USE EFFIENCY OF CANOLA (*Brassica napus* L.) IN NORTH DELTA, EGYPT

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## ABSRTACT

*Two field experiments were conducted at Sakha Agricultural Research station, Kafr El-Sheikh governorate, during the two successive seasons of 2005/06 and 2006/07. The investigation was aimed to study the effect of irrigation at 45%, 60% and 75% of available soil moisture deficit (ASMD), and four nitrogen rates (15, 30, 45, and 60 kg N/fed.) on canola productivity, seed quality and water use efficiency. A split plot design with four replication was used. Irrigation treatments occupied the main plots while nitrogen rates arranged in sub-pots.*

*Results showed that irrigation at 45% ASMD significantly increased plant height, number of racemes, 1000-seed weight, seed yield per plant, seed yield/fed., oil percent, and oil yield by 2.6%, 54.1%, 3.3%, 24.1%, 38.9%, 3.8%, and 44.1%, respectively compared to irrigation at 75% ASMD.*

*Increasing N fertilizer rate from 15 to 60 kg N/fed. significantly increased plant height , number of racemes, 1000-seed weight, seed yield per plant, seed yield/fed., and oil yield/fed. On the other hand, increasing N rate significantly decreased the seed oil content.*

*Seasonal water consumptive use was 35.26, 29.51, and 26.51 cm when canola plants were irrigated at 45%, 60%, and 75% of ASMD, respectively.*

*Values of irrigation water requirements were 61.51cm (2583.4 $m^3$/fed.), distributed on six irrigations, 54.08 cm (2271.4 $m^3$/fed.), distributed on five irrigations, and 46.03 cm (1933.3 $m^3$/fed.) distributed on four irrigations for irrigation at 45%, 60, and 75% of ASMD, respectively.*

*The highest values of water use efficiencies resulted from irrigation at 60% of ASMD. At the same time, increasing the rate of N not only result in increasing higher yield but also increasing the water use efficiencies.*

*Regression slope between total amount of water used in the field and seed yield and oil yield was 23.7 kg/fed and 12.1 kg/fed., respectively.*

*So, under shortage condition of water, irrigation at 60% of ASMD could be recommended for canola production because 14% of irrigation water could be saved against 9% of the seed yield reduction, compared to irrigation at 45% of ASMD.*


***Keywords:** Irrigation, soil moisture deficit, water consumptive use, irrigation water applied, water use efficiencies, nitrogen fertilization, canola crop, and seed productivity.*

## INTRODUCTION

Recently, canola is considered a new oil seed crop in the newly reclaimed areas in Egypt because there is a great shortage in edible oils, and large amounts are imported annually from abroad. Canola, as a winter crop can play an important role to partially cover or reduce this shortage. There is a growing need to understand the effects of irrigation on canola growth, development, productivity, and seed quality especially in the newly reclaimed soils. Furthermore, increased competition for increasingly scarce water resources will impose greater efficiency in irrigation management practices. The most important factors affecting canola crop production is the available soil water content and adding nitrogen fertilization to plants. So, increasing yield of canola requires improving agricultural practices, i.e. irrigation deficit and nitrogen fertilization rates to achieve higher seed and oil yields. Shahin et al., (2000) showed that increasing available soil water content increases plant height, weight of 1000 seeds, number of pods/plant, weight of seeds/plant and seed yield. Increasing N fertilizer application rate from 20 to 40 or 60 kg/fed increased the plant height, weight of seeds/plant and seed yield. They also showed that the seasonal evapotranspiration of rapeseed amounted to 612.1, 503.1 and 425.7 mm for irrigation intervals of 20, 30 and 41 days, respectively. They also added that nitrogen rates of 40 and 60 kg/fed increased water use efficiency by 14.63 and 31.97%, respectively, as compared to 20 kg N/fed. Yield and yield component increased by increasing soil moisture content (Sherif *et al.*, 1995).Gammelvind *et al.*, (1996) showed that water stress in late vegetative and early reproductive growth stages reduced the photosynthetic rate in leaves. Abdol-Amir and Abdol-Mehdi (2006) showed that no. of pods per plant, seed and oil yield decreased as water stress increased. Siag *et al.*, (1993) revealed that mean seed yield was 0.67 t/ha without irrigation and the highest was 1.35 t/h with irrigation at branching and siliqua development. They also pointed out that water use efficiency was highest from a single irrigation at peak flowering. Asghar *et al.*, (2003) revealed that seed oil content decreased with the increase of irrigation frequencies and nitrogen rates up to 120 kg $N/ha^{-1}$. El-Mowelhi *et al.*, (1999) revealed that the average of irrigation applied for canola varieties in Delta, Egypt were 2618.9, 2408.6 and 2168.2 $m^3$/fed. and water consumptive use was 1630.7,

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1473.9 and 1329.7 $m^3$/fed when irrigation was applied at 40% , 60% and 80% depletion of the available water content, respectively. Niazi, and Fooladmand (2006) showed that the irrigation at cumulative evaporation value of 50 mm from class A pan resulted in a maximum grain yield of 3667 kg/ha while a minimum yield of 2250 kg/ha resulted from irrigation at 125mm cumulative evaporation. The maximum and minimum seed oil contents were obtained at cumulative evaporation from class A pan of 125 mm and 50 mm treatment were 47.63% and 44.60%, respectively. Bruck *et al.*, (2001) indicated that the low nitrogen supply will not only result in lower yield but will also reduce the WUE. Sinha *et al.*, (2003) indicated that plant height, and crop growth increased with increasing rates of N up to 60 kg N/ha and were higher under irrigated than non-irrigated conditions. Choudhury *et al.*, (1990) indicated that seed yield increased with increase in N rate up to 90 kg N/ha that resulted in 0.90 t/ha. due to the increases in branch and siliquae numbers. Abd Rasool (2007) indicated that increasing nitrogen fertilizer level up to 60 kg N/fed. significantly increased plant height, number of branches/plant, 1000-seed weight, seed yield /plant, seed and oil yields/fed. of canola.

The objective of this study was to investigate the effect of irrigation at 45%, 60% and 75% of available soil moisture deficit (ASMD), and four nitrogen rates i.e. 15,30, 45, and 60 kg N/fed. on productivity, seed quality and water use efficiency of canola (*Brassica napus* L.).

## MATERIALS AND METHODS

Two field experiments were conduced at Sakha Agricultural Research station, Kafr El-Sheikh governorate, during the two successive seasons of 2005/06 and 2006/07. The soil of the experimental site was clayey in texture. The electrical conductivity and pH of soil paste (0-60 cm layer), and salinity of irrigation water, were 2.13 dS/m, 8.11and 0.50 dS/m, respectively, determined according to Page, (1982). Water table level using observation well was 122 cm below the soil surface. A split-plot design with four replicates was used. Irrigation treatments were allocated in the main plots, while nitrogen rates were assigned to sub-plots. Irrigation treatments started after the first irrigation and were timed, through soil moisture samples, at 45, 60, and 75% available soil water deficit, and nitrogen rates treatments were 15, 30, 45, and 60 Kg N/fed. Sub-plot area was 42 $m^2$ including 10 ridges, 7 m long and 60 cm apart. Plots were isolated by ditches of 1.5 m in width to avoid lateral movement of water. Canola seeds cv. Serw 4 were sown by hand on November 5$^{th}$ and 7$^{th}$ in 2005/06 and 2006/07 seasons, respectively. Planting was in hills 10 cm apart, and seeding rate was 3 kg/fed. Plants were thinned to one plant per hill after 30 days from sowing before first irrigation. The preceding crop was maize in both seasons. Nitrogen fertilizer in form of ammonium nitrate (33.5% N) was added in two equal doses and phosphorus fertilizer was applied, in the form of calcium superphosphate 15.5% $P_2O_5$ at the rate of 30 kg $P_2O_5$/fed. during the tillage operation. All recommended agricultural practices were followed through the growing seasons.

Canola plants were harvested on April 20$^{th}$ and 22$^{nd}$ in 2006 and 2007, respectively. Ten guarded plants were randomly taken from each plot to measure plant height in cm, number of racemes, 1000-seed weight in g, seed yield/plant in g, seed yield/fed in kg, oil percent, and oil yield in kg/fed. Seed yield/fed. was obtained from central area of each plot (1/300 fed.) to avoid any border effect. Crude oil was determined according to A.O.A.C. (1990) using Soxhelt apparatus, and the oil yield/fed. was calculated by multiplying seed yield/fed. by seed oil percentage.

Data were subjected to the combined analysis as described by Snedecor and Cochran (1980). The treatment means were compared according to Duncan's multiple range test (Duncan, 1955).

Sakha meteorological station data, during 2005/06 and 2006/07 seasons, were recorded. Meteorological data including air temperature, relative humidity, and rainfall distribution are presented in Table 1.

**Table (1): Sakha meteorological data of Agricultural Research station during 2005/06 and 2006/07 seasons.**

| Seasons | 2005/06 | | | | | | | 2006/07 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Air temperature °C | | | Relative humidity (%) | | | Rainfall | Air temperature °C | | | Relative humidity (%) | | | Rainfall |
| | Max. | Min. | Mean | Max. | Min. | Mean | (mm) | Max. | Min. | Mean | Max. | Min. | Mean | (mm) |
| November | 24.2 | 10.6 | 17.4 | 77.3 | 56.0 | 66.7 | 8.3 | 23.5 | 8.9 | 16.2 | 77.0 | 58.6 | 67.8 | 3.2 |
| December | 20.0 | 7.0 | 13.5 | 86.5 | 60.0 | 73.3 | 8.8 | 19.7 | 4.5 | 12.1 | 82.0 | 62.2 | 72.1 | 10.0 |
| January | 18.8 | 5.1 | 12.0 | 86.0 | 61.0 | 73.5 | 7.6 | 18.7 | 4.1 | 11.4 | 87.0 | 58.5 | 72.8 | 17.5 |
| February | 22.0 | 6.0 | 13.0 | 93.4 | 66.0 | 79.7 | 18.0 | 21.6 | 5.6 | 13.6 | 95.4 | 67.6 | 81.5 | 44.1 |
| March | 22.6 | 7.0 | 14.8 | 80.0 | 51.2 | 65.6 | 2.1 | 22.0 | 5.8 | 13.9 | 79.2 | 51.7 | 65.5 | 9.0 |
| April | 27.0 | 9.5 | 18.3 | 81.0 | 47.0 | 64.0 | 24.8 | 25.3 | 7.5 | 16.4 | 80.5 | 49.5 | 65.0 | 11.4 |
| May | 28.5 | 11.6 | 20.1 | 79.3 | 45.0 | 62.2 | 0.0 | 28.3 | 11.1 | 19.7 | 78.9 | 45.1 | 62.0 | 0.0 |

**Soil-water relation:**

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depths of 15 cm down to a depth of 60 cm. Soil samples were also collected just before each irrigation, 48 hours after irrigation and at harvest time. Field capacity, permanent wilting point and bulk density were determined according to Klute (1986) to a depth of 60 cm (Table 2).

Table (2): Soil moisture constants for the experimental site.

| Soil depth (cm) | Field capacity (%) | Wilting point (%) | Bulk density (g/cm$^3$) | Available soil water % |
|---|---|---|---|---|
| 0-15 | 46.70 | 25.30 | 1.10 | 21.40 |
| 15-30 | 41.15 | 21.90 | 1.16 | 19.25 |
| 30-45 | 37.20 | 20.33 | 1.26 | 16.87 |
| 45-60 | 35.13 | 19.21 | 1.34 | 15.92 |

**2.1. Irrigation water applied (IWA):**

Depth of irrigation water applied for each treatment was determined according to soil moisture content event before irrigation to its field capacity besides 10% as leaching requirements. Irrigation water applied was calculated by using submerged flow orifice with fixed dimension was used to measure the amount of water applied, as the following equation (Michael, 1978).

$$Q = CA\sqrt{2gh}$$

Where:

Q = discharge through orifice, (l/sec).

C = coefficient of discharge, (0.61).

A = cross-sectional area of the orifice, cm$^2$.

g = acceleration due to gravity, cm/sec.$^2$ (981 cm/sec.$^2$).

h = pressure head, causing discharge through the orifice, cm.

**2.2. Water consumptive use:**

Water consumptive use was calculated using the following equation (Hansen *et al.*, 1979).

$$CU = \sum_{i=1}^{n} D_i * D_{bi} * \frac{PW_2 - PW_1}{100}$$

Where:

CU = water consumptive use (cm) in the effective root zone (60 cm).

$D_i$ = soil layer depth (15 cm).

$D_{bi}$ = soil bulk density, (g/cm$^3$) for this depth.

$PW_1$ = gravimetric soil moisture percentage before irrigation.

$PW_2$ = gravimetric soil moisture percentage, 48 hours after irrigation.

n = number of soil layers (i = 1-4).

**2.3. Water use efficiency (WUE):**

It was calculated according to Jensen (1983).

$$WUE = Y/CU$$

Where:

Y = seed yield in kg/fed.

CU = seasonal water consumptive use in cm.

**2.4. Water utilization Efficiency (WUtE):** was calculated according to Michael (1978).

$$WUtE = \frac{\text{yield in kg}}{\text{irrigation water applied per season in cm}}$$

## RESULTS AND DISCUSSION

**1. Grain yield and its attributes:**

Results in Table 3 showed that irrigation at 45% of ASMD significantly increased plant height, number of racemes, 1000-seed weight, seed yield per plant, seed yield/fed., oil percent, and oil yield by 2.6, 54.1%, 3.3%, 24.1%, 38.9%, 3.8%, and 44.1%, respectively, compared to irrigation at 75% ASMD. A higher seed yield of canola at 45% ASMD could be attributed to the higher yield components such number of racemes, 1000-seed weight, and seed yield per plant (Table 3). Increasing water deficit level in vegetative and early reproductive growth stages reduced the photosynthetic rate in leaves and, in particular, siliquae plants (Gammelvind *et al.*, 1996). The largest contribution to net photosynthesis by oil seedrape leaves occurred during the vegetative and early flowering stages (Chongo and McVetty 2001). Higher water deficit causes a lower seed oil contents (Niazi and Fooladmand, 2006). These results were in agreement with those obtained by El-Mowelhi (1999), and Shahin *et al.*, (2000) who concluded that yield and its attributes of canola was gradually increased as a result of increasing the availability of soil moisture content.

Data in Table 3 revealed that increasing N fertilizer rate from 15 to 60 kg N/fed. significantly increased plant height, number of racemes, 1000-seed weight, seed yield per plant, seed yield/fed., and oil yield/fed. by 2.1%, 24.3%, 1.9%, 21.9%, 35.7% and 30.2%, respectively. Moreover, significant decrease in oil percentage was resulted by increasing the N rate up to 60 kg N/fed. These results could be attributed to role of nitrogen in increasing growth, yield and yield components which reflected increase in metabolites resulted in increases in more number of racemes, and heaviest seed, that reflected increases and seed yield /plan, and hence increased seed yield productivity per fed. The results are Similar results were obtained by Mekki (2003), Malhi *et al.*, (2006), Abdel-Ati (2006), and Abd El-Rasool (2007).

The interaction effect of irrigation and season or between the three factors was not significant for all traits (Table 3). Such results indicated that irrigation treatments showed similar effect from season to season. The entire interaction among the two factors studied was not significant except the interactions between irrigation and nitrogen rates on seed yield/plant, seed yield/fed. and oil yield/fed.

Data illustrated in Table 4 showed that the highest values of seed yield/plant, seed and oil yields/fed. were associated with 45% of ASMD and 60 kg N rate to be 23.5 g/plant, 1660.0 kg/fed, and 761.7 kg/fed, respectively, while the lowest values resulted from irrigation at 75% of ASMD with 15 kg N/fed., that were 16.4 g/plant, 862.5 kg/fed, and 395.0 kg/fed. respectively as shown in Table 4. Nitrogen uptake by canola plants is completely associated with available soil water content in the root zone. So, the response for N rates reached its maximum value by application of 60 kg N/fed. These results are in line with those reported by Choudhury *et al.,* (1990), El-Mowelhi *et al.,* (1999), and Sinha *et al.,* (2003), who mentioned that seed yield/plant and seed and oil yields increased as soil moisture was maintained high by frequent irrigation and nitrogen rates.

**Table (3): Mean values of yield and its attributes of canola as affected by irrigation and nitrogen rates in the combined analysis over both seasons.**

| Treatments | Plant height (cm) | No. of racemes | 1000-seed weight (g) | Seed yield /plant (g) | Seed yield (kg/fed.) | Oil % | Oil yield (kg/fed.) |
|---|---|---|---|---|---|---|---|
| **Irrigation treatments:** | | | | | | | |
| 45% of ASMD | 152.0a | 9.4a | 4.42a | 21.6a | 1428.8a | 46.8a | 667.1a |
| 60% of ASMD | 150.8b | 7.9b | 4.35ab | 19.7b | 1299.4b | 45.5b | 590.4b |
| 75% of ASMD | 148.1c | 6.1c | 4.28b | 17.4c | 1028.4c | 45.1b | 463.1c |
| **Nitrogen rates (kg/fed.):** | | | | | | | |
| 15 | 148.9c | 7.0b | 4.32b | 17.8d | 1090.4d | 46.7a | 510.8d |
| 30 | 149.7c | 7.5b | 4.32b | 18.9c | 1142.9c | 46.0ab | 526.3c |
| 45 | 150.6b | 8.0ab | 4.35ab | 21.1b | 1296.2b | 45.6b | 591.9b |
| 60 | 152.0a | 8.7a | 4.40a | 21.7a | 1479.2a | 44.9c | 665.0a |
| **Interactions:** | | | | | | | |
| Irrig. x season | N.S | N.S | N.S | N.S | N.S | N.S | N.S |
| Irrig. x N rates | N.S | N.S | N.S | ** | ** | N.S | ** |
| Irrig. x N rates x season | N.S | N.S | N.S | N.S | N.S | N.S | N.S |

Means designed by the same letter at each cell are not significant at the 5% level according to Duncan's multiple range test.
N.S: Indicate not significant

**Table (4): Interaction between irrigation and nitrogen rates on seed yield/plant, seed yield (kg/fed.) and oil yield (kg/fed.), over both growing seasons.**

| Variables | Seed yield /plant (g) | | |
|---|---|---|---|
| | Irrigation treatments | | |
| | 45% of ASMD | 60% of ASMD | 75% of ASMD |
| **Nitrogen rates (kg/fed.):** | | | |
| 15 | 19.5d | 17.4e | 16.4f |
| 30 | 21.0c | 18.6d | 16.8f |
| 45 | 22.5b | 20.5c | 17.2e |
| 60 | 23.5a | 22.3b | 19.3d |
| **Nitrogen rates (kg/fed.):** | Seed yield (kg/fed.) | | |
| 15 | 1260.0e | 1148.8g | 862.5j |
| 30 | 1310.0d | 1197.5f | 921.3i |
| 45 | 1485.0c | 1323.8d | 1079.8h |
| 60 | 1660.0a | 1527.5b | 1250.0e |
| **Nitrogen rates (kg/fed.):** | Oil yield (kg/fed.) | | |
| 15 | 602.3d | 535.0ef | 395.0g |
| 30 | 613.9d | 549.4e | 415.8f |
| 45 | 690.3b | 599.4de | 426.0f |
| 60 | 761.7a | 677.9bc | 555.5e |

## 2. Soil-water relations:

### 2.1. Water consumptive use (CU):

Seasonal water consumptive use by canola plants is presented in Table 5. Results showed that seasonal water consumptive use values were 35.26, 29.51, and 26.51 cm when canola plants were irrigated at 45%, 60% and 75% of ASMD, respectively. These results indicated that water consumptive use increased, as soil moisture was maintained high by frequent irrigation. The probable explanation of these results is that higher frequent irrigation provides chance for more consumption of water that ultimately resulted in increasing transpiration by plants and evaporation from the soil surface.

Monthly water consumptive use value started low at the beginning of canola plant growing season, and increased gradually to reach its maximum value at March, as a result of the increase in vegetative growth that requires higher water consumption to plants, then it declined at maturity. These results were confirmed with data reported by Sharaan *et al.*,(2002), who mentioned that peak water consumption of canola was recorded in March.

Data listed in Table 5 indicate that the seasonal amount of water consumed by canola plants was slightly increased with higher N application. This could be attributed to that higher N rate enhanced growth rate and photosynthetic activity.

**Table (5): Monthly and seasonal water consumptive use (cm) as affected by irrigation treatments and nitrogen rates, over both seasons.**

| Irrigation treatments | N rates | Months | | | | | | Water consumptive use (cm) |
|---|---|---|---|---|---|---|---|---|
| | | Nov. | Dec. | Jan. | Feb. | Mar. | April | |
| 45% ASMD | 15 | 2.40 | 3.60 | 5.54 | 7.96 | 11.70 | 3.85 | 35.05 |
| | 30 | 2.40 | 3.69 | 5.55 | 7.98 | 11.72 | 3.87 | 35.14 |
| | 45 | 2.40 | 3.65 | 5.58 | 8.01 | 11.75 | 3.88 | 35.27 |
| | 60 | 2.40 | 3.69 | 5.60 | 8.21 | 11.77 | 3.89 | 35.56 |
| Mean | | | 3.64 | 5.57 | 8.04 | 11.74 | 3.87 | 35.26 |
| 60% ASMD | 15 | 2.40 | 2.78 | 4.28 | 7.08 | 8.94 | 3.71 | 29.19 |
| | 30 | 2.40 | 2.80 | 4.30 | 7.10 | 8.98 | 3.75 | 29.33 |
| | 45 | 2.40 | 2.84 | 4.33 | 7.19 | 9.08 | 3.77 | 29.61 |
| | 60 | 2.40 | 2.89 | 4.43 | 7.25 | 9.13 | 3.80 | 29.90 |
| Mean | | | 2.83 | 4.34 | 7.16 | 9.03 | 3.76 | 29.51 |
| 75% ASMD | 15 | 2.40 | 2.52 | 3.74 | 6.04 | 7.78 | 3.70 | 26.18 |
| | 30 | 2.40 | 2.56 | 3.79 | 6.09 | 7.81 | 3.71 | 26.36 |
| | 45 | 2.40 | 2.64 | 3.82 | 6.12 | 7.93 | 3.74 | 26.65 |
| | 60 | 2.40 | 2.66 | 3.88 | 6.14 | 7.99 | 3.76 | 26.83 |
| Mean | | | 2.60 | 3.81 | 6.10 | 7.88 | 3.73 | 26.51 |
| Overall mean | 15 | 2.40 | 2.97 | 4.52 | 7.03 | 9.47 | 3.75 | 30.14 |
| | 30 | 2.40 | 2.99 | 4.55 | 7.06 | 9.50 | 3.78 | 30.28 |
| | 45 | 2.40 | 3.04 | 4.58 | 7.11 | 9.59 | 3.80 | 30.51 |
| | 60 | 2.40 | 3.08 | 4.64 | 7.20 | 9.63 | 3.82 | 30.76 |

**2.2. Irrigation water requirements (IWR):**

Results in Table 6 indicated that irrigation at 45% of ASMD resulted in higher amount of water applied to be 61.51cm (2583.4 $m^3$/fed.), distributed on 6 irrigations, followed by irrigation at 60% ASMD, to be 54.08 cm (2271.4 $m^3$/fed.), distributed on 5 irrigations, and irrigation at 75% of ASMD of to be 46.03cm (1933.3 $m^3$/fed.), distributed on 4 irrigations, respectively. Sowing irrigation and the first one were the same for all irrigation treatments. The average of the effective rainfall was 5.8 cm over both growing seasons. It is obvious that amount of irrigation water applied was gradually increased as a result of growing up of a vegetative growth that required higher amount of irrigation to meet its water requirements, and then it decreased again. It means that growth stages and meteorological variables affected irrigation water applied.

**Table (6): Irrigation water requirements (cm) as affected by irrigation treatments and effective rainfall, over both seasons.**

| No. of irrigation | Irrigation treatments | | |
|---|---|---|---|
| | 45% ASMD* | 60% ASMD | 75% ASMD |
| Sowing irrigation | 10.71 | 10.71 | 10.71 |
| 1st | 8.33 | 8.33 | 8.33 |
| 2nd | 9.29 | 9.76 | 10.18 |
| 3rd | 10.0 | 10.23 | 11.01 |
| 4th | 8.98 | 9.25 | |
| 5th | 8.40 | | |
| Irrigation water applied | 55.71 | 48.28 | 40.23 |
| ** Effective rainfall | 5.80 | 5.80 | 5.80 |
| Irrigation water requirements | 61.51 | 54.08 | 46.03 |

* ASMD refers to available soil moisture deficit
** Effective rainfall = incident rainfall x 0.7 (Novica, 1979)

**2.3. Water use efficiency (WUE):**

Water use efficiency expressed in kg of seed yield/cm of water consumed is presented in Table 7. Results indicated that irrigation of canola plants at 60% ASMD had the highest WUE value of 43.99, while the lowest was 38.75 kg of seed yield/cm of water consumed, resulted from 75% of ASMD treatments. These findings could be attributed to the highly significant differences among seed yield due to irrigation treatments, as well as differences between water consumptive uses. The present results are in line with those reported by El-Mowelhi (1999) who mentioned that the highest WUE resulted from irrigated plants of canola at 60% of available soil moisture depletion.

**Table (7): Average water use efficiency (kg seed yield/cm of water consumed) as affected by irrigation and nitrogen rates, over both growing seasons.**

| Variables | Irrigation treatments | | | Mean |
|---|---|---|---|---|
| | 45% ASMD | 60% ASMD | 75% ASMD | |
| N-rates (kg N/fed.): | | | | |
| 15 | 35.95h | 39.55f | 32.95lj | 36.08D |
| 30 | 37.28g | 40.83e | 34.95i | 37.69C |
| 45 | 42.10d | 44.71c | 40.52e | 42.44B |
| 60 | 46.68b | 51.09a | 46.59b | 48.12A |
| Mean | 40.50 B | 43.99A | 38.75C | |

Means designed by the same letter at each cell are not significant at the 5% level according to Duncan's multiple range test.

Increasing N rates from 15, 30, 45 and 60 kg N/fed. significantly increased WUE as shown in Table 7. Application of 60 kg N/fed. significantly enhanced WUE by 33.4%, 27.7%, and 13.4% compared to application of N rates of 15, 30, and 45 kg N/fed., respectively. The low N- rates not only result in lower yield but also reduce the WUE (Bruck *et al.*, 2001 and Buttar *et al.*, 2006). It means that WUE can be improved through N-rates, which in turn, influences yield components (Hatfield *et al.*, 2001).

The interaction between irrigation and N rate significantly affected WUE. The highest value of WUE resulted from irrigation at 60% of ASMD with 60 kg N fed., while the lowest WUE resulted from irrigation at 75% of ASMD with 15 kg N fed (Table 7). Optimal deficit irrigation and N rate have the impact on plant response in terms of increased plant growth and yield offer opportunities to improve WUE (Hatfield *et al.*, 2001).

**2.4. Water utilization efficiency (WUtE):**

Mean values of WUtE as affected by available soil moisture deficit and N rate are shown in Table 8. Results showed that the irrigation at 60% of ASMD resulted in the highest WUtE values of 24.03 kg seed yield/cm of water applied. These results could be attributed to the significant differences among seed yield of canola, evapotranspiration, and water applied values. The relative increases were 3.4% and 7.6%, over irrigation at 45% and 75% of ASMD, respectively. It could be recommended to irrigate canola plants at 60% of ASMD under shortage of irrigation water because the seed yield reduced by 9% against 14% of saving irrigation water compared to irrigation at 45% of ASMD.

Data in Table 8 revealed that increasing N rates from 15, 30, 45 and 60 kg N/fed. significantly increased WUtE to be 20.16, 21.15, 24.03, and 27.46 kg seed yield/cm of water applied, respectively. Data illustrated in Table 8 indicated that irrigating canola at 60% of ASMD that fertilized with 60 kg N/fed. significantly produced the highest WUtE of 26.99, while the lowest value of 18.47 kg seed yield/cm of water applied, resulted from irrigation at 75% of ASMD with 15 kg N/fed.

**Table (8): Average water utilization efficiency (kg seed yield/cm of water applied) as affected by irrigation and nitrogen rates, over both growing seasons.**

| Variables | Irrigation treatments | | | Mean |
|---|---|---|---|---|
| | 45% ASMD | 60% ASMD | 75% ASMD | |
| N-rates (kg N/fed.): | | | | |
| 15 | 20.48g | 21.24g | 18.74i | 20.16D |
| 30 | 21.30f | 22.14e | 20.01h | 21.15C |
| 45 | 24.14c | 24.48c | 23.46d | 24.03B |
| 60 | 26.99b | 28.25a | 27.16b | 27.46A |
| Mean | 23.23B | 24.03A | 22.34C | |

Means designed by the same letter at each cell are not significant at the 5% level according to Duncan's multiple range test.

## Regression and Correlation Coefficient:

Equations in Table 9 indicated that each centimeter of water applied increased 23.7 kg/fed., 12.1 kg/fed., and 0.10% of seed yield, oil yield and oil percentage, respectively. This result because seasonal water used is essential to develop a large plant canopy and early ground cover to increase yields of seeds and oil. Seasonal water applied was significantly and positively correlated to seed yield, oil percent, and oil yield.

**Table (9): Regression equations and correlation coefficient (r) between water applied in cm (IW) and seed yield in kg/fed., oil yield in kg/fed. and oil per cent.**

| Variables | Equation | r |
|---|---|---|
| IW | $\hat{Y} = -6.6 + 23.7$ (seed yield) | 0.72 ** |
| IW | $\hat{Y} = -67.6 + 12.1$ (oil yield) | 0.80 ** |
| IW | $\hat{Y} = 41.14 + 0.10$ (oil %) | 0.70 ** |

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## الملخص العربى

## تأثير الرى ومعدلات التسميد النيتروجيني على إنتاجية وجودة وكفاءة استخدام المياه لمحصول الكانولا بمنطقة شمال الدلتا مصر

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أقيمت هذه الدراسة بمزرعة محطة البحوث الزراعية بسخا كفرالشيخ لموسمى ٢٠٠٥/٢٠٠٦ و ٢٠٠٦/٢٠٠٧ بهدف دراسة تأثير الرى عند مستويات مختلفة من استنفاذ الرطوبة الأرضية ومعدلات التسميد النيتروجيني على إنتاجية محصول الكانولا وكفاءة استخدام مياه الرى. واستخدم تصميم القطع المنشقة حيث وزعت معاملات الرى عشوائيا بالقطع الرئيسية وهى الرى عند فقد ٤٥%، ٦٠%، ٧٥% من الماء الميسر ، ومعاملات التسميد النيتروجيني على القطع المنشقة بمعدلات ١٥، ٣٠، ٤٥، ٦٠ كجم نتروجين/فدان.

ويمكن إيجاز أهم النتائج فيما يلي:-

١- أدى الرى عند فقد ٤٥% من الماء الميسر إلى زيادة معنوية لصفات النمو والمحصول ومكوناته ومحتوى البذور من الزيت ومحصول الزيت للفدان.

٢- أدى الرى عند فقد ٤٥% من الماء الميسر إلى الحصول على أعلا القيم لصفة الاستهلاك المائي الموسمي وكمية مياه الرى المضافة حيث بلغت ٣٥,٢٦ سم ، ٦١,٥١ سم على الترتيب.

٣- أدى الرى عند فقد ٦٠% من الماء الميسر والتسميد النيتروجيني حتى ٦٠ كجم نتروجين/فدان إلى زيادة كفاءات الرى.

٤- أدت زيادة التسميد النيتروجيني من ١٥ الى ٦٠ كجم نتروجين/فدان الى زيادة معنوية لكل الصفات تحت الدراسة، عدا صفة محتوى البذور من الزيت فقد لوحظ وجود نقص معنوي فى هذه الصفة بزيادة معدلات التسميد النيتروجيني.

٥- بينت النتائج وجود علاقة ارتباط موجب بين كمية المياه المضافة وكل من محصول البذور ومحصول الزيت ومحتوى البذور من الزيت.

٦- بينت معادلات الانحدار الخطى إلى أن ميل خط الانحدار بين كمية المياه المضافة وكل من محصول البذور ومحصول الزيت ومحتوى البذور من الزيت يساوى ٢٣,٧ كج/فدان ، ١٢,١ كج/فدان ، ٠,١٠% على الترتيب.

٧- بناء على النتائج المتحصل عليها فانه يمكن التوصية فى حالة نقص المياه يتم يرى الكانولا عند فقد ٦٠% من الماء الميسر حيث يمكن توفير ١٤% من ماء الرى المضاف ويصل النقص فى محصول البذور إلى ٩% وذلك بالمقارنة بالرى عند فقد ٤٥% من الماء الميسر.