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EFFECT OF IRRIGATION ON THE PRODUCTIVITY AND WATER USE EFFICIENCY OF FABA BEAN CULTIVARS (*Vicia faba* L) IN NORTH DELTA, EGYPT

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ABSTRACT

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 study aimed to investigate irrigation effect on seed yield and water use efficiency of faba bean cultivars in North Delta, Egypt. A split plot design with four replications was used. Irrigation treatments were sowing irrigation (I_1); sowing irrigation plus 1st irrigation after 30 days from sowing (I_2); sowing irrigation plus 1st irrigation after 30 days and the 2nd irrigation after 90 days from sowing (I_3); sowing irrigation plus 1st irrigation after 30 days and the 2nd irrigation after 90 days and the 3rd irrigation after 120 days from sowing (I_4). Sub plots were devoted to faba bean cvs. Sakha 1, Sakha 3 and Nubaria 1.

Results showed that insignificant increases between irrigation treatment of I_4 and treatment of I_3 in all traits under study i.e. plant height, number of pods/plant, number of seeds/pods, number of seeds/plant, 100-seed weight, seed yield of plant and seed yield. Irrigation treatment of I_4 significantly increased plant height by 4.7%, number of seeds/plant by 22.1%, 100-seed weight by 4.1%, and seed yield/fed by 22.4% compared to irrigation treatment of I_1.

Means values of seasonal water consumptive use of faba bean were 30.05 cm, 25.84 cm, 22.49 cm, and 12.30 cm for irrigation treatments of I_4, I_3, I_2, I_1, respectively. Faba bean cv. Sakha 1 consumed less water than cvs. Sakha 3 and Nubaria 1 by 7.4% and 4.9%, respectively, due to short duration of cv. Sakha 1.

Seasonal irrigation water applied were 47.2 cm (1982 m^3/fed.), 39.1 cm (1642 m^3/fed.), 27.6 cm (1159 m^3/fed.), and 18.8 cm (790 m^3/fed.) for irrigation treatments of I_4, I_3, I_2, I_1, respectively.

Maximum values of crop water use and field water use efficiencies resulted from irrigation treatment of I_1, and faba bean cv. Sakha 3 exhibited the highest crop water use and field water use efficiencies compared to the other tested cultivars.

Means percentage values of water removed from the upper 30 cm soil layer were 76.93%, 72.20%, 66.43% and 63.48% for I_4, I_3, I_2, and I_1 respectively.

Regression slope indicated that each centimeter of seasonal water applied produced 10.5 kg seed yield/fed. and enhanced water consumptive use of faba bean plants by 0.60 cm. On the other hand, it decreased crop water use efficiency by 1.7 kg seed yield/cm of water consumed and field water use efficiency by 1.3 kg seed yield/cm of water applied.

Therefore, irrigating faba bean plants 3 times including sowing irrigation could be applied since the reduction in seeds yield was 1.4% for 17.2% of saving irrigation water applied compared with irrigation 4 times including sowing irrigation. But, when water is scarce, irrigations may be reduced to two, or one, which concomitant water savings, using cultivars which utilize more water and result in higher water use efficiencies in Delta, Egypt.

INTROUCTION

Faba bean (*Vicia faba* L.) is one of the major winter sown legume crops grown in the Mediterranean region, and has considerable importance as a low cost food rich in proteins and carbohydrates in Egypt. The total production in 2004/05 was about 282.000 tons, while the total consumption was estimated to be about 420.000 tons. This means that the percentage of self-sufficiency is only about 67% (Amer *et al.* 2006). So, to reduce the gab between production and consumption, the most effective is being developing new cultivars with high yielding potentiality in addition using the proper management.

Farmers in North Delta, Egypt, generally irrigate winter faba bean two to four times, including sowing irrigation, depending on average rainfalls during the growing season from October to May ranged from approximately 67-200 mm (Egyptian Meteorological Authority**,** 1960).

Substantial and sustainable improvements in the productivity of faba bean can be achieved through integrated farm-resources management, such as on-farm water-productive techniques, high yielding faba bean cultivars selection and appropriate cultural practices which will help to achieve this objective.

El-Galfy, (2005), revealed that the yield and its components of faba bean (plant height, number of branches per plant, number of pods per plant, number of seeds per pod, pod weight, 100-seed weight and seed yield/fed) significantly decreased as the number of irrigations decreased. The yield decreased by 52% and 15.5% with one and two irrigations, respectively, compared to three irrigations. This reduction in yield may be due to lower number of branches, pods, seeds per plant, pod weight and 100-seed weight. Irrigation frequency 4 times after planting appeared to be optimum for obtaining high seed yield of faba bean (Mohamed *et al***.,** 1999). Hassanein (2000) showed that Giza 643 subjected to 2 irrigations at 60 and 90 days after sowing or 3 irrigations at 60, 90 and 120 days after sowing recorded the highest seed yield, whereas Giza Blanka subjected to 3 irrigations recorded the highest straw yield. Xia (1997) showed that plants subjected to drought from initiation of pod-set to full pod-set produced 32% less total dry matter and 45% less seed yield than the irrigated control. Only plants subjected to drought from full pod-set to maturity had a significant lower mean seed weight than the control (well irrigated). Meleha *et al*.(2004) indicated that the highest seed yield of faba bean of 1792.6 kg/fed resulted from the treatment received 51.2 cm, while the lowest seed yield was 1731.4 kg/fed resulted from the treatment received 53.1 cm. They also revealed that actual water consumptive use amounted to 36.7 - 38.1 cm when the amount of water applied ranged from 49.3 to 53.1 cm, and water use efficiency increased with decreasing irrigation water applied. Fardos and Abdel-Nour (2000), found that maximum faba been seed yield was gained from treatment irrigated frequently at 30% available soil moisture depletion (ASMD). Seasonal water consumptive use of faba bean ranged from 344 mm for irrigating at 90% ASMD to 521.3 mm for irrigating at 30% ASMD. The maximum WUE was obtained from irrigation at 60% ASMD. Plies *et al.* (1995) and Tawardros *et al.* (1993) found that the drought conditions during flowering stage significantly decreased yield formation in all cultivars under study, whereas water stress during pod filling stage had little effect on biomass production. This was in agreement with that of Farah *et al.* (1990), who found that water shortage greatly affected faba bean yield. Abd El-Mottaleb and Abbas (1992)**,** found that the highest water consumptive use (1497 m^3/fed.) was obtained when soil moisture suction is kept at 2 bars, while the lowest value were 840 m^3/fed. at 10 bars. Abbas *et al*., (1994) revealed that maximum yield of seed and straw were recorded by irrigation of the faba bean plants at 6 bars. Water consumptive use by faba bean ranged from 35.9 to 37.1 cm. Ainer *et al*. (1993) indicated that the optimum yield of faba bean seeds was obtained by irrigating the crop at 2 bars in the Delta region, and the water use efficiency decreased when the faba bean was irrigated at 10 bars. They also added that water consumptive use of faba bean ranged from 170.2 to 370.5 mm at Sakha region (North Delta).

As for faba bean cultivars, El-Deep et al. (2006) revealed that planting 1706B/87/1999 genotype resulted in higher faba bean yields by 7.2%, 15.6% and 7.2% compared to genotype 1706B/39/1999, cvs. Misr 2 and Giza 40.

The objective of this investigation was to study the effect of irrigation on seed yield productivity of faba bean cultivars and water use efficiency in North Delta, Egypt.

MATERIALS AND METHODS

The investigation was conducted at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, during seasons of 2005/06 and 2006/07.

A split-plot design with four replications was used. Main plots were occupied to irrigation treatments which were sowing irrigation (I_1); sowing irrigation plus 1st irrigation after 30 days from sowing (I_2); sowing irrigation plus 1st irrigation after 30 days and the 2nd irrigation after 90 days from sowing (I_3); sowing irrigation plus 1st irrigation after 30 days and the 2nd irrigation after 90 days and the 3rd irrigation after 120 days from sowing (I_4). Sub plots were devoted to faba bean cvs. Sakha 1, Sakha 3 and Nubaria 1.

The soil was clayey in texture, whereas particle size distribution was 52.10% clay, 27.23% silt and 20.67% sand. Soil pH (1: 2.5) was 8.12 and the electrical conductivity of soil and irrigation water was 2.35 and 0.45 dSm^{-1}, respectively, the analysis was determined according to Page (1982). The plots were isolated by ditches of 1.5 m in width to avoid lateral movement of irrigation water to adjacent plots. The area of each sub plot is 42 m^2 (6 x 7 m^2).

Sowing dates in the first and second seasons were on November 7th and 10th, respectively. All cultural practices for faba bean were applied. Faba bean plants were harvested on 5th and 7th May in the first and second growing seasons for cvs. Sakha 3 and Nubaria 1, respectively, and on 12th and 14th April for cv. Sakha 1

Ten guarded plants were randomly taken from each plot to measure plant height in cm, number of pods/plant, number of seeds/pod, number of seeds/plant, 100-seed weight in g, and seed yield/fed in ardab (ardab = 155 kg). Seed yield/fed. was obtained from central area of each plot (1/300 fed.) to avoid any border effect.

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). Also, a regression and simple correlation coefficient between seasonal irrigation water applied and each of seed yield, water consumptive use and crop water use efficiency was computed according to the method described by Snedecor and Cochran (1980).

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

II. Soil water relations:

Soil moisture content was gravimetrically determined in soil sample taken from consecutive depth of 15 cm down to a depth of 60 cm. For irrigation timing, soil samples were also collected just before each irrigation, 48 hours after irrigation and at harvest time, to estimated water consumptive use (Hansen *et al.,* 1979). Field capacity, permanent wilting point and bulk density were determined according to Klute (1986), and are given in Table 2.

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

Seasons	2005/06							2006/07						
	Air temperature ºC			Relative humidity (%)			Rainfall (mm)	Air temperature ºC			Relative humidity (%)			Rainfall (mm)
	Max.	Min.	Mean	Max.	Min.	Mean		Max.	Min.	Mean	Max.	Min.	Mean	
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

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	46.14	24.78	1.11	21.36
15-30	41.21	21.29	1.21	19.92
30-45	36.84	20.38	1.24	16.46
45-60	34.91	19.13	1.32	15.78
Mean	39.78	21.40	1.22	18.38

Irrigation water applied (IWA):

The amount of water applied at each irrigation was determined on the basis of raising the soil moisture content to its field capacity plus 10% as a leaching requirements. Irrigation water applied was calculated according to the following equation (Michael, 1978).

$$d = D^* B_d^* \frac{F_c - M_c}{100}$$

Where:

d	=	amount of water to be applied during an irrigation event, cm.
D	=	soil depth within the root zone, 60 cm.
B_d	=	soil bulk density, g cm^{-3}
F_c	=	field capacity moisture content (% by weight).
M_c	=	moisture content before irrigation (% by weight).

Submerged flow orifice with fixed dimension was used to measure the amount of water applied according to the following equation (Michael, 1978).

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

Where:

Q	= discharge through orifice, (1/sec.)
C	= coefficient of discharge, (0.61).
A	= cross-sectional area of the orifice, (cm^2)
g	= acceleration of gravity, (cm/sec^2) (981 cm/sec.).
h	= pressure head, causing discharge through the orifice (cm).

Crop water use efficiency (CWUE):

Crop water use efficiency was calculated according to Michael (1978).

$$CWUE = Y/C.U$$

Where:

Y	=	seed yield in kg
C.U	=	seasonal water consumptive use in cm.

Field water use efficiency (FWUE):

It was calculated according to Jensen (1983).

$$FWUE = \frac{\text{Seed yield in kg}}{\text{Amount of applied water (cm)}}$$

Soil moisture extraction pattern (SMEP):

It was calculated according to the following equation (Hansen *et al.,* 1979).

$$SMEP = CU.\ (layer) \times 100/CU\ (seasonal)$$

Where:

CU. (layer)	=	sum of extracted soil moisture in each soil layer (15 cm).
CU (seasonal)	=	total sum of moisture extracted in all soil layers (60 cm).

RESULTS AND DISCUSSION

1. Seed yield and its attributes:

Mean values of all studied characters as affected by irrigation and faba bean cultivars in the combined analysis over the two growing seasons are presented in Table (3). Results in Table (3) showed that higher values of seed yield and its components resulted from irrigation treatments of I_3 and I_4, respectively, without any significant difference between them. Irrigation treatment of I_4 significantly increased plant height by 4.7%, number of seeds/plant by 22.1%, 100-seed weight by 4.1%, and seed yield/fed by 22.4% compared to irrigation treatment of I_1. Seed yield for faba bean of both I_4 and I_3 irrigation treatments was higher than irrigation treatment of I_1 because of higher yield components such as number of pods/plant, number of seed/pod, number of seeds/plant and 100-seed weight as shown in Table (3). Data in Table 3 revealed that number of pods/plant and number of seeds/pod were not significantly affected by irrigation treatments.

A higher yield and its attributes of faba bean plants was gradually increased as a result of increasing in the availability of soil moisture content in root zone which increase seed yield. Similar results were obtained by Fardos and Abdel-Nour (2000), Hassanein (2000), and El-Galfy (2005), who revealed that the yield and its components of faba bean significantly was decreased as the number of irrigations decreased. In the absence of water stress, a longer post-flowering duration allowed the indeterminate to develop a larger canopy and achieve a high final biomass **(**Sau and Minguez, 2000**,** Shawky, *et al.* 2004 and Costa *et al.* 1997). Water stress generally decreased the number of stomata on both leaf surfaces and decreased stomatal opening. Therefore, water stress decreased the rate of CO_2 fixation and inhibited the metabolism of soluble to insoluble photosynthates (Younis, *et al.* 1993).

Data in Table 3 revealed that faba bean cv. Sakha 1 significantly surpassed cvs. Sakha 3 and Nubaria 1 in plant height and number of seeds/plant On the other hand, faba bean cv. Nubaria 1 surpassed faba bean cvs. Sakha 1 and Sakha 3 in 100-seed weight. Faba bean cv. Sakha 3 significantly surpassed cvs. Sakha 1 and Nubaria 1 in seed yield/fed. These differences may be due to the genetic differences among faba bean cultivars. The results are in agreement with those obtained by Amede *et al.* (1999) and Amer *et al*. (2006) and El-Deep *et al*. (2006). Results in Table 3 revealed that number of pods/plant and number of seeds/pod were not significantly affected by faba bean cultivars.

Insignificant effect of irrigation and season interaction was obtained from all traits. Such results indicated that irrigation treatments showed similar effect from season to season. The interaction between irrigation x faba bean cultivars was not significant except the interaction between irrigation and cultivars on plant height, number of seeds/plant, 100-seed weight, and seed yield/fed. as shown in Table (3). All traits under study was not significantly affected by the interaction of irrigation x faba bean cultivars x season (Table 3).

Table (3): Mean values of faba bean yield and its attributes as affected by irrigation treatments and cultivars in the combined analysis over both seasons

Treatments	Plant height (cm)	No. of pods/ plant	No. of seeds/ pod	No. of seeds/ plant	100-seed weight (g)	Seed yield. (ardab/fed)
Irrigation treatments:						
I_1	116.0b	6.1	2.8	17.2c	88.4c	8.65c
I_2	117.9b	6.5	2.9	19.0b	90.1b	9.76b
I_3	120.2a	7.0	3.0	21.0a	91.7a	10.44a
I_4	121.4a	7.1	3.0	21.0a	92.0a	10.59a
Faba bean cultivars:						
Sakha 1	132.0a	7.6	2.9	22.2a	76.5c	9.21c
Sakha 3	106.7c	7.0	2.8	20.0b	90.8b	10.45a
Nubaria 1	118.0b	5.5	3.0	16.7c	104.4a	9.91b
Interactions:						
Irrig. x season	N.S	N.S	N.S	N.S	N.S	N.S
Irrig. x cultivars.	**	N.S	N.S	**	**	**
Irrig. x cultivars x season	N.S	N.S	N.S	N.S	N.S	N.S

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

Data in Table 4 showed that the average values of plant height, number of seeds/plant, 100-seed weight, and seed yield/fed. were significantly affected by the interaction between irrigations treatments and faba bean cultivars, over both seasons.

Table (4): Interaction between irrigation treatments and faba bean cultivars on plant height, number of seed/plant, 100-seed weight and seed yield/fed., over both growing seasons.

Faba bean cultivars	Irrigation treatments			
	I_1	I_2	I_3	I_4
	Plant height (cm)			
Faba bean cultivars:				
Sakha 1	128b	130b	134a	135a
Sakha 3	103d	106cd	108c	109c
Nubaria 1	117f	118ef	119e	119e
	number of seeds/plant			
Faba bean cultivars:				
Sakha 1	19.8b	21.7ab	23.7a	23.7a
Sakha 3	17.0c	19.0b	21.8ab	22.3ab
Nubaria 1	14.8d	16.2cd	17.7c	18.0bc
	100-seed weight (g)			
Faba bean cultivars:				
Sakha 1	72.8d	75.7cd	78.7c	78.9c
Sakha 3	89.2b	90.7b	91.4b	91.8b
Nubaria 1	103.3a	104.0a	105.1a	105.3a
	Seed yield (ardab/fed.)			
Faba bean cultivars:				
Sakha 1	8.60e	9.25cd	9.47d	9.53c
Sakha 3	8.74e	10.16c	11.37a	11.53a
Nubaria 1	8.60e	9.88d	10.47b	10.70b

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

It is obvious form Table 4 that the highest mean values of plant height was obtained from irrigation treatment of I_3 and I_4 with faba bean cv. Sakha 1. However, the lowest value of plant height was obtained from irrigation treatment of $\mathbf{I_1}$ with faba bean cv. Sakha 3. Results in Table 4 revealed that faba bean cv. Sakha 1 resulted in higher number of seeds/plant with irrigation treatments of I_4 and I_3. While 100-seed weight of faba bean cv. Nubaria 1 was higher than faba bean cvs. Sakha 1 and Sakha 3 under all irrigation treatments. The highest seed yield/fed. was obtained from faba bean cvs. Sakha 3 with irrigation treatments of I_4 and I_3. These results could be attributed to the varietal differences (Amer *et al.* 2006 and El-Deep *et al.* 2006).

II. Soil water relations:

I. Consumptive use (CU):

Seasonal consumptive use values for faba bean cultivars, as affected by irrigation treatments and faba bean cultivars are presented in Table 5. It is obvious that the consumptive use increased as the irrigation applications increased. Faba bean plants of irrigation treatment of I_4 has the highest value of water consumption, followed by faba bean plants in the treatments of I_3, I_2 and I_1, respectively. Means values of seasonal water consumptive use were 30.05 cm, 25.84 cm, 22.49 cm and 12.30 cm for irrigation treatments of I_4, I_3, I_2 and I_1, respectively. The most probably explanation for these results is that more available soil moisture resulted from more irrigation times give chance for luxury consumption of water, which ultimately resulted in enhancing transpiration from faba bean plants, in addition to high water evaporation from the soil.

Table (5): Monthly and seasonal water consumptive use (cm) as affected by irrigation treatments and faba bean cultivars, over both seasons.

Irrigation treatments	Faba bean cultivars	Months						Water consumptive use (cm)
		Nov.	Dec.	Jan.	Feb.	March	April	
I_4	Sakha 1	2.51	2.43	3.60	8.72	7.75	3.11	28.12
	Sakha 3	2.51	2.43	3.41	7.66	9. 94	5.52	31.47
	Nubaria 1	2.51	2.43	3.40	7.61	9. 12	5.50	30.57
Mean		2.51	2.43	3.47	8.00	8.94	4.71	30.05
I_3	Sakha 1	2.51	2.43	3.31	6.21	7.84	3.05	25.35
	Sakha 3	2.51	2.43	3.21	4.99	7.97	5.09	26.20
	Nubaria 1	2.51	2.43	3.20	4.97	7.91	4.95	25.97
Mean		2.51	2.43	3.24	5.39	7.91	4.36	25.84
I_2	Sakha 1	2.51	2.43	3.15	5.45	5.11	3.01	21.66
	Sakha 3	2.51	2.43	3.22	3.73	6.84	4.39	23.12
	Nubaria 1	2.51	2.43	3.20	3.60	6.54	4.40	22.68
Mean		2.51	2.43	3.19	4.26	6.16	3.93	22.49
I_1	Sakha 1	2.51	2.43	1.32	1.66	2.60	1.21	11.71
	Sakha 3	2.51	2.43	1.77	2.03	3.06	1.22	13.02
	Nubaria 1	2.51	2.43	1.72	1.69	2.66	1.14	12.15
Mean		2.51	2.43	1.60	1.79	2.77	1.19	12.30
Overall mean	Sakha 1	2.51	2.43	2.85	5.51	5.82	2.60	21.72
	Sakha 3	2.51	2.43	2.90	4.60	6.95	4.06	23.45
	Nubaria 1	2.51	2.43	2.88	4.47	6.56	4.00	22.85

Monthly consumptive use started with low amount of water when faba bean plants were small, then it increased gradually as faba bean plants grow up and reached its peak in March, then it decreased at the end of the season with mature plants. The peak-use period usually occurs when the vegetation is abundant and temperature is high. These results are in agreement with those obtained by Abd El-Mottaleb and Abbas (1992), Abbas *et al.,* (1994), Ainer *et al.,* (1993) and Meleha et al*.,* (2004).

As for faba bean cultivars, data indicated that overall mean values of water comsimptive use by faba bean cvs. Sakha 3 and Nubaria 1 was more than faba bean cv. Sakha 1 by 8.0% and 5.2%, respectively, as shown in Table 5.

2.2. Irrigation water requirements (IWR):

Results in Table 6 indicated that irrigation treatment of I_4 required the highest amount of water applied to be 47.2 cm (1982 m^3/fed.), followed by the treatments of I_3, I_2, and I_1 to be 39.1 cm (1642 m^3/fed.), 27.6 cm (1159 m^3/fed.), and 18.8 cm (790 m^3/fed.), respectively. Sowing irrigation was 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. Theses findings may be attributed to growth stages, and the availability of soil water content in the root zone.

Table (6): Amounts of seasonal irrigation water applied (cm) as affected by the different irrigation treatments, as well as the amounts of effective rainfall (cm), over both seasons.

Variables	Date	Irrigation treatments			
		I_4	I_3	I_2	I_1
Sowing irrigation	Nov. 8th	12.95 cm (544 m^3/fed.)	12.95 cm (544 m^3/fed.)	12.95 cm (544 m^3/fed.)	12.95 cm (544 m^3/fed.)
The first irrigation	Dec., 8th	8.85cm (372 m^3/fed.)	8.85cm (372 m^3/fed.)	8.85cm (372 m^3/fed.)	
The second irrigation	Feb., 7th	11.50 cm (483m^3/fed.)	11.50 cm (483m^3/fed.)		
The third irrigation	March, 9th	8.10 cm (340.2 m^3/fed.)			
Irrigation water applied		41.4 cm (1739 m^3/fed.)	33.3 cm (1399 m^3/fed.)	21.8 cm (916 m^3/fed.)	12.95 cm (544 m^3/fed.)
Effective rainfall*		5.80 cm (244.0 m^3/fed.)	5.80 cm (244.0 m^3/fed.)	5.80 cm (244.0 m^3/fed.)	5.80 cm (244.0 m^3/fed.)
Irrigation water requirements (IWR)		47.2 cm (1982 m^3/fed.)	39.1 cm (1642 m^3/fed.)	27.6 cm (1159 m^3/fed.)	18.8 cm (790 m^3/fed.)

***Effective rainfall = incident rainfall x 0.7 (Novica, 1979)**

Faba bean water use amounts vary with the amount of water available to the plant from the soil and how much comes as rainfall during the growing season. For faba bean to grow without water stress in North Delta, Egypt, approximately 41.4 cm (1739 m^3/fed.) of water would be required. This could come as a combination of stored soil water, growing season rainfall, and irrigation.

Crop water use efficiency (CWUE):

Crop water use efficiency expressed in kg of seed yield/cm of water consumed is presented in Table 7. Results obtained showed that CWUE increased with low irrigation frequencies. Irrigation treatment of I_1 resulted in the highest value of CWUE to be 109.0 kg of seed yield/cm of water consumed, while the lowest one was 54.5 kg of seed yield/cm of water consumed, resulted from irrigation treatment of I_4. These findings could be attributed to the high significant differences among seed yield of faba bean cultivars in addition differences between water consumptive use occurs among faba bean cultivars. The present results are in line with those reported by Hassanein (2000), Ragheb *et al*., (2000) Oweis and Hachum (2003). Shawky, *et al.* (2004) and Meleha *et al*., (2004) who mentioned that the efficiency of water use had decreased as the soil moisture was maintained high by the frequent irrigation.

Table (7): Average crop water use efficiency (kg seed yield/cm of irrigation water consumed) as affected by irrigation treatments and faba bean cultivars over both growing seasons (2005/06 and 2006/07).

Variables	Irrigation treatments				Mean
	I_4	I_3	I_2	I_1	
Faba bean cultivars:					
Sakha 1	52.5k	57.9g	66.2e	113.4a	72.5B
Sakha3	56.8h	67.3de	68.0d	104.0b	74.0A
Nubaria 1	54.3i	62.5f	67.5de	109.7c	73.5AB
Mean	54.5D	62.6C	67.2B	109.0A	

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

As for faba bean cultivars, data in Table 7 showed that faba bean cv. Sakha 3 significantly increased CWUE by 2.1% and 0.7% compared to faba bean cvs. Sakha 1 and Nubaria 1, respectively. It means that faba bean cv. Sakha 3 and Nubaria 1 utilized irrigation water more efficiently than faba bean cv. Sakha 1.

The interaction between irrigation treatments and cultivars in Table 7 showed that the highest CWUE was 113.4 kg seed yield/cm of water consumed resulted from irrigation treatment of I_1 using faba bean cv. Sakha 1 while the lowest one was 52.5 kg seed yield/cm of water consumed resulted from irrigation treatment of I_4 using faba bean cv. Sahka 1. In this respect, the water use efficiency of faba bean cultivars increased markedly with increasing water deficit. So, water use efficiency significantly varied among the cultivars.

2.4. Field water use efficiency (FWUE):

Mean values of field water use efficiency as affected by irrigation treatments and faba bean cultivars are presented in Table 8. Results indicated that the highest values of FWUE were recorded from the irrigation treatment of I_1 whereas the lowest one was obtained from irrigation treatment of I_4. These results could be attributed to the significant differences among faba bean seed yield, and evapotranspiration due to water applied values. It can be recommended to irrigate faba bean 3 times including sowing irrigation since the reduction in seeds yield was 1.4% against 17.2% of saving irrigation water applied compared with irrigation 4 times.

Data illustrated in Table 8 showed that the three tested cultivars were differed significantly with regarding to FWUE. Faba bean cultivars cv. Sakha 3 exceeded faba bean cvs. Sakha 1 by 10.6% and Nubaria 1 by 4.5%, respectively.

The interaction between irrigation treatments and cultivars in Table 8 showed that the highest FWUE was 72.1 kg seed yield/cm of water applied resulted from irrigation treatment of I_1 using faba bean cv. Sakha 3 while the lowest one was 31.3 kg seed yield/cm of water applied resulted from irrigation treatment of I_4 using faba bean cv. Sahka 1.

Table (8): Average field water use efficiency (kg seed yield/cm of water applied) as affected by irrigation treatments and faba bean cultivars over both growing seasons (2005/06 and 2006/07).

Variables	Irrigation treatments				Mean
	I_4	I_3	I_2	I_1	
Faba bean cultivars:					
Sakha 1	31.3l	37.5h	52.0e	70.6b	47.9C
Sakha3	37.8i	45.1f	56.9c	72.1a	53.0A
Nubaria 1	35.1k	41.5g	55.4d	70.9b	50.7B
Mean	34.8D	41.4C	54.8B	71.2A	

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

Soil moisture extraction pattern (SMEP):

Data of mean values of soil moisture extraction percentages in the upper 60 cm of soil depth are presented in Table 9. Results showed that the highest percentage of moisture uptake was occurred at the surface layer 15 cm of the soil profile, while less water was extracted from the successive depths. Means percentage values of water removed from the upper 30 cm soil layer were 76.93%, 72.20%, 66.43% and 63.48% from 0-30 cm soil layer for I_4, I_3, I_2, and I_1 respectively. However, the respective values were 23.07, 27.80, 33.57 and 36.52% withdrawn from the lower 30-60 cm. These values showed that when the soil is kept wet due to multiple irrigation, more water is extracted from the upper 30 cm soil layer. On the other hand, when soil moisture content of the surface layer was subjected to water deficit, as a result of irrigation treatment of I_1, plants of faba bean tended to extract its water requirements from deeper soil layers. These findings could be attributed to the fact that most of faba bean plants roots are concentrated in the upper soil layers and those roots are the most effective in water extraction. Similar results were found by Chimenti *et al.* (2006) who showed that crops extracted significant more water from deeper layers in the soil profile during the stress period.

As for faba bean cultivars, data in Table 9 showed that there is no effect on this trait, and the values were about the same.

Table (9): Percentage of soil moisture extraction by roots form different layers as affected by irrigation treatments and faba bean ultivars, over both seasons.

Irrigation treatments	Faba bean cultivars	Percentage of soil moisture extraction in different soil depths (cm)				Mean of SMEP	
		0-15	15-30	30-45	45- 60	0-30	30-60
I_4	Sakha 1	49.60	27.02	16.82	6.56	76.62	23.38
	Sakha3	49.84	27.32	17.06	5.78	77.17	22.84
	Nubaria 1	49.78	27.21	17.00	6.01	76.99	23.01
Mean		49.74	27.18	16.96	6.12	76.93	23.07
I_3	Sakha 1	44.53	27.40	18.20	9.87	71.93	28.07
	Sakha3	44.77	27.65	18.46	9.12	72.42	27.58
	Nubaria 1	44.68	27.58	18.40	9.34	72.26	27.74
Mean		44.66	27.54	18.35	9.44	72.20	27.80
I_2	Sakha 1	38.45	27.64	20.16	13.75	66.09	33.91
	Sakha3	38.72	27.96	20.40	12.92	66.68	33.32
	Nubaria 1	38.63	27.88	20.25	13.24	66.51	33.49
		38.60	27.83	20.27	13.31	66.43	33.57
I_1	Sakha 1	35.19	28.01	21.44	15.36	63.20	36.80
	Sakha3	35.44	28.34	21.64	14.58	63.78	36.22
	Nubaria 1	35.36	28.10	21.55	14.99	63.46	36.54
Mean		35.33	28.15	21.54	14.98	63.48	36.52
Mean of irrigation	Sakha 1	41.94	27.52	19.16	11.39	69.46	30.54
	Sakha3	42.19	27.82	19.39	10.60	70.01	29.99
	Nubaria 1	42.11	27.69	19.30	10.90	69.80	30.3
Overall mean		42.08	27.68	19.28	10.96	69.76	30.24

Regression and correlation coefficient:

Equations in Table 10 indicated that each centimeter of water applied produced 10.5 kg seed yield/fed. and enhanced water consumptive use of faba bean plants by 0.6 cm.

Table (10): Regression equations and correlation coefficient (r) between irrigation water requirement in cm (IWR) and each seed yield in kg/fed., water consumptive use (cm), crop water use efficiency (CWUE) and field water use efficiency (FWUE).

Variables	Equation	r
Seed yield	$\hat{Y}$= 1178 +10.5 (IWR)	0.96 **
CU	$\hat{Y}$ = 3.2 + 0.6 (IWR)	0.94 **
CWUE	$\hat{Y}$ = 130 – 1.7 (IWR)	- 0.80 **
FWUE	$\hat{Y}$ = 93 – 1.3 (IWR)	-0.79**

On the other hand, the increments in irrigation water requirements for faba bean plants decreased crop water use efficiency (CWUE) by 1.7 kg seed yield/cm of water consumed and field water use efficiency (FWUE) by 1.3 kg seed yield/cm of water applied as shown in Table (9). This results because an irrigation water requirement (IWR) is essential to develop a large plant canopy and early ground cover to increase yield of seeds of faba bean. Irrigation water requirements (IWR) was significantly and positively correlated with seed yield (r = 0.96), and water consumptive use (r = 0.94). However, it was negatively correlated with CWUE (r = -0.80) and FWUE (r = -0.79).

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تأثير الرى على إنتاجية وكفاءة استخدام المياه لبعض أصناف الفول البلدى بمنطقة شمال الدلتا بمصر

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أجريت هذه الدراسة فى محطة البحوث الزراعية بسخا محافظة كفرالشيخ خلال عامى 2006/2005 و 2007/2006 بهدف دراسة تأثير الرى على إنتاجية بعض أصناف الفول البلدى وكفاءة استخدام المياه. واستخدم تصميم القطع المنشقة. حيث وزعت معاملات الرى عشوائيا على القطع الرئيسيه وهى اعطاء رية الزراعة فقط (معاملة أ$_1$) ؛ رية الزراعة والرية الاولى بعد 30 يوم من الزراعة (معاملة أ$_2$) ، رية الزراعة والرية الاولى بعد 30 يوم والرية الثانية بعد 90 يوم من الزراعة (معاملة أ$_3$) ، رية الزراعة والرية الاولى بعد 30 يوم والرية الثانية بعد 90 يوم والرية الثالثة بعد 120 يوم من الزراعة (معاملة أ$_4$). بينما وزعت الأصناف (سخا 1 ، سخا 3 ، النوبارية 1) عشوائيا على القطع المنشقة. وقد تم دراسة الصفات التالية: ارتفاع النبات ، عدد القرون/نبات ، عدد البذور/القرن ، عدد البذور/النبات ، وزن 100 بذرة و محصول البذور/فدان بالإضافة إلى بعض العلاقات المائية.

ويمكن تلخيص أهم النتائج فى الآتى:

1- لا توجد زيادة معنوية فى معاملة الرى (أ4) و (أ3) فى كل الصفات تحت الدرسة.
2- أدى معاملة الرى (أ$_4$) إلى زيادة معنوى لصفات النمو والمحصول ومكوناته حيث زاد ارتفاع النبات 4.7 % ، عدد البذور فى النبات 22.1%، وزن الالف بذرة 4.1% ، ومحصول البذور 22.4 % مقارنة بمعاملة الرى أ$_1$.
3- تفوق الصنف سخا 3 فى انتاجية محصول البذور بينما تفوق الصنف سخا 1 فى صفة ارتفاع النبات و تفوق الصنف نوبارية 1 فى صفة وزن 100 بذرة.
4- بلغ قيم الاستهلاك المائى للفول البلدى 30.05سم ، 25.84سم ، 22.49 سم ، 12.30 سم لمعاملات الرى (أ$_4$) ، (أ$_3$) ، (أ$_2$) ، (أ$_1$) على الترتيب. تفوق الصنف سخا 3 والصنف نوبارية 1 على الصنف سخا 1 فى صفة الاستهلاك المائى بحوالى 8.4% و 5.5% على الترتيب.
5- بلغ قيم الاحتياجات المائية الموسمية للفول البلدى 47.2سم (1982 م3/فدان) ، 39.1سم (1642 م3/فدان) ، 27.6 سم (1159 م3/فدان) ، 18.8 سم (790 م3/فدان) لمعاملات الرى (أ$_4$) ، (أ$_3$) ، (أ$_2$) ، (أ$_1$) على الترتيب. تفوق الصنف سخا 3 والصنف نوبارية 1 على سخا 1 فى صفة الاستهلاك المائى بحوالى 8.0% و 5.2% على الترتيب.
6- أمكن الحصول على أعلى القيم لصفة كفاءات الرى مع معاملة الرى أ$_1$.
7- سجل الصنف سخا 3 أعلى القيم لصفة كفاءة الرى المحصولية والحقلية.
8- بلغ متوسط قيم الماء الممتص من الطبقة السطحية للتربة (0- 30 سم) 76.93%، 72.20%، 66.43% و 63.48% لمعاملات الرى (أ$_4$) ، (أ$_3$) ، (أ$_2$) ، (أ$_1$) على الترتيب.
9- أظهر تحليل بيانات الانحدار ان كل سم من الاحتياجات المائية الموسمية للفول البلدى ينتج 10.5 ك ج/فدان ويزيد الاستهلاك المائى الموسمى 0.6 سم ، بينما ينقص كفاءة الرى المحصولية 1.7 ك.ج بذور/سم ماء مستهلك و كفاءة الرى الحقلية 1.3 ك.ج بذور/سم ماء مضاف.
10- توجد علاقة ارتباط معنوى موجب بين الاحتياجات المائية الموسمية للفول البلدى وكل من الانتاجية والاستهلاك المائى الموسمى بينما كان الارتباط معنوى سالب مع كفاءات الرى.

نستخلص مما سبق انه يوصى بعدد 3 ريات متضمنة رية الزراعة (معاملة الرى أ$_3$) للفول البلدى حيث الانخفاض فى الانتاجية يصل 1.4% مقابل توفير فى مياه الرى يعادل 17.2% مقارنة بالرى 4 مرات متضمنة رية الزراعة (معاملة الرى أ$_4$). الاانه فى حالة نقص مياه الرى فيفضل تقليل الريات متوقف ذلك على كمية المياه المراد توفيرها مع زراعة الاصناف ذات الكفاءات العالية فى استخدام مياه الرى.