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IMPACT OF IRRIGATION INTERVAL ON SUGAR BEET'S WATER RELATIONS

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ABSTRACT

Two field experiments were carried out at Sakha Agricultural Research Station, North Nile Delta region during the two growing seasons 2001/2002 and 2002/2003 to find out the main effect of irrigation intervals on (2,3 or 4 weeks) sugar beet water parameters and maximizing productivity per each unit of applied water.

Obtained results showed that root and sugar yield were the highest (26.012 and 4.648 ton/fed i.e.62.429 and 11.155 ton/ha, respectively) under the same condition of 3 weeks irrigation interval. Sucrose and purity percentage (17.88 and 84 88%) were in the same line with the soil moisture of irrigation each 21 days. It might be stated that the most convenient irrigation interval of sugar beet in North Nile Delta region is about 21 days (3 weeks). While irrigation interval of 4 weeks resulted in the maximum percentage of Alkaline coefficient Ac, (3.53%).

The average seasonal water applied, which consists of irrigation water (IW) and rainfall (R_f) for sugar beet was bout 2826.60 m^3/fad. (67.3 cm) to 2182.95 m^3/fed. (52.0 cm) depending upon rainfall and soil moisture status for 2 and 3 weeks intervals , respectively.

During the growing season, 3 weeks irrigation interval treatment received 2144.10 m^3/fed. as irrigation water and 327.60 m^3/fed. as rainfall (51.05 cm IW and 7.8 cm R_f). In other words, seasonal water duty of sugar beet in Kafr El-Sheikh equaled 86.7 % as irrigation water and 13.3% as rainfall.

Average beet water consumptive use could be arranged in descending order as: 2193.66 m^3/fed. (52.23 cm), 1838.55 m^3/fed. (43.78 cm) and 1548.75 m^3/fed. (36.88 cm) for 2,3 or 4 weeks intervals, respectively. Rate of beet consumptive use was arranged as: 0.28, 0.23 and 0.19 cm/day for the same treatments, respectively.

The highest average of water utilization efficiency (W.UT.E.) for root yield was 10.53 kg/m^3, which resulted from 3 weeks irrigation intervals. On the other hand, the lowest value of 8.58 kg/m^3 resulted from irrigation each 2 weeks. The same trend was obtained regarding W.UT.E. in relation to sugar yield, the average values were 1.88 and 1.40 kg/m^3,with the same treatments respectively.

Similar direction was obtained regarding the effect of irrigation intervals on the water use efficiency (W.U.E.) for both root and sugar yields.

The average values of consumptive use efficiency (E cu) were, 77.7, 74.5 and 71.1% for 2,3 or 4 weeks irrigation intervals , respectively.

INTRODUCTION

Irrigation plays a vital role in maximizing the beet production. In the same manner number of irrigation has an important role in producing sugar beet in Kafr El-Sheikh Governorate, which is considered as the main farm of sugar beet in Egypt, which contribute about 80% from the national cultivated beet area and almost 80% from the national sugar beet production.

Doorenbos *et al.* (1979) stated that the upper limit of crop production is set by the environmental conditions and the genetic potential of the crop.

The extent to which this limit can be reached will always depend on how finely the engineering aspects of water supply are in accordance with the biological needs for water in crop production. Therefore, efficient use of water in crop production can only be attained when the planning, design and operation of the water supply and distribution system is geared toward meeting in quantity and time, including the periods of water shortage, the crop water needs required for optimum growth and high yields.

Ibrahim *et al.* (1988) calculated the water balance for Kafr El-Sheikh Governorate. They found that the Governorate face a shortage in irrigation water amounting to 14.5; 12.1 and 23.2% for months of March, April and May, respectively. The stated months are considered as the duration of the second half of beet growing seasons. at which, root formation and sugar accumulation could be existed. Meaningfully, such months have a direct effect on marketable yield. Therefore, saving of irrigation water becomes a target in Kafr EL-Sheikh Governorate to direct the saving water to irrigate summer crops, which of more need for irrigation water.

Massoud and Shalaby (1998) stated that irrigation every 15, 30 or 45 days gave total water application of 10805, 7607 and 5766 m^3/ha, while the total water consumed was 6028, 5107 and 3449 m^3/ha. Sugar yield was not significantly affected by irrigation interval. While water use efficiency increased as irrigation interval increased.

Composeo *et al.* (2001) reported that the highest root yield (76 ton/ha) and the best dense juice purity (90.2%), were obtained by the irrigation scheduling at 70% of total available water *i.e.* 30% depletion, with irrigation intervals of 11 days, irrigation volumes of 80 mm and only 4 irrigation events. This irrigation regime caused a reduction in the total fresh biomass (from 111.1 to 92.3 gm, because of reduced shoot biomass, and increased root and sugar production that varied around 49 and 5.5 gm, respectively. Moreover, the importance of water use efficiency normalization is stressed.

The aim of this investigation is to answer the question of what is the optimum number of irrigations require to maximize the production of sugar beet ?.

MATERIALS AND METHODS

The duration of the study extended over two growing seasons 2001/2002 and 2002/2003 at the Research Farm of Sakha Agricultural Research Station, Kafr El-Sheikh, Egypt . The site is allocated at 31°-07 latitude *i.e.* North Nile Delta with an elevation of bout 6 meters above sea level. Soil of the experimental field is clayey in texture Table (1). Total depths of rainfall were 10 and 5 cm during the two growing seasons, respectively.

A monogerm variety SX4105 was sown on November 5, 2001 and November 7, 2002. All cultural practices were the same as in the area, except the intervals of irrigation: as illustrated:

A.- Watering every 2 weeks.
B.- Watering every 3 weeks.
C.- Watering every 4 weeks.

The statistical design and analysis for mentioned treatments were complete randomized with four replications.

Table (1): Soil particle distribution and soil water constants for the experimental field.

Soil	Soil particle distribution			Textural	F.C.	W.P.	a.w	Db
depth (cm)	Sand %	Silt %	Clay %	class	%	%	%	gm/cm^3
0-15	14.20	32.70	53.10	Clay	48.00	26.21	21.79	1.03
15-30	20.51	35.00	44.49	Clay	43.10	22.00	21.10	1.40
30-45	20.00	41.10	38.90	Clay loam	40.35	21.05	19.30	1.43
45-60	21.80	41.77	36.43	Clay loam	38.11	20.14	17.97	1.46

Data collections:

1.Yield (ton/fed.):

The yield was collected from the central ridges and then computed on the basis of one feddan as ton/fed.

a. Root yield (ton/fed.).

b. Sugar yield (ton/fed.), estimated by multiplying root yield by sucrose percentage.

2.Yield quality:

a.Sucrose percentage.

b.Purity percentage.

c.Alkaline coefficient percentage (Ac) percentage.

Sucrose, purity and alkaline coefficient percentage (Ac) were determined at Delta Sugar Company Limited Laboratories, Kafr El-Sheikh.

3.Irrigation control:

Application of irrigation water was delivered and controlled by a measuring weir fixed upstream with a discharge rate of 0.01654 m^3/sec. at effective head of 10 cm.

4.Seasonal water applied (Wa):

Seasonal water applied (Wa) was calculated as described by Giriappa (1983):

$$Wa = IW + ER + S$$

Where:

IW = Irrigation applied

ER = Effective rainfall

S = Amount of moisture contributed to consumptive use from the soil profile either as stored moisture in root zone and/or that contributed from the shallow ground water.

5.Crop consumptive use (C.U):

Crop consumptive use (C.U.) was calculated by the direct methods: (Doorenbos *et al*., 1979):

$$C.U. = \frac{F.C. - \theta}{100} \times D_b \times D$$

Where:

F.C. = Field capacity (%)

θ = Soil moisture content before irrigation (%).

D_b = Bulk density (kg/m^3).

D = Depth of soil layer = 15 cm.

6. Water efficiencies:

a.Water utilization efficiency (W.UT.E):

It was calculated according to Doorenbos and Pruitt (1975) as:

$$\text{W.UT.E. for yield (root or sugar)} = \frac{\text{Yield in kg / fed.}}{\text{Wa in m}^3\text{ / fed.}}$$

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

It was calculated according to Doorenbos and Pruitt (1975) as:

$$\text{W.U.E. for yield (root or sugar)} = \frac{\text{Yield in kg / fed.}}{\text{C.U. in m}^3\text{ / fed.}}$$

C.Consumptive use efficiency (E cu):

Values of consumptive use efficiency (E cu) was calculated by Doorenbos and Pruitt (1975).

$$\text{E cu} = \frac{\text{ETc}}{\text{Wa}} \times 100$$

Where:

Etc = Total evapotranspiration ≃ consumptive use

Wa = Water applied to the field.

All data were subjected to statistical analysis according to the procedures outlined by Snedecor and Cochran (1967) and treatment means were compared by Duncan's multiple range test (Duncan, 1955). Combined analysis for the obtained data were statistically analysed using the procedures outlined of SAS Computer Package Programme (1992).

RESULTS AND DICUSUSIION

Yield (ton/fed.):

I.Root yield (ton/fed.):

Irrigation intervals had highly significant effects on root yield over both seasons. Average root yield of sugar beet is tabulated in Table (2). The general trend of the obtained results showed that the yield gradually increased by increasing intervals from 2 to 3 weeks. Further increase in irrigation interval did not correspond to increased in yield. The average values were 24.230, 26.012 and 21.940 ton per feddan, respectively. So, to get maximum root yield of sugar beet in North Delta it might be recommended that irrigation interval should be 3 weeks. This case of suitable soil water resulted in healthy plants and consequently, a higher yield could be obtained and vise versa regards the extra or the less availability of soil water. These results are in agreement with those of Nissen *et al.* (1987), Bailey (1990) and Emara (1996) who concluded that the abundance of soil moisture may be lead to considerable increase in number of harvested plants and better early growth of beet.

II.Sugar yield (ton/fed.):

Highly significant effect of irrigation interval on sugar yield was obtained over the two seasons of study. As shown in Table (2), sugar yield for the treatment B was significantly higher (4.648 ton/fed) than that of treatment A (3.949 ton/fed.). In case of treatment C sugar yield showed a marked decrease (3.823 ton/fed.). There is no significant difference between treatment A and C during the course of study. these results showed that sugar yield has increased by increasing the irrigation interval from 2 to 3 weeks i.e the highest sugar yield could be obtained from irrigation interval of 3 weeks during the growing seasons. This increase in sugar yield was obtained due to both increases in sugar percentage and root yield. Similar trend in sugar yield was reported by Nissen *et al.* (1987) and Emara (1996) who mentioned that sugar yield was adversely affected by water deficit.

Yield quality :

I.Sucrose percentage:

Concerning the effect of irrigation treatments i.e. irrigation intervals on sucrose percentage, it was highly significant overall both seasons. As shown in Table (2), the values were 17.88, 17.39 and 16.31% for treatments B, C and A, respectively. These results indicated that increasing the interval between irrigations up to 3 weeks caused a marked increase in sucrose percentage. By elongate the irrigation interval up to 4 weeks sucrose percentage has a clear reduction. Dunham (1993) stated that increasing the impurities in the roots of stressed plants decreased extraction of white sugar. So, irrigation improved sugar beet quality by reducing these impurities. Similar trend were obtained by Nissen *et al.* (1987) and Emara (1996) who mentioned that irrigation significantly increased apparent sucrose content.

II.Purity percentage:

Regarding the effect of irrigation intervals on purity percentage, it was highly significant over both seasons. As shown in Table (2), average purity percentage for treatment B showed a higher increase (84.88%) over that of both treatments C (81.81%) and A (78.05%) during both seasons. These results indicated that by increasing the irrigation intervals from 2 to 3 weeks a marked increase in purity percentage could be achieved, while the elongation of the interval up to 4 weeks caused a clear decline. These results stand in the same line with those recorded by Nissen *et al.* (1987) and Emara (1996) who stated that water stress during the growing beet season not usually improved purity percentage.

III.Alkaline coefficient (Ac) percentage:

Alkaline coefficient (Ac) is considered as an indictor to determine the juice impurity percentage. As shown in Table (2) it was highly significant affected by irrigation interval over both seasons. There was an positive effect of the irrigation interval on the Alkaline coefficient (Ac). The average values of Ac percentage in the two seasons were 2.94, 3.46 and 3.53% for treatments A, B and C, respectively. This trait of Ac is affected by both the sodium + potassium (Na + K) as nominator and amino nitrogen (amino N) as dominator So, increasing the dominator, the Ac will be decreased and vise versa. On other words, the highest average of Ac (3.53%) was obtained by 4 weeks irrigation interval (treatment C). While the lowest average (2.94 %) was resulted from treatment A (2 weeks irrigation intervals). No significant difference was noticed between the treatment B and C. So, the 15th irrigation interval not usually improved quality percentage. It is worthwhile to mention that the threshold value of Ac is 1.8%. Meaningfully, that by lowering the value of Ac less than 1.8%, indicated that impurities conditions has been occurred which might be resulted from improper fertilization. So, in the same direction values higher than 1.8% indicated that high purity sugar beet yield is obtained. Similar trend was cleared by Alvino (1983) and Dunham (1993).

Table (2): **Yield and quality of sugar beet as affected by irrigation intervals in the two growing seasons, 2001/2002 and 2002/2003.**

Characters	Treatments								
	A			B			C		
	1st	2nd	Comb.	1st	2nd	Comb.	1st	2nd	Comb.
Yield (ton/fed.)									
Root yield	23.687	24.772	24.230 b	26.055	25.968	26.012 a	21.844	22.036	21.940 c
F-test			**			**			**
Sugar yield	3.811	4.086	3.949 b	4.643	4.653	4.648 a	3.806	3.841	3.823 b
F –test			**			**			**
Quality (%)									
Sucrose	16.14	16 49	16.31 b	17 85	17 92	17 88 a	17.45	17 33	17.39 a
F-test			**			**			**
Purity	77.65	78.45	78.05 c	84.87	84.89	84.88 a	82.00	81.62	81.81 b
F-test			**			**			**
Ac* (%)	2.92	2.96	2.94 b	3.46	3 46	3 46 a	3 51	3.54	3.53 a
F-test			**			**			**

* Ac = Alkaline coefficient = $\frac{(Na + K)}{\text{Amino N}}$

Water parameters:

I.Seasonal water applied (Wa):

Seasonal water applied (Wa) for sugar beet consists of two main components namely irrigation water (IW) and rainfall (R_f) as shown in Table (3).

As a result of treatment B (3 weeks irrigation interval) produced the maximum root yield of the two seasons, seasonal water duty of this treatment is in the range of 2471.70 m^3/fed. or 58.85 cm. This amount of water came from about 51 cm as irrigation water and 8 cm as rainfall. Irrigation water was applied through 5 watering after the sowing irrigation based on plant needs to water as the traditional farmers irrigate their fields in the area. Meaningful timing of irrigation was depending upon the availability of irrigation water and rainfall status.

Irrigation each 15 days (Treatment A) received the maximum average of water applied (2499.00 m^3/fed. or 67.3 cm). Comparing the two other treatments of B and C with treatment A, average saving of irrigation water in the two growing seasons were; 354.90 and 643.64 m^3/fed. i.e. 14.20 and 25.76%, respectively. Similar trend was obtained by Ibrahim *et al.* (1988).

So, it might be stated that by applying 3 weeks irrigation interval for watering sugar beet, the national saving water for beet acreage in Kafr El-Sheikh could be amounted with 28 392000 mi/m^3 (80 000 fed.). This huge amount of irrigation water should be used for irrigation other crops or in horizontal expansion in Agriculture.

II.Crop consumptive use (ETc):

Consumptive use of water by sugar beet in cm was determined under different intervals of delivered irrigations. Table (3) presents the obtained data which revealed a negative relation between the values of seasonal consumptive use (ETc) and the intervals of irrigation.

From the data obtained, it is obvious that the highest consumptive use was for treatment A (2 weeks, irrigation intervals) with average seasonal value 52.23 cm. On the other hand, the lowest value 36.88 cm was resulted from treatment C (4 weeks, irrigation interval). The average values of seasonal rate consumptive use were 0.28, 0.23 and 0.19 cm/day for treatments A, B and C, respectively. This finding may be attributed to the sufficient wetness in the effective root zone which resulted from the highest number of irrigations applied to treatment A compared with that applied to B and C. These results are similar to those found by Bailey (1990) and Emara (1996).

III.Water efficiencies:

a.Water utilization efficiency (W.UT.E.):

Water utilization efficiency is an indicator to find out the yield per unit water applied (Wa).

From data recorded in Table (3), it is noticed that there was an adverse effect of the volume of water applied on this trait. The average values of W.UT.E. in the two seasons were 8.58, 10.53 and 10.06 kg root/m^3. for treatments A, B and C, respectively. This trait of W.UT.E. is affected by both the yield as nominator and the water applied as dominator. So, increasing the dominator, the efficiency will be decreased and vise versa. In other words, treatment B (3 weeks, irrigation intervals) was accompanied with the highest average of W UT.E (10.53 kg/m^3). While the lowest value 8.58 kg/m^3 resulted from treatment A (2 weeks irrigation intervals).

Regarding the W.UT.E according to sugar yield, the same direction was obtained (Table 3). In other words, treatment B resulted in the maximum value (1.88 kg sugar/m^3). While the lowest value (1.40 kg/m^3) was found with treatment A. Similar results were noticed by Bailey (1990) and Emara (1996) who stated that an adverse effect was pronounced between volume of applied irrigation water and W.UT.E. regarding both beet root and sugar yield.

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

Water use efficiency is a parameter or an indicator to the revenue of the consumed water. In other words, it determines the capability of the plants to convert the utilized water in crop yield. Obtained values of W.U.E. that are presented in Table 3 showed a reversible relationship with increasing the intervals between irrigation. The highest value of W.U.E. (14.18 kg root/m^3 and 2.53 kg sugar/m^3) was recorded from the treatment B (3 weeks irrigation intervals), whereas the lowest value (11.05 kg root/m^3 and 1.80 kg sugar/m^3) was accompanied with the interval of 2 weeks between irrigation (treatment A).

So, in conclusion, both efficiencies of utilization and use. (W.UT E. and W.U.E). are essential to evaluate this study from the irrigation water point of view. Meanwhile, the policy of effective water management is to maximize the crop yield per unit of water. In other words, two targets are considered, the water saving and increasing yield, or at least saving water without insignificant decreasing in crop yield.

C.Consumptive use efficiency (E cu):

Consumptive use efficiency (E cu) reflects the capacity of root to utilize the moisture stored in the soil between irrigation intervals. The data in Table (3) revealed that the highest value of Ecu (77.72%) was recorded with treatment A. So by increasing the interval between irrigation, the consumptive use efficiency (E cu) was decreased with the decreasing values of consumptive use (CU). Similar results were obtained by Doorenbos *et al.* (1979) who stated that the consumptive use efficiency increased with the increase of consumptive use and with the decrease in water applied.

Table (3): **Water parameters of sugar beet as affected by irrigation intervals in the two growing seasons 2001/2002 and 2002/2003.**

Parameters	Treatment								
	A			B			C		
	1st	2nd	Av.	1st	2nd	Av.	1st	2nd	Av.
Wa(m^3/fed.)	2891.70	2761.50	2826.60	2507.40	2436.00	2471.70	2236.50	2129.40	2182.95
IW(m^3/fed.)	2446.50	2551.50	2499.00	2062.20	2226.00	2144.10	1791.30	1919.40	1855.35
R_r(m^3/fed.)	445.20	210.00	327.60	445.20	210.00	327.60	445.20	210.00	327.60
ETc(m^3/fed.)	2140.32	2247.00	2193.66	1756.44	1920.66	1838.55	1484.28	1613.22	1548.75
Etc rate(cm/day)	0.27	0.28	0.28	0.22	0.24	0.23	0.18	0.20	0.19
Water efficiencies:									
W.UT.E.(kg/m^3)									
Root yield	8.19	8.97	8.58	10.39	10.66	10.53	9.77	10.35	10.06
Sugar yield	1.32	1.48	1.40	1.85	1.91	1.88	1.70	1.80	1.75
W.U.E. (kg/m^3)									
Root yield	11.07	11.03	11.05	14.83	13.52	14.18	14.72	13.66	14.17
Sugar yield	1.78	1.82	1.80	2.64	2.42	2.53	2.56	2.38	2.47
E cu(%)	74.06	81.37	77.72	70.05	78.85	74.45	66.37	75.76	71.07

So, in conclusion, it might be to recomment irrigation interval for sugar beet in the main national area of its production (Kafr El-Sheikh Governorate) as 3 weeks (Trt. B) for the following achievements:

- Highest root and sugar yield (26.012 and 4.648 ton/fed.).

- Moderate amount of applied and consumed water in comparison of irrigation each 15 day (2 weeks).
- Highest values of W.UT.E. 10.53 and 1.88 kg/m^3 for root and sugar yield, respectively.
- Highest values of W.U.E. 14.18 and 2.53 kg/m^3 for root and sugar yield, respectively.

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تأثير فترات الرى على العلاقات المائية لبنجر السكر

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أقيمت تجربتان حقليتان خلال موسمي النمو ٢٠٠١ /٢٠٠٢ ، ٢٠٠٢/٢٠٠٣ بمحطة البحوث الزراعية بسخا (شمال دلتا النيل) لمعرفة التأثير الرئيسي لفترات الرى على العلاقات المائية المختلفة وتعظيم الانتاجية لكل وحدة من الماء المضاف لبنجر السكر وقد أوضحت النتائج الاتى:

- سجلت معاملة الرى كل ٣ أسابيع أعلى القيم لمحصولى الجذور والسكر حيث كانت على التوالى ٢٦,٠١٢ ، ٤,٦٤٨ طن/فدان (٦٢,٤٢٩ ، ١١,١٥٥ طن/هكتار) كما كانت النسبة المئوية لكل من السكروز والنقاوه فى نفس اتجاه توفر الرطوبة الارضية للرى كل ٢١ يوم حيث بلغت النسبة ١٧,٨٨ ، ٨٤,٨٨% على الترتيب. وبذا يتضح أن أفضل فترة لرى بنجر السكر فى منطقة شمال الدلتا حوالى ٢١ يوم (ثلاثة أسابيع). بينما أوضحت النتائج أن الرى كل ٤ اسابيع قد سجلت أعلى القيم للنسبة المئوية لمعامل القلوية (٣,٥٣%).
- سجل المتوسط الموسمى للماء المضاف (ماء الرى + الامطار) لبنجر السكر قيما تراوحت بين ٢٨٢٦,٦٠ م^3/فدان (٦٧,٣سم) الى ٢١٨٢,٩٥ م^3/فدان (٥٢,٠ سم) إعتمادا على كمية ماء المطر وحالة الرطوبة الارضية وذلك للرى كل أسبوعين وأربعة أسابيع على التوالى.
أما عند الرى كل ٢١ يوم فقد سجلت قيم الماء المضاف خلال موسم النمو حوالى ٢١٤٤,١٠ م^3/فدان كماء رى بالاضافة الى ٣٢٧,٦٠ م^3/فدان كماء مطر أى ٥١,٠٥ سم ماء رى + ٧,٨ سم ماء مطر ، بمعنى أخر فان كمية المياه الموسمية اللازمة لرى بنجر السكر بكفرالشيخ تساوى ٨٦,٧% كماء رى بالاضافة الى ١٣,٣% كماء مطر.
- سجل متوسط الاستهلاك المائى لبنجر السكر قيما بلغت ٢١٩٣,٦٦ (٥٢,٢٣ سم) ، ١٨٣٨,٥٥ (٤٣,٧٨ سم) ، ١٥٤٨,٧٥ م^3/فدان (٣٦,٨٨ سم) للرى كل أسبوعين ، وثلاثة وأربعة أسابيع على التوالى. كما بلغت قيم معدل الاستهلاك اليومى ٠,٢٨ ، ٠,٢٣ ، ٠,١٩ سم/يوم لنفس المعاملات السابقة على التوالى.
- كان أعلى متوسط لكفاءة استخدام المياه لمحصول الجذور ١٠,٥٣ كجم/م^3 والذى نتج من الرى كل ثلاثة اسابيع. على الجانب الاخر كانت اقل القيم ٨,٥٨ كجم/م^3 والتى نتجت من الرى كل اسبوعين. وقد تلاحظ نفس الاتجاه لكفاءة استخدام المياه بالنسبة لمحصول السكر حيث بلغت القيم ١,٨٨ ، ١,٤٠ كجم/م^3 على التوالى.
وقد سجلت قيم الكفاءة الاستعماليه للمياه نتيجة تأثير فترات الرى اتجاه مشابه لكل من محصول الجذر والسكر.
- كذلك اوضحت البيانات أن متوسط قيم كفاءة استهلاك الماء بلغ ٧٧,٧ ، ٧٤,٥ ، ٧١,١% للمعاملات الثلاث على التوالى.