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WATER REQUIREMENTS OF SOME CROPS IN NORTH SINAI GOVERNORATE:
2- EFFECT OF IRRIGATION INTERVALS AND PLANT DENSITY ON ACTUAL EVAPOTRANSPIRATION, WATER USE EFFICIENCY, CHEMICAL ASALYSIS AND YIELD OF FODDER BEET PLANTS.

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ABSTRACT

A study was carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences, Suez Canal University in El-Arish, during two successive seasons, 2004/2005 and 2005/2006. The experiment aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on fodder beet (*Beta vulgaris L. cv.* VÖrÖshenger). The experiment was assigned for cultivating fodder beet plants. The experiment included 9 treatments for the interaction between 3, 5 and 7 days irrigation intervals and 40, 50 and 60 cm distances between drip lateral lines. Each treatment plot consisted of 3 lateral lines, each was 10 m long. The treatments plot area was either 12, 15 or 18 m^2. Seeds of fodder beet plants were sown on the 1st of October in 2 successive seasons, 2004/2005 and 2005/2006, at a rate of 3 $kg.fed^{-1}$. Actual evapotranspiration and fresh and dry yield of roots and top weights increased with decreasing irrigation intervals. However, they increased with increasing the distance between irrigation lines in both seasons. The water use efficiency increased with increasing irrigation intervals, while it was decreased with increasing the distance between irrigation lines. Treatment 3 days irrigation interval had the highest values of root and top content of crude protein, but it gave the lowest value of crude fiber and total ash content in both seasons. Treatment 7 days irrigation interval had the lowest root and top content of crude protein but it gave the highest crude fiber and total ash content in both seasons. The highest value of actual evapotranspiration was obtained at 3 days irrigation intervals with 60 cm distance between irrigation lines. The irrigation every 3 days with 60 cm distance between irrigation lines gave the highest yield, while the irrigation every 7 days with 40 cm distance between irrigation lines gave the highest water use efficiency.

Keywords: Water requirement - Drip irrigation - Irrigation intervals - Fodder beet - North Sinai

INTRODUCTION

Fodder beet (*Beta vulgaris,* L.) is an important winter forage crop. It is very promising in North Sinai, because it is tolerant to high soil salinity and somewhat low water requirement. Its total yield; above and under the ground, can directly be used in animal feeding, especially dairy cows, or may be processed as silage. The roots can also be stored in the soil for a period of time without being greatly damaged, thus used when needed. Therefore, its cultivation may help in overcoming the problem of animal feeding shortage in summer season. In Egypt, production and distribution of fodder crops are of prime concern to animals breeding. Therefore, cultivating new lands in North Sinai by fodder beet, to produce more green fodder, is very promising to decrease the gap between production and consumption especially under the limited area of the Nile Valley. Consumptive use is affected by many management and natural factors (climate, soil, and topography). Climatic factors include temperature, precipitation, solar radiation, humidity, wind movement, and length of growing season. Management factors can usually be controlled, although many are interrelated with the natural factors.

Anton, (1991) claimed that consumptive use of fodder beet grown at Bahtim-Egypt increased by shortening irrigation intervals. He added that seasonal evapotranspiration varied widely between 338.2 to 621.2 mm and 337.9 to 565.2 mm of water under different water regime treatments in the first and second seasons , respectively. The prediction of actual evapotranspiration (ET_a) and crop coefficients (K_c) as a function of growth period are very important for the determination of crop water use and scheduling irrigation at a regional level, Allen *et al.* (l998). The reduction of ET_a by changing irrigation programs can be managed by the applications of deficit irrigation, KÖksal *et al.* (2001). Under stress conditions, ET_a is calculated by the combining effect of K_c and soil water stress coefficient K_s, Bandyopadhyay and Mallick, (2003).

Root yield is a good indicator for plant ability in producing thicker roots and accumulating more dry matter which is reflected on yield per land area. In calcareous soil at Ras Sudr-Egypt, Hilal *et al.* (1992) pointed out that deeper irrigation significantly increased root yield as compared to light daily irrigation of fodder beet and other crops. Also, Misiha *et al.* (1992) on fodder beet and Clarke *et al.* (1993) on sugar beet grown under UK conditions, reported that irrigation enhanced root yield. Rzekanowski (1994) stated that irrigation positively influenced the production capabilities of fodder and sugar beet. Koszanski *et al.* (1995a) and Podstawka and Ceglarek (1995) mentioned that fodder beet root yield increased from 55.1 and 80.75 $t.ha^{-1}$ without irrigation to 65.6 and 88.06 $t.ha^{-1}$ with irrigation, respectively. Talik and Plawinski (1995) and Borowczak *et al.* (1996) mentioned that fodder and sugar beet root yields improved by increasing irrigation amounts Gad-allah, (1995) concluded that irrigating fodder beet, grown at Ras Sudr region, Egypt, every 14 days resulted in maximum total fresh yield (28.54 ton/fed) compared with 7 and 21 days irrigation intervals, which gave 19.17 and 25.82 $ton.fed^{-1}$., respectively. Similar trends were recorded for total dry yield. In addition, Tahoon (1995) illustrated that prolonging irrigation intervals for fodder beet decreased total weight per plant.

Kamel *et al.* (1990) found that fodder beet yield decreased by increasing hill spacing. Increasing plant spacing tended to reduce root fresh and dry yields as well as total fresh yield. Also, Basha (1998) reported that fodder beet maximum root yield ($ton.fed^{-1}$.) was obtained from sowing at 35 cm between hills. Assey *et al.* (1992) reported that planting fodder beet plants at 55 cm row spacing produced maximum root weight and root yield. On the other hand the narrower hill distance (15 cm) produced the higher top yield. Rzekanowski (1994) stated that irrigation significantly decreased total protein content from 8.41 to 6.33 % in roots and from 14.47 to 10.90 % in leaves of fodder beet plants grown on very light soil compared with non-irrigated plants. Also, Koszanski *et al.* (1995b) and Podstawka and Ceglarek (1995) revealed that root and leaf protein content slightly reduced by irrigating fodder beet. In addition, Tahoon (1995) found that prolonged irrigation intervals from 6 to 12 days a significantly reduced total crude protein in fodder beet tops after 120, 150 and 180 days from sowing from 6.12, 13.40 and 18.40 to 3.12, 8.58 and 15.02 g/100 g dry weight, respectively).

Sobiech *et al.* (1993) found that fodder beet root protein yield increased significantly with irrigation. However, Gad-allah (1995) stated that subjecting fodder beet to water stress by prolonging irrigation intervals increased root and top protein contents. Also, Khafagi and EL-Lawendy (1997) and Kevresan *et al.* (1998) found that as soil moisture decreased, leaf and root protein content decreased. Crude fiber is a structural carbohydrate component which help and support plants to withstand the lack of water requirement. Also, it is important in feeding animals as it is a roughage component. Tahoon (1995) revealed that increasing irrigation reduced ash content of both fodder and sugar beet. who mentioned that the longest irrigation interval (12 days) gave the superiority of the total ash content in tops and roots of fodder beet plants (28.65 and 5.85 %), respectively, after 180 days from sowing compared with the lower irrigation interval treatments (3, 6 and 9 days). However, total protein contents decreased with increasing irrigation intervals. This work aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on yield, yield components well as the water use efficiency of fodder beet plants under the conditions of North Sinai, Egypt.

MATERIALS AND METHODS

Field experiment was carried out at the Experimental Farm of the Faculty of Environmental Agricultural Sciences, Suez Canal University in El-Arish, during two successive seasons, 2004/2005 and 2005/2006. The experiment aimed to study the effect of irrigation intervals and distances between drip irrigation laterals on fodder beet (*Beta vulgaris L. cv.* VÖrÖshenger) yield and its components.

The determined soil moisture saturation percentage, field capacity, wilting point and available water are given in Table 1a.The initial mechanical and chemical properties of the soil used in the experiments are given in Table 1b. The chemical properties of the irrigation water for both seasons are given in Table 1c.

Table 1a: Soil moisture constants for the investigated soil.

Depth (cm.)	Saturation percentage		Field capacity		Wilting point		Available water	
	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)	% gg^{-1}	Soil moisture ($mm.15cm^{-1}$)	% $g.g^{-1}$	Soil moisture ($mm.15cm^{-1}$)
0-15	29.77	73.68	11.90	29.45	5.17	12.80	6.73	16.65
15-30	30.22	75.25	11.89	29.61	5.06	12.60	6.83	17.01
30-45	36.46	80.39	13.67	30.14	5.14	11.33	8.53	18.81
45-60	28.75	62.96	11.18	24.48	5.84	12.79	5.34	11.69
60-75	26.43	52.73	10.88	21.71	5.68	11.33	5.20	10.38

Table 1b : Initial soil mechanical and chemical properties.

Soil properties	Season									
	2004-2005					2005-2006				
	Soil depth (cm.)									
	0-15	15-30	30-45	45-60	60-75	0-15	15-30	30-45	45-60	60-75
Mechanical properties										
Coarse sand %	63.00	59.00	46.00	44.00	46.00	63.22	60.10	45.00	44.30	45.0
Fine sand %	21.82	18.80	21.30	23.30	21.80	20.80	19.80	20.30	24.30	21.80
Silt %	7.00	13.50	21.49	17.50	20.00	7.06	12.50	24.50	18.20	21.00
Clay %	8.18	8.70	11.21	15.20	12.20	8.92	7.60	10.20	13.2	12.20
Soil texture	Loamy sand		Sandy loam			Loamy sand		Sandy loam		
Bulk density ($Mgm.m^{3}$)	1650	1660	1470	1460	1330	1650	1660	1470	1460	1330
Chemical properties (soluble ions in (1:5) soil water extract)										
Ca^{++} ($meq.l^{-1}$)	4.5	3.0	4.4	5.4	4.5	5.01	3.91	4.6	5.85	4.6
Mg^{++} ($meq.l^{-1}$)	3.91	4.0	4.18	3.6	3.3	3.93	4.12	4.20	3.72	3.35
Na^{+} ($meq.l^{-1}$)	1.75	2.45	2.90	3.05	2.65	3.25	2.91	3.30	3.61	2.89
K^{+} ($meq.l^{-1}$)	0.34	0.25	0.42	0.65	0.35	0.31	0.26	0.30	0.52	0.36
CO_3^{--} ($meq.l^{-1}$)	-	-	-	-	-	-	-	-	-	-
HCO_3^{-} ($meq.l^{-1}$)	4.0	4.0	7.0	5.7	4.87	4.6	4.4	6.98	5.8	4.68
Cl^{-} ($meq.l^{-1}$)	5.0	4.25	3.5	4.5	4.32	6.1	5.30	3.96	5.32	4.68
SO_4^{--} ($meq.l^{-1}$)	1.5	1.45	1.4	2.50	1.61	1.8	1.5	1.46	2.58	1.71
EC($dS\ m^{-1}$) in (1:5) soil water extract)	1.05	0.97	1.19	1.27	1.08	1.25	1.02	1.3	1.37	1.19
pH in (1:2.5) soil water suspension extract)	8.0	8.13	8.06	8.19	8.25	8.1	8.0	8.12	8.05	8.09
Organic matter %	0.185	0.153	0.136	0.123	0.119	0.190	0.171	0.154	0.142	0.129
$CaCO_3$ %	14.39	22.58	22.65	22.60	21.85	14.32	22.48	22.75	22.80	21.95

Table 1c : Chemical properties of irrigation water.

pH	EC		Soluble ions ($meq.l^{-1}$)							
	dSm^{-1}	ppm	Cations				Anions			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{--}	SO_4^{--}
2004/2005										
7.02	5.70	3648	20.90	17.71	18.13	0.26	46.40	2.76	-	7.84
2005/2006										
7.32	6.00	3840	21.51	19.32	18.94	0.23	48.71	2.98	-	8.31

Soil parameters determined before conducting the experiments were:

1. Particles size distribution was determined using the international A.C.A. Pippete method (Piper, 1950).
2. Bulk density was determined using J.R.H. Coutts cylinder (Piper, 1950).
3. Calcium carbonate was determined as $CaCO_3$ % by means of Collin's calcimeter (Jackson, 1967).
4. Soil pH value was determined in 1:2.5 soil water suspension.
5. Water holding capacity, field capacity and wilting point were determined by the weighing method using the pressure cocker and pressure membrane method (Richard, 1954).

The soil water extract for the 1:5 soil water ratio was chemically analyzed for:

a) Electrical conductivity (E.C), conductimetrically using Radiometer compenhagen N.V. type CDM 2d, Jackson (1967).

b) Carbonate and bicarbonate, titremetrically using H_2SO_4 and phenophthalein and bromocresol green as indicators.
c) Chloride following Mohr's method, Richard (1954).
d) Soluble sulfate was taken by the difference between the summation of soluble cations and anions.
e) Soluble potassium and sodium, by the flame photometer, Richard (1954).
f) Calcium and magnesium, by the versenate method using ammonium purpurate as an indicator for Ca^{++} and Eriochrome black T for Ca^{++} plus Mg^{++}, Jackson (1967).

Soil moisture was determined by the weighing method after and before irrigation, Richard (1954). Air temperature and relative humidity were recorded from the meterological station at El-Arish, North Sinai Governorate.

Treatments:

The experiment was assigned for cultivating fodder beet plants. The experiment included 9 treatments for the interaction between 3, 5 and 7 days irrigation intervals and 40, 50 and 60 cm distances between drip lateral lines. Each treatment plot consisted of 3 lateral lines, each was 10 m long. The treatments plot area was either 12, 15 or 18 m^2. Seeds of fodder beet plants were sown on the 1^{st} of October in 2 successive seasons, 2004/2005 and 2005/2006, at a rate of 3 $kg.fed^{-1}$. Plants were thinned to 2 plants/hill on 30/10 and thinned again to 1 plant/hill on 14/11. The irrigation water was saline ground water (3648 ppm) pumped from a local well. After a 60 days pretreatment period, irrigation intervals treatments started for all plots on 30/11. For the 3 days irrigation interval treatment, it ended on 25/4. The last irrigation took place on 23/4. For the 5 days irrigation interval treatment, it ended on 23/4. The last irrigation occurred on 19/4. For the 7 days irrigation interval treatment, it ended on 25/4. The last irrigation occurred on 19/4. The periodical divisions for growth period for both crops and volumes of applied water are presented in Table (2).

The experimental design was Randomized Complete Block (RCBD) in split-plot design with three replications. The main plots were chosen for the irrigation treatments whereas the sub-plots were chosen for the distances between drip irrigation lateral lines or plant rows.

Data recorded

1. Water relationships

A) Consumptive use of water (CU.):

Consumptive use of water (CU.) was calculated using the equation given by Israelson and Hansen (1962) as follows:

$$CU. = D \times AD \times \frac{e_z - e_i}{100}$$

Where:
CU. = Consumptive use in cm.
D = Irrigated soil depth in cm.
AD = Bulk density, gm/cm, of the chosen irrigated soil depth.
e_z = Soil moisture percent after irrigation.
e_i = Soil moisture percent before the next irrigation.

2

B) Water use efficiency (W.U.E.):

The consumed water by fodder beet plant was calculated according to **Yaron** *et al.,* (1973) as follows:

$$W.U.E. = \frac{Y}{ET_a}$$

Where:

Y = Crop yield in kg.fed^{-1}.,

ET_a = Evapotranspiration in m^3.fed^{-1}.

The actual evapotranspiration, ET_a, is assumed to be synonymous to the calculated consumptive use of water (CU). Consequently, daily and monthly water consumptive use were calculated for specified soil depths for all treatments.

2. Plant Growth Characters

Random samples of five fodder beet plants were taken from each sub plot after 100, 130, and 160 days from sowing. Random samples of wheat plants were taken from each sub plot at the end of the season. The following vegetative parameters were investigated:

1) Root length (cm.), was measured from the end of the root tip to the discoidal stem,
2) Root diameter (cm.), was determined by measuring root circumference in cm. divided by 3.14,
3) Top length (cm.), was measured from the discoidal stem to the longest leaf,
4) Number of leaves per plant,
5) Fresh and dry weight of leaves (g.plant^{-1}),
6) Root and top fresh and dry weight (g.plant^{-1})

3. Crop Yield

Plants were harvested on April 29th in both seasons. The following data were recorded:

1. Fresh and dry root yield, ton.fed^{-1}.,
2. Fresh and dry top yield, ton.fed^{-1}.,
3. Sugar yield for sugar beet, ton.fed^{-1}..

4. Chemical Analyses

Representive plant samples were collected at harvest from each sub plot. Each sample was divided into roots and tops. Samples were dried at 70 C^o to a constant weight. They were milled to a fine powder and kept for the following analysis:

4.1. Crude protein (CP)

The dry material were wet digested with sulphuric-Perchloric acids mixture after Piper, (1947). Total nitrogen was deermined colormetically using spectrophotometer (Model 1600 Jenwoeyco) as described by Allen (1959). Crude protein percentage was calculated by multiply the total nitrogen by the factor 6.25.

4.2. Crude fiber content (CF) was determined using the method described in A.O.A.C. (1986).

4.3. Total ash content was determined using the method described in A.O.A.C. (1986).

5. Statistical Analysis

Analysis of variance was used to test the degree of variability among the obtained data. Duncan's Multiple rang test was used for the comparison among treatment means, Duncan, (1955). MSTATC program was used for the statistical analysis.

RESULTS AND DISCUSSION

1. Effect of irrigation intervals

1.1 Actual Evapotranspiration (ET_a)

Water consumptions were computed from the data of soil moisture depletions; i.e. the differences between soil moisture contents before and after irrigations. They are determined gravimetrically and calculated on oven dry basis.

Values obtained for ET_a in mm for fodder beet in the two seasons are given in Table 3. Data reveal that it obviously decreased with increasing irrigation intervals. It highest total monthly values were 791.57 and 818.33 mm obtained for 3 days irrigation interval in the first and second growth seasons, respectively. The lowest ones were 219.00 and 229.46 mm obtained for 7 days irrigation intervals treatment. Consequently, the average total volumes of consumed water for both seasons were 3380.790, 2029.251 and 941.766 $m^3.fed^{-1}$. for plants irrigated every 3, 5 and 7 days, respectively. Average percent ET_a values for both seasons relative to the applied volumes of water were 78.89, 74.41 and 43.91 for the previously mentioned irrigation intervals, respectively. The same conclusion reached for sugar beet crop, concerning the relation between the total water consumed and the total water applied, was also found for fodder beet crop.

Data in Table 3 reveal that, fodder beet daily ET_a generally increased till April in both seasons similar to the trend obtained for growing sugar beet. These results agree with those reported by Ibrahim, *et al.* (1993); Sorour (1995); Emara (1996) and El-Zayat (2000) who found that water stress decreased consumptive use or actual evapotranspiration of fodder and sugar beet crops.

1.2. Crop Yield

1.2.1. Fresh yield

Total fresh weights of fodder beet terrestrial parts plus roots were 64.000, 40.510 and 31.099 $ton.fed^{-1}$. for the first season as affected by irrigating every 3, 5 and 7 days by 4285.229, 2727.10 and 2144.616 $m^3.fed^{-1}$., respectively. They were 62.190, 39.210 and 29.840 $ton.fed^{-1}$., for the second season, respectively. It was astonishingly found that although the total volumes of applied water for fodder beet crop were similar to those applied to sugar beet crop, yet, the ratios for fresh weights of fodder beet to sugar beet crop were 1.47, 1.24 and 1.18% for the 3, 5 and 7 days irrigation interval treatments, respectively, for the first season, and 1.57, 1.33 and 1.29% for the second season, respectively. Total fodder beet fresh weights were divided into roots and terrestrial parts.

Table 3: Fodder beet daily, monthly averages and total actual evapotranspiration (ETa, mm) as affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Month	Irrigation intervals (days)					
	3		5		7	
	Daily	Monthly	Daily	Monthly	Daily	Monthly
2004-2005 season						
October	2.07	64.1	1.50	46.50	1.09	33.24
November	1.88	56.40	1.41	42.30	0.98	29.40
December	2.70	83.70	1.92	59.52	0.61	18.91
January	3.52	109.12	2.11	65.41	0.78	24.18
February *	3.76	105.28	2.24	62.72	0.93	26.04
March	6.14	190.34	4.29	132.99	1.45	44.95
April**	6.52	182.56	2.43	68.04	1.51	42.28
Total		**791.57**		**477.48**		**219.00**
2005-2006 season						
October	1.93	59.83	1.50	46.50	1.02	31.62
November	1.82	54.90	1.45	43.50	0.19	29.70
December	2.70	83.70	1.93	59.83	0.62	18.22
January	4.04	125.24	2.1	65.10	0.84	26.04
February*	4.54	127.12	2.22	62.16	1.12	31.36
March	6.04	187.24	4.5	139.50	1.55	48.00
April**	6.45	180.60	2.58	72.24	1.59	44.52
Total		**818.33**		**488.83**		**229.46**

*** 28 days for February, and ** 28 days for April.**

1.2.1.1 Root yield

Irrigation intervals significantly affected root yield in both seasons, Table 4. Prolonging irrigation intervals from 3 to 7 days decreased root fresh weight from 45.610 to 22.050 ton.fed^{-1}. for the first season and from 44.660 to 21.090 ton.fed^{-1}. for the second season. The high fresh root yield obtained for the 3 days irrigation interval may be related to the interaction between genetical and environmental conditions. The progressive increase in fodder beet root fresh yield in response to irrigation compared with water stress conditions was reported by many investigators such as Cucci and Caro (1986), Anton (1991), Hilal, *et al.,* (1992); Podstawka and Ceglarek (1995), Talik and Plawinski (1995), Drashkov (1996) and Manga, *et al.,* (1998). Also, Fabeiro, *et al.,* (2003) and Tognetti, et al., (2003) found similar results on sugar beet.

1.2.1.2 Top yield

Data in Table 4 show significant differences obtained for fresh top yields due to irrigation intervals treatments in both seasons. Top yield increased by decreasing irrigation intervals. The highest top yields, 18.390 and 17.530 ton.fed^{-1}., were obtained for the 3 days irrigation interval treatment in the 1st and 2nd seasons, respectively. However, 7 days irrigation interval treatment produced the lowest yields, 9.049 and 8.75 ton.fed^{-1}. The high production in the top yield is the result of applying abundant irrigation water. These results are in agreement with those reported by Sobiech, *et al.,* (1993), Rzekanowski (1994), Gad allah, (1995), Koszanski*, et al.,* (1995a), Grzes, *et al.,* (1997), and Tognetti, *et al.,* (2003) who stated that adequate soil moisture in fodder or sugar beet root zone improved top fresh yield.

1.2.2 Dry yield

1.2.2.1 Root yield

Data presented in Table 4 show high that fodder beet dry root yields per fed. were significantly affected by applying different irrigation intervals in both seasons. Increasing irrigation intervals decreased root dry yield from 9.030 and 8.520 to 4.707 and 4.190 ton.fed^{-1}., in the first and second seasons, respectively when irrigation intervals were 3 and 7 days, respectively. Such sharp reduction in root dry yield by prolonging irrigation intervals may refer to the great reduction in root fresh yields. Supporting results are obtained by Hofman, *et al.,* (1992), and Kirda, *et al.,* (1999) who pointed out that irrigation fodder and sugar beet enhanced root dry yields.

Table 4: Fodder beet roots and tops fresh and dry yields for plants affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Irrigation intervals (days)	Fresh yield (ton.fed^{-1}.)		Dry yield (ton.fed^{-1}.)	
	Root	Top	Root	Top
		2004/2005 season		
3	45.610 a	18.390 a	9.030 a	3.677 a
5	30.050 b	10.460 b	6.012 b	2.094 b
7	22.050 c	9.049 b	4.407 c	1.810 b
		2005-2006 season		
3	44.660 a	17.530 a	8.520 a	3.440 a
5	29.120 b	10.090 b	5.520 b	1.970 b
7	21.090 c	8.750 c	4.190 c	1.720 b

***Means having the same alphabetical letter within each colum is not significantly different at the 0.05 level, according to Duncan's multiple range test.**

1.2.2.2 Top yield

Data in Table 4 show that irrigation intervals treatments significantly affected top yields (ton/fed.) in the two investigated seasons. It increased gradually by decreasing irrigation intervals from 7 to 3 days. The optimum top yields were 3.677 and 3.440 ton.fed^{-1}., for irrigation every 3 days in the first and second seasons, respectively. The lowest top yields were 1.810 and 1.720 ton.fed^{-1}, for irrigation every 3 and 7 days in the first and second seasons, respectively. This increase in top dry yields, in response to decreasing irrigation intervals, may refer to increasing leaf areas. In this concern, Anton (1991) and Sobiech, *et al.,* (1993), in their study on fodder beet, as well as Massoud and Botros (1999), and Fabeiro, *et al.,* (2003), in their study on sugar beet, concluded that water stress significantly decreased top dry yield.

1.3 Water Use Efficiency (WUE)

Data in Table 5 indicate that, the highest average WUE for the 2 investigated seasons was 22.9 kg.m^{-3} obtained when fodder beet crop was irrigated every 7 days. The lowest average value was 13.4 kg.m^{-3} obtained for fodder beet crop irrigated every 3 days. These results are extremely higher than those obtained for sugar beet crop. It is noticed that decreasing irrigation intervals from 7 to 3 days resulted in increasing twice the production of roots fresh weight and 3 times the volume of consumed water. The average values for roots fresh weights were 21.570, 29.585 and 45.135 ton.fed^{-1}. for the 7, 5 and 3 days irrigation intervals. In the mean time, the average values for consumed water were 3380.79, 2029.251 and 941.766 m^3.fed^{-1}., respectively. In this respect, in order to economize the use of irrigation water, it is recommended to irrigate fodder beet crop every 7 days because of the benefit gained from the applied water. However, if high fresh fodder production is required, then irrigating fodder beet crop every 3 days is recommended providing that abundant irrigation water is present.

Table 5:Fodder beet crop water use efficiency, WUE, for plants affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Irrigation intervals (days)	Fresh yield (kg.fed^{-1}.)	Total consumed water (m^3.fed^{-1}.)	Water use efficiency (kg.m^{-3})	Fresh yield (kg.fed^{-1}.)	Total consumed water (m^3.fed^{-1}.)	Water use efficiency (kg.m^{-3})
	2004/2005 season			***2005/2006 season***		
3	45610	3324	13.70	44660	3437	13.00
5	30050	2079	14.50	29120	2057	14.20
7	22050	922	23.90	21090	964	21.90

1.4 Crop Major Constituents

The effects of irrigation intervals on fodder beet root and top major constituents during 2004/2005 and 2005/2006 seasons, at harvest, affected by irrigation intervals are presented in Table 6.

1.4.1 Crude protein (CP) percentage

Data given in Table 6 were used to calculate average crude protein percentages for both seasons in roots and tops. The obtained values decreased as a result of prolonging irrigation intervals from 3 to 7 days. They were 10.42, 9.66 and 8.39% in the roots and 13.95, 12.66 and 11.54% in the tops as a result of irrigation every 3, 5 and 7 days, respectively.

Total crude protein production were calculated for the 2 investigated seasons using average percent crude protein derived from data given in Table 6, and average dry weights of roots and tops, which were 8.775, 5.766 and 4.299 ton.fed^{-1}. for the roots and 3.559, 2.032 and 1.765 ton.fed^{-1}. for the tops as the crop was irrigated every 3, 5 and 7 days, respectively. The obtained results for total crude protein production were 0.914, 0.557 and 0.360 ton.fed^{-1}. in the roots and 0.496, 0.257 and 0.204 ton.fed^{-1}. in the tops, respectively. These trends indicate that roots protein contents are higher than plant tops protein contents, although percent crude protein in tops are higher than in the roots, and protein contents always decreased as irrigation intervals increased. The decrease in crude protein as a result in decreasing water supply may refer to the decrease in nitrogen assimilation or protein storage in the roots. The positive effect of increasing water supply on protein production in fodder beet roots and tops was confirmed by the results obtained by Tahoon (1995) who found a marked decline in plant protein content during moisture stress. Also, he added that this decline was due primarily to the increase in protein hydrolysis.

1.4.2 Crude fiber (CF) percentage

The results in Table 6 show that irrigation intervals have highly significant effect on root and top crude fiber percentages at harvest. These results were used to calculate average crude fiber percentages for both seasons in plant roots and tops. The obtained values increased as a result of increasing irrigation intervals from 3 to 7 days. They were 7.33, 7.82 and 8.53% in the roots and 13.46, 14.64 and 15.52% in the tops as fodder beet crop was irrigated every 3, 5 and 7 days, respectively. These results agree with those reported by Ceglarek and Gasiorowska (1997**)** who pointed out that subjecting fodder beet to water stress increased crude fiber percentages of roots and leaves.

Table 6: Fodder beet roots and tops crude protein, crude fiber and total ash for plants affected by irrigation intervals during 2004/2005 and 2005/2006 seasons.

Irrigation intervals (days)	Crude protein (%)		Crude fiber (%)		Total ash (%)	
	Root	Top	Root	Top	Root	Top
			2004/2005 season			
3	10.55 a	14.20 a	7.41 c	13.56 c	6.76 b	17.86 b
5	9.72 b	12.74 b	7.81 b	14.67 b	7.35 b	18.45 b
7	8.52 c	11.72 c	8.63 a	15.52 a	8.04 a	20.12 a
			2005-2006 season			
3	10.28 a	13.69 a	7.24 c	13.36 c	6.59 c	17.47 c
5	9.59 b	12.58 b	7.83 b	14.60 b	7.21 b	18.32 b
7	8.25 c	11.35 c	8.42 a	15.51 a	7.93 a	19.71 a

***Means having the same alphabetical letter within each colum is not significantly different at the 0.05 level, according to Duncan's multiple range test.**

Total crude fiber production were calculated using average crude fiber percentages and average dry weights of plant parts. The obtained results were 0.643, 0.451 and 0.366 ton/fed. for plant roots and 0.479, 0.297 and 0.274 ton.fed^{-1}. for plant tops as a result of irrigating the crop every 3, 5 and 7 days, respectively. The obtained results indicate that, although percent plant parts crude fibers increased as crop irrigation intervals increased from 3 to 7 days, yet total crude fiber production decreased.

1.4.3 Total ash percentage

Data in Table 6 show that the total ash percentages, which are known to be a good criterion of the total mineral contents, were affected by irrigation intervals. These results were used to calculate average total ash percentages for both seasons in plant roots and tops. The obtained values increased as a result of increasing irrigation intervals from 3 to 7 days. They were 6.68, 7.28 and 7.99% for plant roots and 17.67, 18.39 and 19.92% for plant tops as fodder beet crop was irrigated every 3, 5 and 7 days respectively. These results align with those obtained by Tahoon (1995) who found that tops and roots total ash percentages increased gradually with increasing irrigation interval.

Total amounts of ash in fodder beet roots and tops were calculated using average total ash percentages and average dry weights of plant parts. The obtained results were 0.586, 0.420 and 0.343 ton.fed^{-1}. for plant roots and 0.629, 0.374 and 0.352 ton.fed^{-1}. for plant tops as a result of irrigating the crop every 3, 5 and 7 days, respectively. These results indicate that the absorption of minerals from the soil decreased as irrigation intervals increased. Therefore, 7days irrigation interval for light texture soil caused water stress condition which is also reflected on fresh weight production, Table 4.

2. Effect of plant density

2.1 Actual Evapotranspiration (ET_a)

Actual evapotranspirations (ET_a) in mm for fodder beet during the two investigated seasons affected by the distance between irrigation lines are given in Table 7. The data for the average daily ET_a reveal almost similar trend as that obtained for sugar beet crop. The highest average daily value was obtained for 60 cm distance between irrigation lines during March, 4.29 mm. However, the lowest average value was obtained for 40 cm distance between lateral lines during November, 1.19 mm.

Table 7: Fodder beet averages daily, monthly and total actual evapotranspiration (ET_a, mm) as affected by the distance between lines during 2004/2005 and 2005/2006 seasons.

Month	distance between lines (cm.)					
	40		50		60	
	Daily	Monthly	Daily	Monthly	Daily	Monthly
			2004/2005 season			
October	1.39	42.99	1.51	46.91	1.76	54.56
November	1.23	37.00	1.39	41.80	1.56	46.90
December	1.52	47.22	1.75	54.35	1.96	60.66
January	1.95	60.45	2.13	66.03	2.33	72.33
February *	2.08	58.15	2.34	65.61	2.51	70.37
March	3.64	112.94	4.00	124.10	4.23	131.13
April**	3.12	87.45	3.53	98.75	3.81	106.77
Total		**446.203**		**497.560**		**542.727**
			2005/2006 season			
October	1.35	41.95	1.43	44.43	1.66	51.46
November	1.14	34.20	1.41	42.30	1.62	48.60
December	1.51	46.71	1.81	56.01	1.94	60.24
January	2.16	66.96	2.33	72.13	2.52	78.02
February*	2.38	66.64	2.66	74.48	2.68	74.95
March	3.62	112.32	4.12	127.82	4.34	134.64
April**	3.18	89.04	3.57	100.05	3.87	108.36
Total		**457.823**		**517.223**		**556.270**

*** 28 days for February, and ** 28 days for April.**

Data in Table 7 reveal that, average total fodder beet ET_a values were almost similar to these obtained for sugar beet crop. The obtained value for the 40, 50 and 60 cm between irrigation lines were 452.01, 507.39 and 549.50 mm, respectively. These trends are also thought to be related to the increase in evaporation from the soil areas between plants, not directly to transpiration from plants because plants vigour were almost equal for all treatments. Similar results were reported by Sorour (1995).

2.2 Crop Yield

2.2.1 Root fresh and dry yields

Data presented in Table 8 show that cultivating fodder beet at 40, 50 and 60 cm distances between irrigation lines significantly increased roots fresh and dry weights for the 2 investigated seasons. The highest fresh root yields varied from 38.130 to 37.183 ton.fed^{-1}. for the first and second seasons, respectively, when irrigation lines were 60 cm. apart. The lowest values varied from 27.77 to 26.80 ton.fed^{-1}. for the first and second seasons, respectively, when irrigation lines were 40 cm. apart. Roots average fresh weights were 27.285, 31.349 and 37.657 ton.fed^{-1}. for 40, 50 and 60 cm distances between irrigation lines, respectively. The obtained values for relative turgidities for roots were 83.58, 83.92 and 82.55%, respectively, and they were 80.13, 80.27 and 80.20% for tops, respectively, indicating that plants vigour as concluded from actual ET_a were almost equal as obtained for sugar beet crop.

Data obtained for average roots dry weights between the 2 seasons were 4.481, 5.041 and 6.572 ton.fed^{-1}. for the previously mentioned distances of irrigation lines, respectively. This obtained trend is similar to that obtained for average roots fresh weights. These results agree with those obtained by Stanacev (1970) and Basha (1998).

2.2.2 Top fresh and dry yields

Data given in Table 8 show that, top fresh and dry yields significantly increased as the distance between irrigation lines increased in both seasons. The average top fresh and dry weights between the 2 seasons were 10.525, 12.115 and 14.499 ton.fed^{-1}. and 2.091, 2.390 and 2.871 ton.fed^{-1}. for 40, 50 and 60 cm distances between irrigation lines, respectively. The obtained trends for average top fresh and dry weights agree with the trend obtained for actual ET_a values.

Table 8: Fodder beet fresh and dry yields as affected by the distances between irrigation lines during 2004/2005 and 2005/2006 seasons.

Distance between lines (cm.)	Fresh yield (ton.fed^{-1}.)		Dry yield (ton.fed^{-1}.)	
	Root	Top	Root	Top
		2004/2005 season		
40	27.770 c	10.860 c	3.782 b	2.172 c
50	31.810 b	12.380 b	4.999 ab	2.477 b
60	38.130 a	14.660 a	6.077 a	2.932 a
		2005/2006 season		
40	26.800 c	10.190 c	5.180 b	2.010 c
50	30.887 b	11.850 b	5.983 b	2.303 b
60	37.183 a	14.337 a	7.067 a	2.810 a

***Means having the same alphabetical letter within each colum is not significantly different at the 0.05 level, according to Duncan's multiple range test.**

It was interestingly found that fodder beet average roots fresh weights were 2.59, 2.59 and 2.60 times tops average fresh weights for the previously mentioned distances of irrigation lines. Although this trend is almost constant, it was decreasing for sugar beet crop. In the mean time, average fodder beet roots dry weights were 2.14, 2.11 and 2.29 times their average tops dry weights, respectively. Consequently, this crop is sensitive to irrigation water regime and to the degree of soil particles coherence. These results are in agreement with those reported by Assey *et al.,* (1992).

2.3 Water Use Efficiency (WUE)

Data given in Table 9 show that, water use efficiency values varied between approximately 14 to 16 kg of fresh fodder beet roots per one cubic meter of irrigation water. Such calculated values were about 50% higher than those obtained for sugar beet crop. Hence, if it is necessary to conserve irrigation water, then irrigation lines should be 40 cm apart and plants to be irrigated every 7 days taking into consideration that roots fresh yield will be half as much as that produced when plants were irrigated every 3 days.

Table 9: Fodder beet crop averages water use efficiency for plants affected by the distance between irrigation lines.

Distance between lines or rows (cm.)	Average fresh yields ($ton.fed^{-1}$.)	Volume of consumed water ($m^3.fed^{-1}$.)	Water use efficiency ($kg.m^{-3}$)
40	27.285	1898.44	14.37
50	31.349	2131.04	14.71
60	37.675	2307.90	16.32

3. Effect of interaction between irrigation intervals and plant density

3.1. Actual evapotranspiration (ET_a)

The effect of interaction between irrigation intervals and distances between irrigation lines on ET_a are presented in Table 10. $ET_{a\ values}$ were more influenced by irrigation intervals than by the distances between irrigation lines. Generally, abundant irrigation water increased ET_a at any distance between irrigation lines. The highest total average value between seasons for fodder beet ET_a was 866.755 mm for irrigation every 3 days when irrigation lines were 60 cm apart. The least average depth of consumed water was 185.015 mm when fodder beet was irrigated every 7 days and irrigation lines were 40 cm apart.

3. Crop Yield and Water Use Efficiency

The effect of interactions between irrigation intervals and distances between irrigation lines on the average values between the 2 investigated seasons for roots fresh, dry, tops fresh and dry weights in ton/fed. were significantly affected, Table 11. All values for the previously determined variables increased as the distance between irrigation lines increased. On the contrary to this trend, all values increased as irrigation intervals decreased from 7 to 3 days; i.e. number of irrigation increased. The largest total average roots fresh, dry and tops fresh and dry weights were 56.180, 8.777, 22.965 and 4.575 $ton.fed^{-1}$., respectively, when fodder beet was irrigated every 3 days and the distance between irrigation lines was 60 cm.

10- 11

The least average values for the same parameters were 19.455, 3.804, 8.284 and 1.665 ton.fed^{1}., respectively, when fodder beet was irrigated every 7 days and the distance between irrigation lines was 40 cm. It should also be stated that the highest roots fresh weight production was associated with the highest volume of consumed water, 3640 m^3/fed. It was also noticed that applying 59% of this volume of water per feddan; i.e. irrigating every 5 days, was responsible for producing 59% of the produces fresh roots. Hence, WUE values must be considered for choosing the best means of growing fodder beet. Decreasing the volume of consumed water will increase water use efficiency but roots fresh yield will decrease. Therefore, if it is necessary to produce high amounts of fresh roots then ample amounts of irrigation water must be provided.

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الاحتياجات المائية لبعض المحاصيل بمحافظة شمال سيناء:
2- تأثير فترات الري وكثافة النباتات على النتح-بخر الفعلي، وكفاءة استخدام المياه، والتحليل الكيماوي، والمحصول لنباتات بنجر العلف

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أجريت هذه الدراسة بالمزرعة التجريبية لكلية العلوم الزراعية البيئية بالعريش جامعة قناة السويس خلال موسمي 2005/2004 ، و2006/2005م. وذلك بهدف دراسة تأثير فترات الري والمسافة بين خطوط الري بالتنقيط على محصول بنجر العلف "صنف فورأوشنجر". اشتملت التجربة على تسع معاملات وتشمل التداخل (التفاعل) بين ثلاث فترات ري (3، 5 و 7 أيام)، و ثلاث مسافات بين خطوط الري بالتنقيط (40، 50 و 60 سم). احتوت كل وحدة تجريبية على 3 خطوط ري بطول 10 م، وكانت مساحة الوحدة التجريبية هي 12، 15 و 18م^2 لمسافات الزراعة على التوالي. زرعت بذور نباتات بنجر العلف في الأول من أكتوبر في كلا الموسمين (205/2004، و 2006/2005) بمعدل 3 كجم/فدان. تزايد معدل النتح-بخر الفعلي والوزن الطازج والجاف لمحصول الجذور والعرش مع نقص فترات الري، بينما تزايدت مع زيادة المسافة بين خطوط الري في كلا الموسمين. تزايدت كفاءة استخدام المياه مع زيادة الفترة بين الريات، بينما تناقصت مع زيادة المسافة بين خطوط الري. نتج عن معاملة الري كل 3 أيام أعلى قيمة لمحتوى الجذور والعرش من البروتين الخام، بينما أعطت أقل القيم لكل من محتواها من الألياف الخام والرماد الكلى في كلا الموسمين. أعطت معاملة الري كل 7 أيام أقل القيم من محتوى الجذور والعرش من البروتين الخام، بينما أعطت أعلى القيم من محتوى الجذور والعرش من الألياف الخام والرماد الكلي في كلا الموسمين. وجدت أعلى قيمة للنتح–بخر الفعلي عند الري كل 3 أيام مع 60سم مسافة بين خطوط الري. الري كل 3 أيام مع 60سم مسافة بين خطوط الري نتج عنها أعلى محصول، بينما الري كل 7 أيام مع 40سم مسافة بين خطوط الري نتج عنها أعلى كفاءة استخدام للمياه.

Table 10: Fodder beet average monthly and total actual evapotranspiration (ET_a, mm) as affected by irrigation intervals and distances between irrigation lines.

Month	Irrigation intervals (days)											
	3				5				7			
	Distances between irrigation lines (cm)											
	40	50	60	Average	40	50	60	Average	40	50	60	Average
October	57.040	59.675	69.595	62.103	40.240	45.415	52.700	46.118	29.450	31.930	36.735	32.705
November	46.650	57.750	62.100	55.500	38.450	41.175	45.750	41.792	22.350	27.000	35.400	28.250
December	73.315	86.490	91.295	83.700	52.700	61.225	65.410	59.778	14.880	17.825	24.645	19.117
January	108.810	117.025	125.860	117.232	62.310	65.875	67.580	65.255	19.995	24.335	32.085	25.472
February	103.880	120.260	124.600	116.247	59.920	68.180	64.820	64.307	23.380	27.300	35.560	28.747
March	171.120	195.145	200.105	188.790	127.100	135.625	146.010	136.245	39.680	47.120	52.545	46.448
April	168.140	183.120	193.200	181.487	61.320	71.260	78.120	70.233	35.280	43.820	51.380	43.493
Total	**728.955**	**819.465**	**866.755**	**805.058**	**442.040**	**488.755**	**520.390**	**483.728**	**185.015**	**219.330**	**268.350**	**224.232**

Table 11: Effect of interaction between irrigation intervals and distance between irrigation lines on fodder beet averages between seasons for root and top fresh and dry yields, consumed water and water use efficiency.

Parameters	Irrigation intervals (days)											
	3				5				7			
	Distances between irrigation lines (cm)											
	40	50	60	Average	40	50	60	Average	40	50	60	Average
Root fresh yield ($ton.fed^{-1}$.)	37.040	42.195	56.180	45.138	25.360	29.780	33.610	29.583	19.455	22.065	23.185	21.568
Top fresh yield ($ton.fed^{-1}$.)	7.246	8.248	10.836	8.777	5.052	5.869	6.379	5.767	3.804	4.400	4.691	4.298
Root dry yield ($ton.fed^{-1}$.)	13.885	17.030	22.965	17.960	9.399	10.285	11.145	10.276	8.284	9.034	9.382	8.900
Top dry yield ($ton.fed^{-1}$.)	2.740	3.360	4.575	3.558	1.869	2.047	2.177	2.031	1.665	1.764	1.862	1.764
Consumed water ($m^3.fed^{-1}$)	3061.611	3441.753	3640.371	3381.245	1856.568	2052.771	2185.638	2031.657	777.063	921.186	1127.07	941.770
Fresh roots water use efficiency ($kg.m^{-3}$)	12.10	12.26	15.43	13.35	13.66	14.51	15.38	14.56	25.07	23.97	20.57	22.90