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# EFFECT OF VARIABLE WATER APPLICATION RATES ON YIELD OF FLAX AND IRRIGATION WATER USE EFFICIENCY

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## ABSTRACT

Two field experiments were conducted at the Experimental Farm of Sakha Agric. Res. Station during the two successive seasons 2006/2007 and 2007/2008. The aim of this work is to study the influence of irrigation intervals (traditional, irrigation at 60 %depletion of available soil moisture and irrigation at 100 and 80 % of cumulative pan evaporation) and applied irrigation water at flow rates (30 and 60 L/sec) on productivity of flax and some irrigation efficiencies. The design of the experiments were split-plot design. The obtained results could be summarized as follows:

Seed yield and other plant parameters such as plant height, , capsules number per plant and protein content had significantly affected with various irrigation treatments. Irrigation at 100%, 80% from cumulative pan evaporation and 50%depletion of available soil moisture were superior to traditional treatment, respectively. Irrigation at 100 % pan evaporation recorded the highest values of flax seed yield (540.8 and 539.4 kg/fed.), straw yield(3.545and3.767ton/fed.),plant height(114.9 and 116.2cm), technical length (101.8 and 100.5cm)and capsules number per plant(13.93and14.89)in the first and second seasons, respectively

Irrigation of flax plants at 60 % depletion of available soil moisture resulted in the highest oil content (41.98 and 40.4 %) in the first and second seasons, respectively.

Irrigation at high flow rate( 60 L/sec) increased values of plant height, technical length, number of capsules per plant, seed yield, straw yield, oil and protein contents compared to low flow rate (30L/ Sec.)in the two growing seasons.

● The interaction between irrigation intervals and flow rate (I x F) had significant effects on the technical length in the 1st season, while in the2$^{nd}$ season, the interaction had a significant effect on all parameters except seeds yield and protein content.

- The lowest values of water applied (1914.83 and 1967.6m$^3$ /fed.) were found under irrigation at 100 % pan evaporation , while the highest values of water applied (2463.5and 2530.5 m$^3$/fed.) were recorded with traditional irrigation in the 1$^{st}$ and 2$^{nd}$ seasons, respectively.
- The amount of water applied (2266.23 and 2334.2m$^3$/fed.) with flow rate of 30 L/sec. was higher than that 2087.9 and 2140.1m$^3$/fed. with flow rate of 60 L/sec in the 1$^{st}$ and 2$^{nd}$ seasons, respectively.
- Water consumptive use (m$^3$/fed) generally behaved the same trend of water applied for all treatments.
- Water application efficiency values were higher with treatments which irrigated at 100% and 80% from cumulative pan evaporation and 60%depletion from available water than traditional treatment. Also, the values were increased with increasing flow rate. Irrigation losses had almost the opposite trend to that encountered with water application efficiency.
- The highest average values of CWUE and FWUE were recorded under irrigation at 100 % pan evaporation and flow rate of 60 L/sec. in the two growing seasons.

- Irrigation at 80 % from cumulative pan evaporation achieved the highest value of water application efficiency (77.00 and 76.91%) in the 1st and 2nd seasons, respectively.

It can be recommended to use evaporation pan class A in irrigation scheduling (proper time and amount of water) to maximize the return from unit of water applied and save irrigation water.

**Keywords**: irrigation, water flow rate, depletion, pan evaporation, flax crop

## INTRODUCTION

Economic irrigation requires application of water at the proper time, and suitable amount to meet the needs of the crop growth, to prevent salt accumulation in the soil, and the excessive waste of water. Improving the irrigation system constitutes the key element in achieving the national goal of increasing irrigation efficiency, and fulfilling the equity of water distribution among farmers in order to achieve the maximum crop yield.

Moursi and El – Hariri (1977), El-Gebaly and Badawi (1978) and El – Kady (1985) obtained significant increases in technical length, length of top capsules, stem diameter, number of capsules/plant, straw yield/fed., seed yield/fed., oil percentage and total protein content with increasing of available soil moisture. They noticed that water consumptive use of flax was increased with increasing the irrigation frequency. Hussein, *et al.* and Shams El – Din *et al.* (1996) indicated that holding one irrigation at stem elongation or at seed filling stages decreased significantly flax seed and straw yields. They added that the highest values of water use efficiency were recorded with holding one irrigation at stem elongation stage. El-Mowelhi *et al.*(1999)concluded that under surface irrigation, the values of crop and field water use efficiencies were 0.22 and 0.16kg flax seed yield / $m^3$ of water consumed or applied, respectively were obtained at 7 days intervals with water applied equal 75 % ET0. Mean values of water application efficiency and percolation losses of 66.94 % and 33.06 %.. Hussein *et al.* (1983) found that flax straw and seed yields were decreased with exposing flax plants to drought during the critical growth stages ( before flowering and seed filling stages). Abd El-Rahman (1985) concluded that water application and water use efficiency increased as the flow rate increased.

Sorour and El – Kady (1995) reported that water stress during stem elongation stage reduced technical length , stem diameter, straw yield and fiber yield compared with recommended irrigation treatment. They added that delaying drought period from vegetative to productive stages caused more reduction in number of capsules / plant , number of seeds / capsule, 1000–seed weight, seed yield and protein content.

Buchong *et al*, (2006) found that, the optimum controlled soil water deficit levels, should range 50–60% of water field capacity (WFC) at the middle vegetative growth period (jointing), and 65–70% of W FC at both of the late vegetative period (booting), and early reproductive period (heading) followed by 50–60% of FWC at the late reproductive periods (the end of filling or filling and maturity). Ali *et al.* (2007) showed that the highest water productivity and productivity of irrigation water, were obtained from the alternate deficit treatment (single- or two-stage deficit and no-deficit), where deficits were imposed at maximum tillering (jointing to shooting) and flowering to soft dough stages of growth period, followed by single irrigation at crown root initiation stage. Under both land- and water-limiting conditions, the alternate deficit strategy showed maximum net financial return . Omar et al, (2008) concluded that Irrigation at 100, 80% from cumulative pan evaporation and 50%depletion from available soil moisture were superior to traditional treatment by about 21.3, 9.0 and 17.7 % for wheat grain yield and by 13.1, 10.2 and 20.1% for soybean seeds, respectively. The highest values of field water use and crop water use efficiencies (kg/$m^3$) for wheat and soybean yields were recorded with irrigation at 100 % cumulative pan evaporation. Amounts of water applied and water consumptive use ($m^3$/fed), under discharge of 30 L/sec. were higher than that of 60 L/sec. for both crops

The aim of this work is to study the influence of irrigation intervals and irrigation flow rate on productivity and some water relations of flax crop.

## MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of Sakha, Agric. Res. Station during the two successive seasons 2006/2007 and 2007/2008 to focus the light on the effects of irrigation intervals and irrigation flow rates on productivity and some water relations of flax crop. Seeding rate was 60 kg/fed. The sub plot was 16x100m.The seeds of flax were sown on rows , 15cm apart. The experiments were conducted in a split-plot design with four replicates. The main plots were randomly assigned to four irrigation intervals, and the sub-plots were assigned to two irrigation discharge as follows:

**Main plots:**

1. Traditional irrigation where the amount of irrigation water applied was equal to farmer practices in the area ($I_1$).
2. Irrigation at 50% soil moisture depletion of available water to refill the root zone to field capacity ($I_2$).
3. Irrigation at 80 % of class A pan evaporation ($I_3$).
4. Irrigation at 100 % of class A pan evaporation ($I_4$).

**Sub-plots:**

1. Irrigation flow rate of 30 L/S ($F_1$).
2. Irrigation flow rate of 60 L/S ($F_2$).

Allowable depletion was 50 % of total available water, for the two seasons and the rooting depth was assumed to be constant at 60cm. The available water in the effective root zone (128mm) was used to calculate the allowable depletion. Therefore, irrigation water was applied when 64mm (50% x 128 mm) of available water had evaporated from the pan in case of 100 % pan evaporation treatment, and 51.2 mm (80 % x 64) in case of treatment 80% pan evaporation.Takinig in consideration, pan coefficient (0.8), crop coefficient and irrigation efficiency (supposed to be 0.7) when calculating the applied water for ($I_3$) and ($I_4$) treatments. The crop coefficient for flax for different growth stages was taken from FAO Irrigation and Drainage Technical Paper No. 56. , Allen *et al.*(1999).

In case of soil moisture depletion treatment, irrigation started when 50 % of soil available water was depleted by monitoring soil moisture content every week by gravimetric method. Traditional irrigation was as farmers practices.

Flax (*Linum usitatissimum*) L Sakha 1 commercial cultivar was planted on November 5, 2006 and November 9, 2007 in the two growing seasons, respectively. The common agricultural practices of growing flax plants were performed according to the local recommendations of the Ministry of Agriculture, Egypt. . The harvesting date was took place in the first of May 2007 and 2008. The following characters studied are:-

Plant height,(cm.)
Technical length, (cm.)
Number of capsules / plant.
Seed yield( kg/fed.)
Straw yield( ton/fed.)
Oil content,( %)
Protein,( %.)

Oil content and crude protein were determined according to the method described by A.O. A.C. (1990).

*Amount of water applied*

Amount of irrigation water was measured by using a rectangular sharp crested weir. The discharge was calculated using the following equation as described by (Masoud, 1969).

$$Q = CLH^{3/2}$$

*Where*: Q = Discharge ($m^3$/sec)
L = Length of the crest in meter.
H = Head in meter.
C = Empirical coefficient that must be determined from discharge measurement.

The metrological data were recorded from Sakha Climatological Station are presented in Table (1)

*Water consumptive use* (CU): was calculated according to (Israelsen and Hansen, 1962) as follows:

$$CU = \sum_{i=1}^{i=n} \frac{Pw_2 - pw_1}{100} \times D_{bi} \times D_i$$

***Where:***

*CU* : Water consumptive use in cm.
$Pw_2$ : Soil moisture percent after irrigation in the i th layer
$Pw_1$ : Soil moisture percent before the next irrigation in the i th layer
$D_{bi}$ : Bulk density g/$cm^3$ of the i th layer of the soil
$D_i$ : Depth of the i th layer of the soil, cm
*i* : Number of soil layer sampled in the root zone depth (D).

**Field water use efficiency: was calculated as follows:**

FWUE (kg/$m^3$) = Yield (kg/fed.) ⁄ Amount of water applied ($m^3$/fed).

**Crop Water use efficiency (C.W.U.E) : was calculated by using the following formula:**

C.W.U.E ($kg/m^3$) = Yield (kg/fed.) ⁄ Seasonal water consumptive use ($m^3$/fed), (Doorenbos and Pruitt, 1977).

- *Water application efficiency:* is the ratio of the average depth of irrigation water infiltrated and stored in the effective root zone to the average depth of irrigation water applied, Michael (1978**).**

***Irrigation water losses*: consists of deep percolation and runoff:**

Loss % =100 − Water application efficiency %

Infiltration rate (IR) was determined using double cylinder infiltrometer as described by Garcia (1978). Soil physical and chemical properties (Table 2) were determined according to Klute (1986) and Page (1982) .Data are subjected to statistical analysis according to Snedecor and Cochran (1980).

## RESULTS AND DISCUSSION

**1- Yield and yield components.**

Data in Table (3) show that yield and yield components had been significantly affected by various irrigation regime treatments in the two growing seasons. Irrigation at 100% from cumulative pan evaporation recorded the highest seed yield (540.8 and 539.4 kg/fed.) and straw yield (3.545 and 3.767 ton/fed.)as well as yield characters, plant height (114.9 and 116.2 cm), technical length (101.8 and 100.5 cm), number of capsules/ plant, (13.93 and 14.89) and protein content (22.03 and 22.51 %) in the first and second seasons, respectively. On the other hand irrigation of flax plants at 50 % depletion of available soil water resulted in the highest oil content( 41.89 and 40.40 %) in the first and second seasons, respectively.

Data listed in Table (3) show that there were highly significant differences in number of capsules/ plant and seed yield with various irrigation flow rates( 30 and 60 L/sec) in the two growing seasons. Irrigation at high flow rate (60L/sec.) significantly increased plant height, technical length, number of capsules / plant, flax seed yield, and protein content in the two growing seasons. These decrements in production of flax under low flow rate could be attributed to that the chance for more leaching of water and its load of fertilizers could be occurred.. On the other hand, under other treatments which accompanied with less water content, more energy is forced to extract more water with its content of fertilizers, which in turn resulted in decreasing the withdrawn of fertilizers. Similar results were obtained by Omar *et al.* (2008) and El-Hamdi and Knany (2000).

The interaction between irrigation intervals and flow rates (I x F) had significant effects on the technical length in the 1st season, while in the 2nd season the interaction had a significant effect on all parameters except seed yield and protein content.

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**2.Some water relations:**

**2.1. Applied water, water consumptive use and some irrigation efficiencies:**

Data presented in Table (4) reveal that, the total amount of water applied under irrigation intervals treatments, were in the following order: Traditional > 50 % depletion >80 % pan evaporation > 100 % cumulative pan evaporation. The lowest (values1914.83 and1967.6m$^3$ /fed.) of water applied were found under irrigation at 100 % cumulative pan evaporation, while the highest values (2463.5 and 2530.5 m$^3$/fed.) of water applied were recorded with traditional irrigation in the 1$^{st}$ and 2$^{nd}$ seasons, respectively. It was observed that irrigation at 80 % cumulative pan evaporation received higher amount of water than that received under irrigation at 100 % cumulative pan evaporation due to the more number of irrigations (6 irrigations).

On the other hand, data listed in Table (4) show that, the amount of water applied 2266.23 and 2334.2 m$^3$/fed. with flow rate 30 L/sec. was higher than that 2087.9 and 2140.1 m$^3$/fed. with flow rate 60 L/sec. in the 1$^{st}$ and 2$^{nd}$ seasons, respectively. Similar results were obtained by El-Mowelhi *et al.* (1999) and Omar *et al.*(2008).

Water consumptive use (m$^3$/fed) generally behaved the same trend of water applied for all treatments. The lowest average values 1468.95 and 1507.9 m$^3$/fed. of water applied were recorded with irrigation at 100 % cumulative pan evaporation in the 1$^{st}$ and 2$^{nd}$ seasons, respectively.

The presented data in Table (4) show that, the highest average values of F.W.U.E (0.28 and 1.85 kg/m$^3$) in the 1$^{st}$ season and (0.27 and 1.92 kg/m$^3$) in the 2$^{nd}$ season for seed and straw yields, respectively were obtained with irrigation at 100 % pan evaporation. The highest average values of C.W.U.E (0.37 and2.41 kg/m$^{3)}$ in the 1$^{st}$ season and (0.36 and 2.50 kg/m$^3$) in the 2$^{nd}$ season for seed and straw yields, respectively were obtained with irrigation at 100 % pan evaporation. Irrigation with flow rate of 60 L/sec achieved the highest values of F.W.U.E and C.W.U.E compared to 30 l/sec.

The obtained results revealed that irrigation of flax at 80 % cumulative pan evaporation resulted in the highest average values (77.0 and 76.91%) of water application efficiency in the 1$^{st}$ and 2$^{nd}$ seasons, respectively. Moreover, Irrigation with flow rate of 60 L/sec achieved the highest average values (72.15 and 72.21 %) of water application efficiency in the 1$^{st}$ and 2$^{nd}$ seasons, respectively. Similar results were obtained by Abd El-Rahman (1985), El-Mowelhi *et al.* (1999), Zhen Li *et al.* (2004) , Jiamin *et al.* (2005) and Omar *et al.* ( 2008).

**Table (4): Some water relations as affected by various irrigation intervals and irrigation flow rate.**

| Treatments | Water applied, m3/fed. | F.W.U.E. kg/m$^3$ | | C.U, m3/fed. | C.W.U.E. kg/m$^3$ | | Water application efficiency, % |
|---|---|---|---|---|---|---|---|
| | | Seed | Straw | | Seed | Straw | |
| **First season** | | | | | | | |
| **Irrigation intervals** | | | | | | | |
| **Traditional** | 2463.5 | 0.19 | 1.24 | 1621.83 | 0.29 | 1.89 | 65.83 |
| **5٠% depletion** | 2237.7 | 0.21 | 1.53 | 1522.29 | 0.30 | 2.25 | 68.03 |
| **80%pan evaporation** | 2093.18 | 0.23 | 1.56 | 1611.75 | 0.29 | 2.02 | 77.00 |
| **100%pan evaporation** | 1914.83 | 0.28 | 1.85 | 1468.95 | 0.37 | 2.41 | 76.71 |
| **Irrigation flow rate (F)** | | | | | | | |
| **30L/Sec** | 2266.23 | 0.20 | 1.44 | 1606.1 | 0.29 | 2.03 | 70.87 |
| **60L/Sec.** | 2087.9 | 0.24 | 1.50 | 1506.33 | 0.34 | 2.08 | 72.15 |
| **Second season** | | | | | | | |
| **Irrigation intervals** | | | | | | | |
| **Traditional** | 2530.5 | 0.18 | 1.07 | 1664.9 | 0.28 | 1.63 | 65.79 |
| **50% depletion** | 2299.55 | 0.20 | 1.31 | 1562.7 | 0.30 | 1.93 | 67.96 |
| **80%pan evaporation** | 2151.1 | 0.22 | 1.49 | 1654.5 | 0.29 | 1.94 | 76.91 |
| **100%pan evaporation** | 1967.6 | 0.27 | 1.92 | 1507.9 | 0.36 | 2.50 | 76.64 |
| **Irrigation flow rate (F)** | | | | | | | |
| **30L/Sec.** | 2334.2 | 0.19 | 1.38 | 1649.5 | 0.28 | 1.95 | 70.67 |
| **60L/Sec.** | 2140.1 | 0.24 | 1.47 | 1545.4 | 0.34 | 2.03 | 72.21 |

### 2.2. Irrigation date and number of irrigations:

The obtained results in Table (5) revealed that the method on which irrigation was scheduled affect the date of irrigation and the number of irrigations for flax crop. Irrigation at 80 % cumulative pan evaporation resulted in 6 irrigations such as traditional one but with different irrigation dates. While irrigation at 100 % cumulative pan evaporation and irrigation at 50%depletion of available soil water, resulted in 5 irrigations but differed in dates during the two growing seasons.

### Conclusion*:*

From the above mentioned discussion, It could be concluded that under the condition of this study, using pan class A (100%pan evaporation) and irrigation with flow rate 60L/sec. in irrigation scheduling (proper time and amount of water) is the preferable treatment to produce the maximum flax yields and save the irrigation water at North Nile Delta.

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## تأثير معدلات التصرف المختلفة على إنتاجية محصول الكتان وكفاءة استخدام مياه الرى

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أقيمت تجربتين حقليتين في المزرعة البحثية بمحطة البحوث الزراعية بسخا بشمال الدلتا وذلك خلال موسمي النمو الشتوي ٢٠٠٦/ ٢٠٠٧، ٢٠٠٧/ ٢٠٠٨ وذلك لدراسة تأثير مواعيد إضافة مياه الري ( ١٠٠%، ٨٠% من وعاء البخر ،استنفاذ ٥٠% من الرطوبة الأرضية الميسرة مقارنة بالري السطحي التقليدي عند المزارع ) ومعدل تصرف المياه (٣٠ و٦٠ لتر في الثانية) على إنتاجية الكتان وبعض كفاءات الري. وقد صممت التجربة بطريقة القطع المنشقة مرة واحدة في أربع مكررات.

**تشير النتائج إلى ما يلي :-**

- تأثر محصول الكتان معنويا في إنتاجية البذور وبعض المقاييس الأخرى مثل طول النباتات وعدد الكبسولات ومحتوى البذور من البروتين مع معاملات الري المختلفة عند ١٠٠% ،٨٠% من وعاء البخر واستنفاذ ٥٠% من الرطوبة الأرضية على التوالي وذلك مقارنة باستخدام طريقة الري السطحي التقليدي.
- أدت جدولة الرى عند ١٠٠% من القيم التراكمية لوعاء البخر الى أعلى القيم في إنتاجية البذور( ٥٤٠,٨ و ٥٣٩,٤ كجم / فدان ) والقش ( ٣,٥٤٥ و ٣,٧٦٧ طن / فدان )وطول النباتات (١١٤,٩ و١١٦,٢سم ) والطول الفعال (١٠١,٨ و ١٠٠,٥سم ) وعدد الكبسولات لكل نبات (١٣,٩٣ و ١٤,٨٩ ) في موسمي النمو على التوالي
- زاد إنتاج البذور من الزيت حيث كانت أعلى القيم (٤١,٩٨ و ٤٠,٤ % ) مع معاملة الري عند استنفاذ ٥٠% من الرطوبة الأرضية الميسرة وذلك في الموسم الأول والثاني على التوالي

- أدت إضافة مياه الرى بمعدل تصرف ٦٠ لتر بالثانية إلى تسجيل أعلى القيم في إنتاجية البذور ،محصول القش ومختلف المقاييس الأخرى ( طول النباتات- الطول الفعال – عدد الكبسولات – محتوى البذور من الزيت والبروتين ) .
- تشير النتائج إلى أن هناك تأثير معنوي نتيجة للتأثير المتبادل لكل من فترات الرى ومعدل إضافة المياه على طول النباتات في الموسم الأول، بينما في الموسم الثاني كان هناك تأثيرا معنويا على كافة المقاييس لمحصول الكتان باستثناء إنتاجية البذور ومحتواها من البروتين.
- أخذت كمية المياه المضافة للحقل والمستهلكة بواسطة النباتات (م٣/ فدان) مع معاملات الرى المختلفة الترتيب التالي : الرى التقليدي > استنفاذ ٥٠% > ٨٠% من وعاء البخر > ١٠٠% من وعاء البخر . حيث سجلت أقل القيم لكميات مياه الرى المضافة ( ١٩١٤,٨٣ و ١٩٦٧,٣متر مكعب للفدان مع استخدام الرى عند ١٠٠% من وعاء البخر، بينما أعلى القيم (٢٤٦٣,٣ و ٢٥٣٠,٥ متر مكعب للفدان ) سجلت مع معاملة الرى التقليدي في كل من الموسم الأول والثاني على التوالي .
- بلغت كمية المياه المضافة للحقل أعلى القيم (٢٢٦٦,٢٣ و ٢٣٣٤,٢ متر مكعب للفدان ) مع استخدام معدل تصرف للمياه المضافة ٣٠ لتر في الثانية ، بينما كانت ( ٢٠٨٧,٩ و ٢١٤٠,١ متر مكعب للفدان ) عند استخدام معدل تصرف ٦٠ لتر في الثانية في الموسم الأول والثاني على التوالي.
- أخذت كميات المياه المستهلكة نفس اتجاه كميات المياه المضافة .
- كان هناك زيادة لقيم كفاءات الرى التطبيقية (% ) مع معاملات الرى ١٠٠% من وعاء البخر و ٨٠% من وعاء البخر واستنفاذ ٥٠% من الرطوبة الأرضية مقارنة بمعاملة الرى التقليدية لمحصول الكتان .
- سجلت أعلى القيم لكفاءات استخدام المياه على مستوى الحقل والمحصول عند تعويض كميات المياه عند ١٠٠% من وعاء البخر واستخدام معدل تصرف ٦٠ لتر بالثانية .

يمكن التوصية بإضافة مياه الرى عند ١٠٠% من وعاء البخر ومعدل تصرف ٦٠لتر في الثانية لتعظيم الاستفادة من وحدة المياه المضافة تحت الظروف المحلية لمنطقة شمال الدلتا .

**Table (1):The metrological data of Sakha Climatological Station during the growing seasons.**

| Month | Air Temp.C° | | Relative humidity,% | | wind speed , km/24 hr.at 2m height | Solar radiation, MJ /m2 | Soil Temp.C° | Ep, mm/day | rain, mm/day |
|---|---|---|---|---|---|---|---|---|---|
| | T, MAX. | T, MIN. | RH, MAX. | RH, MIN. | | | | | |
| Nov. 06 | 23.17 | 8.85 | 77.9 | 58.5 | 62.6 | 12.9 | 17.29 | 2.89 | 0.00 |
| Dec. 06 | 19.7 | 4.5 | 82.9 | 62.6 | 58.2 | 9.8 | 13.3 | 1.97 | 0.32 |
| Jan. 07 | 18.7 | 4.1 | 87.0 | 58.5 | 57.2 | 9.2 | 13.0 | 1.90 | 1.20 |
| Feb. 07 | 21.6 | 5.6 | 95.4 | 67.6 | 60.0 | 14.0 | 16.1 | 2.30 | 1.60 |
| Mar-07 | 22.0 | 5.8 | 79.2 | 51.7 | 75.0 | 14.3 | 18.3 | 3.50 | 0.00 |
| Apr-07 | 25.3 | 7.5 | 80.5 | 49.5 | 100.0 | 18.6 | 19.5 | 5.30 | 0.00 |
| May-07 | 30.0 | 12.0 | 76.3 | 45.0 | 111.0 | 22.0 | 24.0 | 6.50 | 0.00 |
| Nov. 07 | 26.0 | 8.0 | 78.0 | 52.7 | 53.0 | 13.0 | 18.3 | 2.73 | 0.28 |
| Dec. 07 | 21.0 | 3.7 | 79.0 | 55.5 | 60.0 | 9.2 | 13.0 | 1.92 | 0.46 |
| Jan. 08 | 18.0 | 1.4 | 74.0 | 58.0 | 58.0 | 9.0 | 13.5 | 1.63 | 1.20 |
| Feb. 08 | 20.4 | 3.00 | 79.0 | 63.3 | 81.0 | 13.5 | 15.9 | 3.18 | 1.30 |
| Mar-08 | 25.0 | 5.80 | 77.0 | 53.0 | 72.0 | 14.0 | 18.1 | 3.84 | 0.00 |
| Apr-08 | 27.8 | 8.3 | 70.0 | 46.0 | 98.5 | 19.0 | 19.3 | 6.15 | 0.00 |
| May-08 | 29.0 | 10.0 | 70.5 | 42.5 | 110.0 | 22.0 | 23.1 | 6.91 | 0.00 |

**Table (2): Some soil properties for the experimental field before planting.**

| Soil depth (cm) | Particle size distribution | | | Texture class | Bulk density, g/cm$^3$ | EC, dS/m at 25c$^0$ | Soil moisture characteristics | | | I R, cm/hr |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sand% | Silt% | Clay% | | | | FC% | WP% | AW% | |
| 0--15 | 9.14 | 33.75 | 57.11 | Clayey | 1.14 | 1.3 | 40.4 | 22.02 | 18.38 | 1.35 |
| 15--30 | 9.55 | 33.14 | 57.31 | Clayey | 1.18 | 1.3 | 42.95 | 23.32 | 19.63 | |
| 30--60 | 8.98 | 38.49 | 52.53 | Clayey | 1.26 | 1.5 | 36.25 | 19.7 | 16.55 | |
| 60--90 | 9.21 | 39.05 | 51.74 | Clayey | 1.26 | 1.5 | 37.76 | 20.69 | 17.07 | |

EC=Electrical conductivity, FC=Field capacity ,WP=Wilting point ,
AW= Available water and IR= Infiltration rate .

**Table (3): Flax yield and its components as affected by various irrigation intervals and irrigation flow rate.**

| Treatments | Plant height, cm | Technical length, cm | No. of capsules/ plant | Seed yield, kg/fed. | Straw yield, ton/fed. | Oil content, % | Protein content, % | Plant height, cm | Technical length, cm | No. of capsules/ plant | Seed yield, kg/fed. | Straw yield, ton/fed. | Oil content, % | Protein content, % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Season: 2006 /2007 | | | | | | | Season : 2007/2008 | | | | | | |
| **Irrigation regime (I)** | | | | | | | | | | | | | | |
| **Traditional** | 111.8 | 94.9 | 12.94 | 462.6 | 3.058 | 40.16 | 21.68 | 111.8 | 96.5 | 13.38 | 460.9 | 2.717 | 38.82 | 21.87 |
| **60% depletion** | 103.1 | 97.4 | 12.97 | 459.4 | 3.425 | 41.89 | 20.97 | 107.6 | 98.9 | 13.45 | 465.9 | 3.019 | 40.4 | 22.02 |
| **80% pan evaporation** | 109.8 | 96.9 | 13.73 | 471.9 | 3.255 | 40.19 | 21.9 | 114.4 | 96 | 14.33 | 472.5 | 3.215 | 38.67 | 21.52 |
| **100% pan evaporation** | 114.9 | 101.8 | 13.93 | 540.8 | 3.545 | 41.6 | 22.03 | 116.2 | 100.5 | 14.89 | 539.4 | 3.767 | 38.04 | 22.51 |
| **F test** | * | ns | ** | ** | ns | ns | ** | * | ns | ** | ** | ns | ** | * |
| **L.S.D 0.05** | 7.67 | - | 0.512 | 27.85 | - | - | 0.16 | 5.42 | - | 0.328 | 33.01 | - | 0.101 | 0.56 |
| **L.S.D 0.01** | - | - | 0.308 | 40 | - | - | 0.23 | - | - | 0.471 | 47.41 | - | 0.145 | - |
| **Irrigation flow rate (F)** | | | | | | | | | | | | | | |
| **30 L/S** | 109.2 | 97 | 13.3 | 459.7 | 3.136 | 40.75 | 21.60 | 111.8 | 95.5 | 13.88 | 452.8 | 3.215 | 38.01 | 21.89 |
| **60 L/S** | 110.6 | 98.5 | 13.49 | 507.6 | 3.255 | 41.17 | 21.69 | 113.2 | 100.4 | 14.15 | 519.1 | 3.143 | 39.95 | 22.07 |
| **F test** | ns | ns | ** | ** | ns | ns | * | ns | ** | ** | ** | ns | ns | ** |
| **L.S.D 0.05** | - | - | 0.097 | 23.02 | - | - | 0.207 | - | 2.69 | 0.119 | 20.97 | - | - | 0.07 |
| **L.S.D 0.01** | - | - | 0.137 | 32.27 | - | - | - | - | 3.78 | 0.167 | 29.39 | - | - | 0.1 |
| **Interaction (I x F)** | ns | * | ns | ns | ns | ns | ns | * | ** | * | ns | * | ** | ns |

**Table (5): Effect of irrigation scheduling methods on the irrigation date and number of irrigations.**

| Traditional Irrigation | | Irrigation at 60 % depletion | | Irrigation at100% pan | | Irrigation at 80 % pan | |
|---|---|---|---|---|---|---|---|
| **Irrigation date** | **Number of irrigations** | **Irrigation date** | **Number of irrigations** | **Irrigation date** | **Number of irrigations** | **Irrigation date** | **Number of irrigations** |
| **First season** | | | | | | | |
| 19-Nov-06 | 6 | 19-Nov-06 | 5 | 19-Nov-06 | 5 | 19-Nov-06 | 6 |
| 10 Dec 06 | | 10 Dec 06 | | 10 Dec 06 | | 10 Dec 06 | |
| 01/Jan.-07 | | 6-Jan.-07 | | 20-Jan-07 | | 13-Jan-07 | |
| 08Feb.-07 | | 12-Feb-07 | | 24-Feb-07 | | 17-Feb-07 | |
| 05-Mar-07 | | 22-Mar-07 | | 22-Mar-07 | | 08-Mar-07 | |
| 04-Apr-07 | | Harvesting | | Harvesting | | 25-Mar-07 | |
| Harvesting | | | | | | Harvesting | |
| **Second season** | | | | | | | |
| 25 Nov-07 | 6 | 25 Nov-07 | 5 | 25 Nov-07 | 5 | 25 Nov-07 | 6 |
| 15 Dec 07 | | 15 Dec 07 | | 15 Dec 07 | | 15 Dec 07 | |
| 11/Jan.-08 | | 13-Jan.-08 | | 18-Jan-08 | | 13-Jan-08 | |
| 06Feb.-08 | | 14-Feb-08 | | 20-Feb-08 | | 23-Feb-08 | |
| 03-Mar-08 | | 19-Mar-08 | | 23-Mar-08 | | 08-Mar-08 | |
| 30-Mar-08 | | Harvesting | | Harvesting | | 25-Mar-08 | |
| Harvesting | | | | | | Harvesting | |