WATER SAVING WITH THE USE OF DIFFERENT IRRIGATION SYSTEMS UNDER EGYPTIAN CONDITIONS

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ABSTRACT

The performance of three different irrigation systems (drip, sub-surface and sprinkler irrigation) in terms of actual irrigation water requirements, crop yield, water use efficiency and water saving was experimentally investigated under condition of sugar-beet planting in sandy soil.

Water saving through the use of the three irrigation systems was studied as a function of change in water regime (100, 75 and 50%) and planting dates (1 Oct., 20 Oct. and 10 Nov.).

Water saving was also recorded in the case of planting using compost comparing with the case of planting with no compost.

The experimental results reveal to the following:

- *The highest amount of water saving was recorded under the use of sub-surface irrigation system with 50% water regime in the case of using compost and with delaying planting date to 10 Nov.*
- *The highest values of crop yield and water use efficiency were found under the use of drip irrigation system with 100% water regime in the case of using compost and at 1 Oct. planting date.*

Keywords: *irrigation systems, sugar-beet, water regime, planting date, compost, water saving*

INTRODUCTION

Water is the source of life on Earth for all living organisms. Water is the second most important of all natural resources on Earth next to air as its quantities are fixed, whether it is

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fresh water, salt water, surface water or underground water. Water resources in Egypt are becoming scarce. Surface-water resources originating from the Nile are now fully exploited, while groundwater sources are being brought into full production. Egypt is facing increasing water needs, demanded by a rapidly growing population, by increased urbanization, by higher standards of living and by an agricultural policy which emphasizes expanded production in order to feed the growing population.

The amount of water used for agriculture has declined slowly during the past decade, it still accounts for the largest share (84 %) or 49.7 billion m^3 per year. This amount does not include an annual estimated loss of 2 billion m^3 due to evaporation from irrigation systems, annual evapotranspiration losses are estimated at 34.8 billion m^3. The government has launched a national program for irrigation improvement and water management. Surface irrigation systems were used in most cultivated lands of the Nile Valley and Delta witch have low efficiency.

Economic use of water is a vital problem which confronts farmers and agricultural scientists in irrigated areas of arid and semi-arid regions. Knowledge of the right amounts of irrigation water is essential to obtain economically maximum yields of different crops.

Irrigation water management involves determining when to irrigate, the amount of water to apply at each irrigation event and during each stage of plant, and operating and maintaining the irrigation system.

Irrigation systems are selected, designed and operated to supply the irrigation requirements of each crop on the farm while controlling deep percolation, runoff, evaporation, and operational losses, to establish a sustainable production process.

Several studied have been conducted to determine the effect of irrigation systems on water saving. **Sakellariou *et al*. (2002)** evaluated the surface and sub-surface drip irrigation application effects on sugar-beet crop performance, under two levels (100 and 80%) of water application depth and found that the subsurface drip irrigation leaded to greater yield and higher sugar yield making significant water saving compared to surface drip irrigation. **Hanson and May (2004)** obtained yield increases when drip system were used compared to the sprinkler systems with similar amounts of applied water; additionally, drips systems reduced percolation below the root zone. **Perry *et al.* (2009)** found that drip systems generally use half as much water as furrow irrigation. **Mevhibe *et al.* (2010)** found that drip irrigation in sugar-beet production allows saving in input use more than sprinkler and furrow irrigation systems and that it increases productivity and profit. The spread of especially drip irrigation in sugar-beet production has increased the economic use of water and profitability, through savings in input and reduction of costs.

On the other hand, to achieve the goal of water saving **Ali *et al.* (2007)** stated that water saved by deficit irrigation can be used to irrigate more land (on the same farm or in the water user's community), which given the high opportunity cost of water may largely compensate for the economic loss due to yield reduction. **Lytle *et al.* (2008)** found that deficit irrigation was feasible for corn, sunflowers, and soybeans crops. This research showed reduction of 15% of the corn yields for a saving of 17.78 cm when compared to full irrigation. **Topak *et al.* (2011)** studied the effect of deficit irrigation treatments (75, 50 and 25% of full irrigation) on sugar-beet (Beta vulgaris L.) yield and water use efficiency (WUE). And found WUE was the highest in DI25% irrigation conditions and the lowest in full irrigation conditions. The results revealed that irrigation of sugar-beet with drip irrigation method at 75% level (DI25) had significant benefits in terms of saved irrigation water and large WUE, indicating a definitive advantage of deficit irrigation under limited water supply conditions.

Another ways for water saving are by changing the crop planting date and by the compost application. **Mamo (2000)** reported that compost application increased the water holding capacity at the field capacity and at the permanent wilting point but did not change the available water capacity. **Ghanem and Ebaid (2001)** reported that increasing organic manure significantly increased saved water, water use efficiency, yield and its components. **Andrew (2008)** determined planting date (mid-April (early), late May (mid), and mid-June (delayed)) influenced crop and water use (WU of barley. Early planting resulted in excellent forage yields. Water use was higher for the first planting date than for the second and third dates. **Abdou *et al*. (2011)** studied the effects of three sowing dates (D_1: 1st June, D_2: 15th June and D_3: 1st July) on yield of sunflower. The results indicated that the sowing date treatments significantly affected seed yield. The highest seed yield were obtained from 1st of June sowing however, July 1st sowing date gave the lowest values. The highest water use efficiency was obtained from (D_1) treatment. **Farsiani *et al*. (2011)** studied the effect of sowing date (4th May, 24th May, 13th June and 3rd July) on yield and yield components and seed sugar content in sweet corn and found that, the 3rd of July treatment (control) will be the best date for quantitative yield, this sowing date maybe very useful for water saving.

It is clear from the above literature review that water saving can be achieved by using modern irrigation systems. There are also many ways for water saving as implementation of deficit irrigation practices, changing crop planting date and application of compost.

So, the objectives of this research are to:-

- Study the effect of different irrigation systems and water regimes on water saving and crop yield.
- Study the effect of sugar-beet planting dates and use of compost rates on water saving and crop yield.

MATERIALS AND METHODS

Field experiments were carried out in open field conditions during the season of 2011-2012 at Wadi EL-Natrown on Farm Irrigation Department Research Station, Water Management and Irrigation Systems Research Institute, El-Bohera Governorate.

The soil physical and chemical properties of the experimental plots were determined according to [**Klute, 1986 and Page, *et al*. 1982**] shown in Table (1).

The irrigation water was obtained from local well. The irrigation water has a pH of 7.14 and total soluble salts of 755 ppm. Sodium adsorption ratio value was 12.1.

Materials

The irrigation systems

Three irrigation systems were installed in the experimental area. The three irrigation systems contains the following general components:

- Pump: An electrical centrifugal pump is used with 44.1 kW engine power and a discharge of 100 m^3/h at 4 bar operating pressure.
- Control head consists of (centrifugal pump, pressure regulator, pressure gauges, flow meter and filters).
- Pipe network consists of main, sub-main lines, secondary lines and manifold (160 mm diameter PVC is used for main line, between 90 and 110mm PVC for sub-main line, between 63-75 mm for secondary lines between 63-50 mm for manifold line).

Table (1): Physical and chemical analysis of the experimental field during 2011 and 2012 seasons.

Soil layer (cm)	Particle size distribution %			Texture class	Field capacity (%)	Wilting point (%)	Available water (%)	Bulk density (g/cm^3)	EC (ds/m)	PH
	Sand	Silt	Clay							
0 –20	94.5	3.5	2.0	Sandy	13.25	5.5	7.75	1.65	1.45	8.23
20-40	95.0	3.3	1.7		14.25	4.9	9.35	1.56	1.55	8.11
40-60	95.7	3.0	1.3		14.50	4.3	10.2	1.44	1.65	7.97

- Drip irrigation system have lateral drip-lines GR that are made of polyethylene pipes with 16 mm diameters, 25 cm dripper distance, 3.51 lit/h dripper discharge at 1.35 bar operating pressure and 60 cm between laterals. Fig. (1) showed the layout of drip irrigation system.
- Sub-surface irrigation system have lateral with leaky pipe porous flexible rubber hose 16 mm diameter with flow rate of 1.55 lph/m at 1.55 bar operating pressure and 60 cm between laterals. Lateral leaky pipes were installed at 15 cm under the soil surface and the distance between laterals 60cm. Fig. (1) showed the layout of sub-surface irrigation system
- Sprinkler irrigation system have lateral lines that are made of PVC pipes with 50 mm diameters, 12 m sprinkler distance, sprinkler riser 0.75 inch diameter, 1.25 m high, rotating sprinklers 1.9 mm out diameter and 2.2 m^3/h discharge under operating pressure of 2.2 bar. Fig. (2) showed the layout of sprinkler irrigation system.

The cultivated crop

Sugar-beet *Beta vilgarus* (Samba) was sown at the rate of 5 kg /fed and hand planted at 3-5 cm depth on 25 cm planting space and 60 cm between rows with two seeds per hill on 1/10/2011. Thirty five days from seeding, the seedling was thinned to one plant per hill. It is worthy to mention that irrigation treatments took place after the thinning stage. Application of irrigation scheduling treatments started after the initial stage of crop. Calcium super phosphate at (15.5% P_2O_5) at the rate of 100 kg/fed was added during field preparation. Nitrogen fertilization (ammonium nitrate 33.5%N) at the rate of 200 kg/fed was added and divided on 5 times the first one after thinning and the 4 times between the time and times 15 days. Potassium sulphate (48 % K_2O) was added at a rate of 50 kg/fed on 2 times with nitrate.

Methods

Experemintal coditions

Experiments were carried out as a function of change in the following parameters.

Irrigation systems, three irrigation systems were used for irrigating sugar-beet crop (Sprinkler, drip and sub-surface irrigation).

Water regimes, three water regimes were studied as follow:
100, 75 and 50% of actual irrigation water requirements

Planting dates, sugar-beet crop was cultivated at three dates as follows:
1 Oct, 20 Oct and 10 Nov.

Use of compost, sugar-beet crop was treated as follows:
With compost (added at rate of 5 ton/fed) and no compost.

Measurements and calculations

Evalution of the above mentioned experemintal parameters was carried out taking into consederation the following indicators:

1. **Actual irrigation water requirements**

The amount of actual irrigation water requirements under each irrigation system was calculated according to **James (1988)** by using the following equation:

$$IRa = \frac{[(FC - \theta v) \times d] + LR}{Es}$$

Where:

IRa= total actual irrigation water requirements (mm/intervals)
FC= soil moisture content at field capacity (%)
θv = soil moisture content (%) under soil condition.
d= depth of soil layer (20 cm for the initial stage and 30 cm for the last stage).
Es = system efficiency (%).
LR =Leaching requirements was calculated according to **Droonbos and Pruitt (1977)** using the following equation:

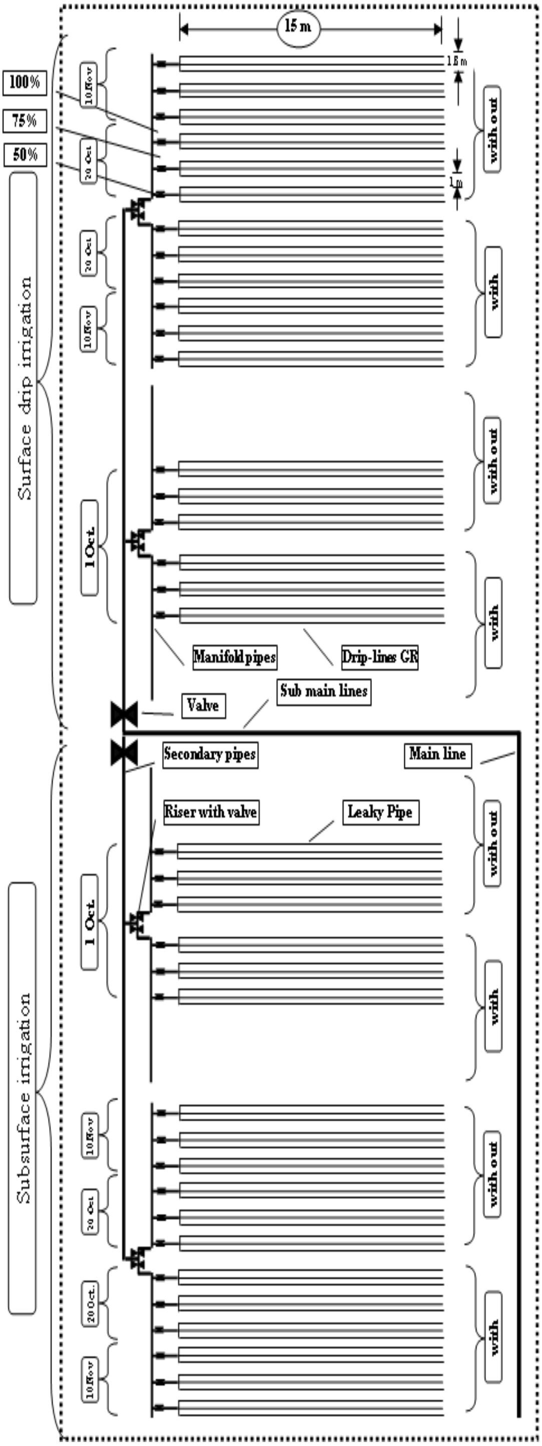

Fig. (1): Drip and subsurface irrigation systems layout.

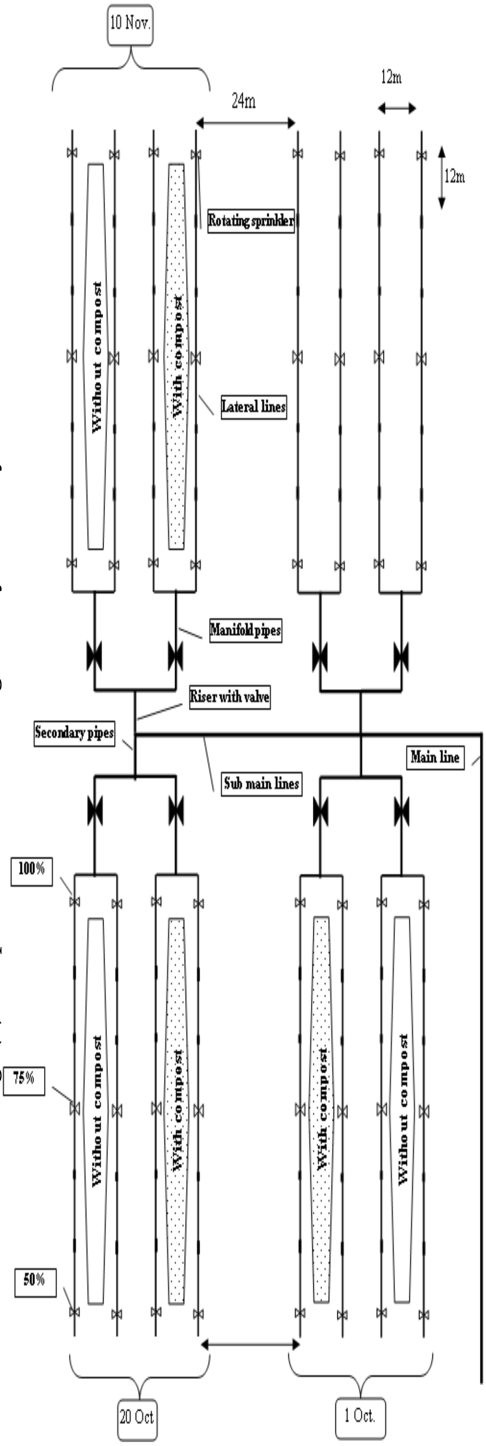

Fig. (2): Sprinkler irrigation system layout.

$$LR = \frac{ECw}{5ECe - ECw}$$

Where:

ECw = Electric conductivity for irrigation water (dS/m)

ECe = Electric conductivity of soil required suiting certain productivity deficit (dS/m).

2. Crop yield

- Root yield (Meg/fed).
- Sugar yield (Meg/fed) = root yield (Meg/fed) × sucrose %.

3. Water use efficiency

Water use efficiency (WUE) was calculated for both root yield and sugar yield according to **Jensen (1983),** as follows

$$WUE_{\text{root yiled}} = \frac{\text{root yield (kg/fed)}}{\text{actual irrigation water requirments (m}^3\text{/fed)}}, \ \text{kg/m}^3$$

$$WUE_{\text{sugar yield}} = \frac{\text{sugar yield (kg/fed)}}{\text{actual irrigation water requirments (m}^3\text{/fed)}}, \ \text{kg/m}^3$$

4. Water saving

The water saving per every treatment was calculated by the follows formula:

$$\text{Water saving (m}^3\text{/fed)} = Rwr - IRa$$

Where: Rwr = recommended water requirements.

RESULTS AND DESCUTION

1- Total actual irrigation water requirements.

The total actual irrigation water requirements to sugar-beet under all treatments are shown in Fig. (3).

Concerning the irrigation systems, the obtained data revealed that the total actual irrigation water requirement for sub-surface irrigation is lower than that for drip irrigation and sprinkler irrigation. While the highest total actual irrigation water requirements was remarked with the use of sprinkler irrigation under all treatments. By using sub-surface irrigation system the total actual irrigation water requirement decreased by 21.2 and 5.3 % compared with sprinkler and drip irrigation systems respectively at 100% water regime under planting date 1 Oct. and with the use of compost.

Concerning water regimes, the obtained results show that the water regime plays an important role to reduce total actual irrigation water requirements. Increasing water regime from 50 to 75 and 100% the total actual irrigation water requirements increased by 36.45 and 73 % using drip irrigation system under planting date of 1 Oct. and with the use of compost.

Relating to the planting date, data show that by delaying the planting date to 20 Oct and 10 Nov., the total actual irrigation water requirements decreased by 6.8 and 14.3% compared to 1 Oct. using sprinkler irrigation system under 100% water regime and with the use of compost.

As to the effect of compost application on total actual irrigation water requirements, results show that the use of compost increased the water holding capacity of the soil. With compost the total actual irrigation water requirements decreased, vice versa without compost the value increased by 5% using sub-surface irrigation system under planting date 1 Oct. and 100% water regime.

2. Crop yield

Fig. (4), show the root yield as well as sugar-beet yield under all treatments.

Relating to the irrigation system, data show that drip irrigation system has high value of root yield, while the sub-surface irrigation system has low value under all treatments. Drip irrigation system increased the root yield by 20.5 and 44.6% compared with sprinkler and sub-surface irrigation system under planting date 1 Oct., 100% water regime and with the use of compost.

With regard to the effect of water regime on root yield, applying amount of water equal to 50% water regime caused reduction for root yield under all treatments. It is clear that increasing the applied irrigation water, resulted in increasing root yield under all treatments. The highest value of root yield was scored from 100% water regime, while the lowest value of root yield was gained from 50% water regime under different treatments.

The root yield increased by about 29.4 and 70.3, 17.6 and 45.5 and 34.7 and 77.4% when applying 100% water compared with applying 75 and 50% under sprinkler, drip and sub-surface irrigation systems under planting date 1 Oct. and with the use of compost. These results go parallel with those obtained by **Abd El-Wahab *et al.* (1996).**

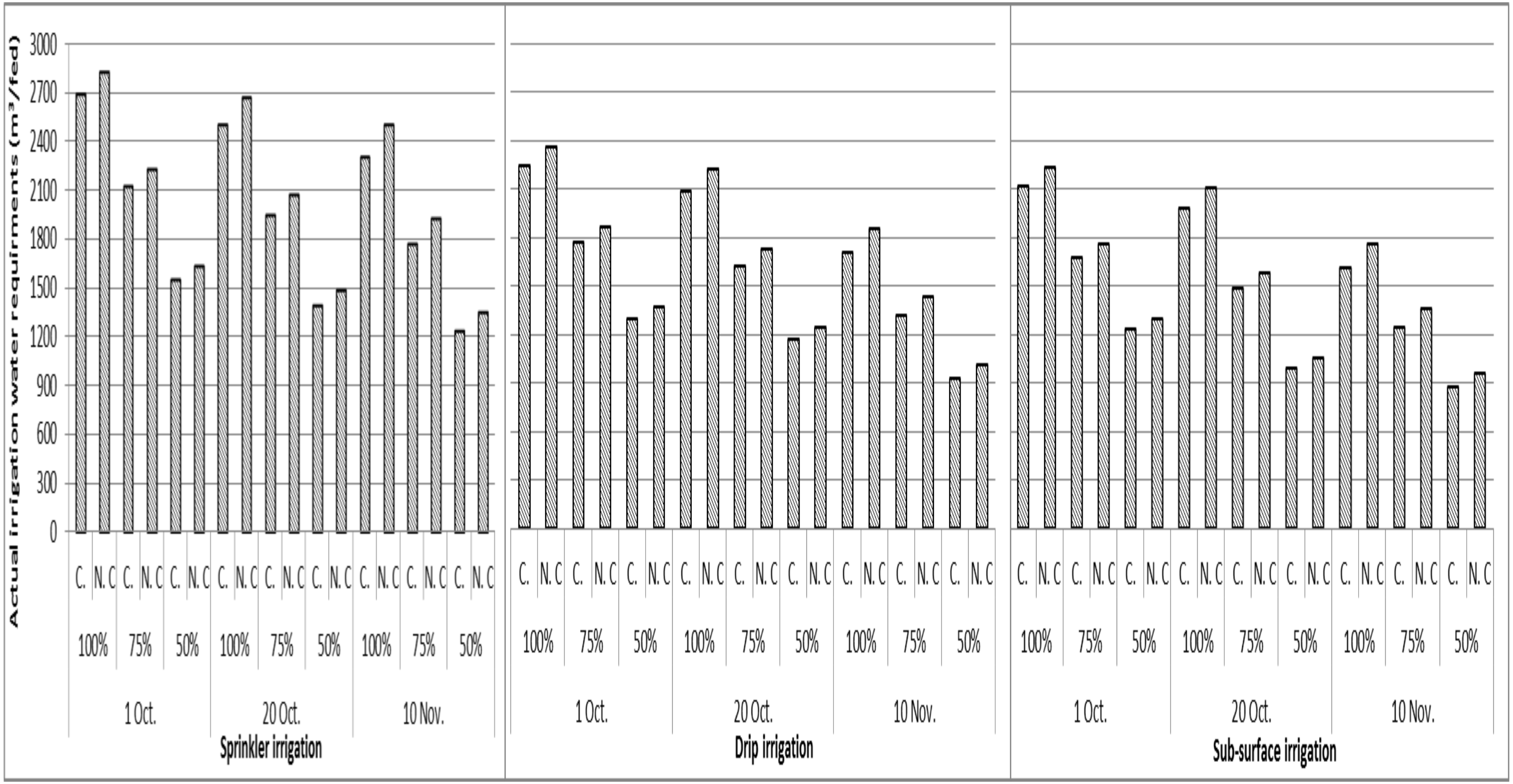

Fig. (3): Effect of irrigation systems on actual irrigation water requirements under different treatments.
C : Compost N. C. = No compost

Concerning the planting date, data show that changing planting date affects the root yield, by delaying the planting date from 1 Oct. to 10 Nov. the root yield reduced by 24.4, 22.4 and 27.7% using sprinkler, drip and sub-surface irrigation systems respectively, under 100% water regime and with the use of compost.

As to applying compost, the obtained results show that the used compost increased the root yield compared with no compost under all treatments. The highest values of the root yield were 17.7, 21.4 and 14.8 Meg/fed, while the lowest values were 15.4, 19.1 and 12.8 Meg/fed under sprinkler, drip and sub-surface irrigation systems respectively, with planting date 1 Oct. and 100% water regime. The use of compost increased the yield by 15.6, 12.1 and 15.6% compared with no compost under sprinkler, drip and sub-surface irrigation systems respectively, with planting date 1 Oct. and 100% water regime.

Concerning the effect of irrigation systems on sugar yield, it is obvious from the results show in Fig. (4), that sugar yield was increased when sugar-beet subjected to irrigate with drip irrigation system either in the sprinkler and sub-surface irrigation system, and the reduction in sugar yield were more pronounced with irrigated by sub-surface irrigation system under all treatments. Moreover, the highest sugar yield was 4.51 Meg/fed when sugar-beet irrigated by drip irrigation system under planting date 1 Oct. and 100% water regime with the use of compost. While the lowest value was 1.1 Meg/fed when sugar-beet irrigated by sub-surface irrigation system under planting date 10 Nov., 50% water regime and with no compost.

Relating to the effect of water regime on sugar yield, sugar yield increased by more than 62.6, 39.3 and 72.3% with increasing applied water from 50 to 100% using sprinkler, drip and sub-surface irrigation systems under 1 Oct. planting date and with the use of compost. These results are similar to those found by **Cucci and Caro (1986)** who reported that irrigation increased sucrose yield by 39%. Similar results were found by **Abd El-Wahab *et al.* (1996).**

Regarding the planting date, results show that the planting date 10 Nov. reduced the sugar yield to 2.45, 3.33 and 2.05 Meg/fed compared with 2.89, 3.81and 2.45 and 3.54, 4.51and 3.27 Meg/fed under 1 and 20 Oct.

using sprinkler, drip and sub-surface irrigation systems respectively, under 100% water regime and with the use of compost. Planting date 20 Oct. increased the sugar yield by 18.2, 14.3 and 11.5% compared with 10 Nov., while reduced the value by 15.4, 19.1 and 12.8% compared with 1 Oct. under sprinkler, drip and sub-surface irrigation systems, respectively, with 100% water regime and with the use of compost.

As to the application of compost, data show that the use of compost increased the sugar yield, while without compost the sugar yield reduced under all treatments.

3. Water use efficiency.

The amount of water used to produce 1 kg of root yield or 1 kg of sugar yield under the condition of this experiment is shown in Fig. (5). The lower the amount of water used to produce 1 kg, the higher the WUE.

The results indicated that higher WUE values of both root and sugar yield were 11.37 and 2.66 kg/m^3 was obtained under drip irrigation system, while the sprinkler irrigation system treatments induced lower values 6.7 and 1.4 kg/m^3 under planting date 1 Oct., 50% water regime and with the use of compost. In general the results lead to the conclusion that, the greatest values were obtained under drip and sub-surface irrigation systems and the lowest values was recorded with used sprinkler irrigation system. Similar trend was obtained by (**Chartzoulakis and Michelakis 1988).**

Considering the water regime, the results indicated that the values of WUE for root yield were 6.61, 9.56 and 6.98, 6.48, 10.3 and 5.56 and 6.71, 11.34 and 6.8 and were 1.32, 1.33 and 1.4, 2.37, 2.24 and 2.66 and 1.54, 1.48 and 1.55kg/m^3 for sugar yield for treatments 100, 75 and 50% under sprinkler, drip and sub-surface irrigation systems, respectively with planting date 1 Oct. and with the use of compost.

Relating to the planting date, data obtained that the values of WUE of root and sugar yield affected by delaying planting date under all treatments. 1 Oct. has the highest WUE, the values were 6.61 and 1.32, 9.56 and 2.37 and 6.98 and 1.54 kg/m^3 were found under sprinkler, drip and sub-surface irrigation systems, under 100% water regime and with the use of compost.

The values of WUE increased gradually with the use of compost compared to with no compost. The increase reached up to 22.3 and

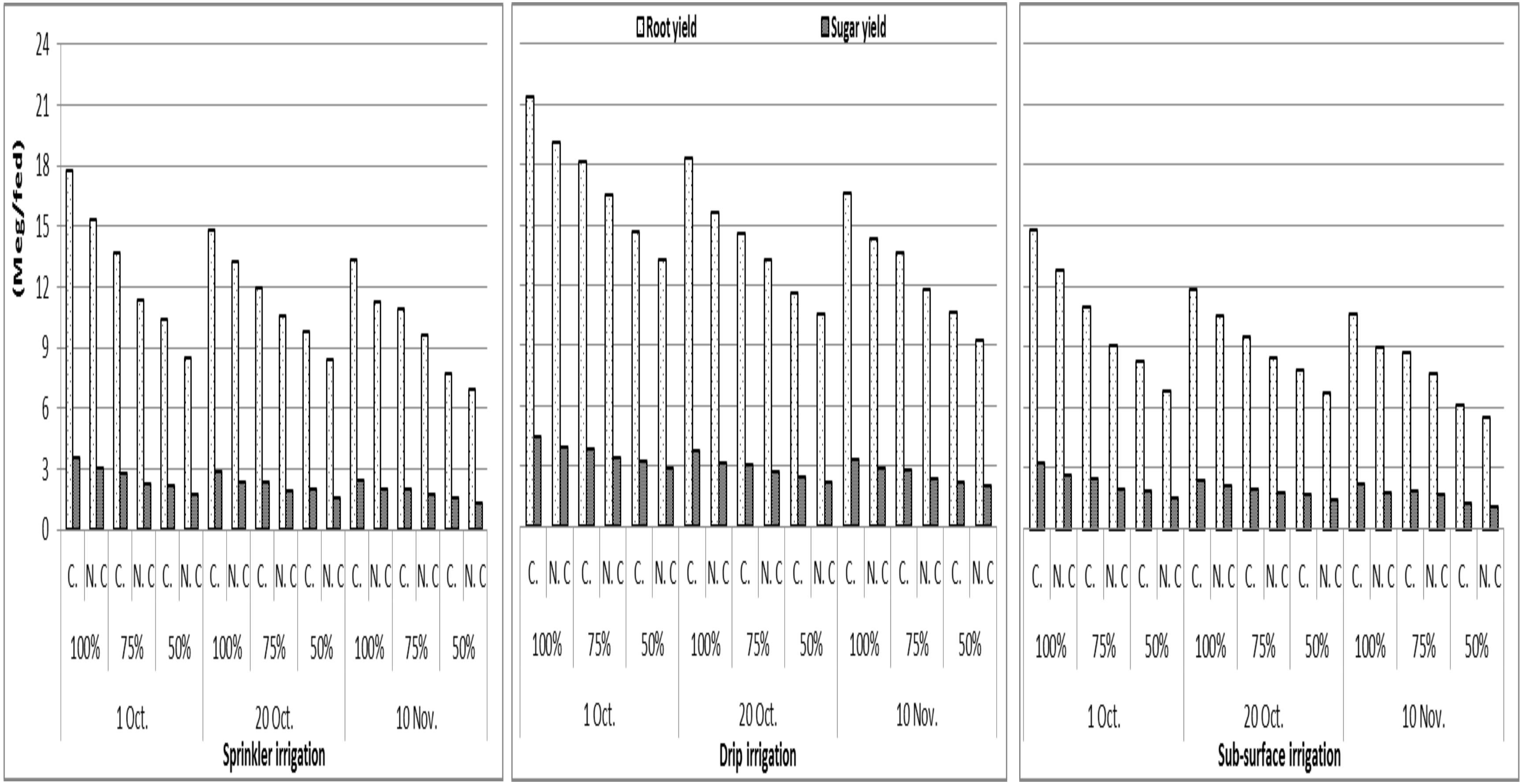

Fig. (4): Effect of irrigation system on root and sugar yields under different treatments.

17.4% for both root and sugar yield, respectively compared with the use case of no compost under all treatments. These results are in harmony with those reported by **Awad (1998)**.

4. Water saving

The data in Fig. (6) showed that the water saving under the different treatments compared with the actual irrigation water requirements 3000 m^3/fed Fig. (6) showed that all the treatments saved water.

Considering the effect of irrigation systems on water saving, results show that the highest value of water saving was obtained under sub-surface irrigation system, comparing with drip and sprinkler irrigation systems. While the lowest value of water saving was obtained under sprinkler irrigation system.

As to the effect of water regime on water saving, results show that water regime saved water. 100% water regime decreased the water saving by 64.2, 38.2 and 33.7 and 78.2, 55.3 and 50.4% compared with 75 and 50%, under sprinkler, drip and sub-surface irrigation systems, respectively with the use of compost and 1 Oct. planting date.

Regard with the planting date, the data show that delaying planting date from 10 Nov. increased the water saving by 40.3, 41.8 and 35.4 and 121.5, 70.1 and 57.6% compared with planting date 20 and 1 Oct. under sprinkler, drip and sub-surface irrigation systems, respectively with 100% water regime and with the use of compost.

The results also indicated that higher water saving was found by using compost, vice versa the lowest value was recorded in the cases of no compost under all treatments, because the compost increased the water holding capacity in the soil.

CONCLUSION

The experimental results indicated the following conclusion:-

- Drip irrigation system achieved the highest values of root and sugar yields, while sprinkler irrigation recorded the lowest values. On the other hand sucrose % increased with use sub-surface irrigation system.
- Using water regime of 50% decreased both root yield and sugar yield compared with 75% and 100%.
- The highest value of total actual irrigation water requirements was found under planting date of 1 Oct. but the lowest value was found under planting date of 10Nov. The results indicated that delaying planting date

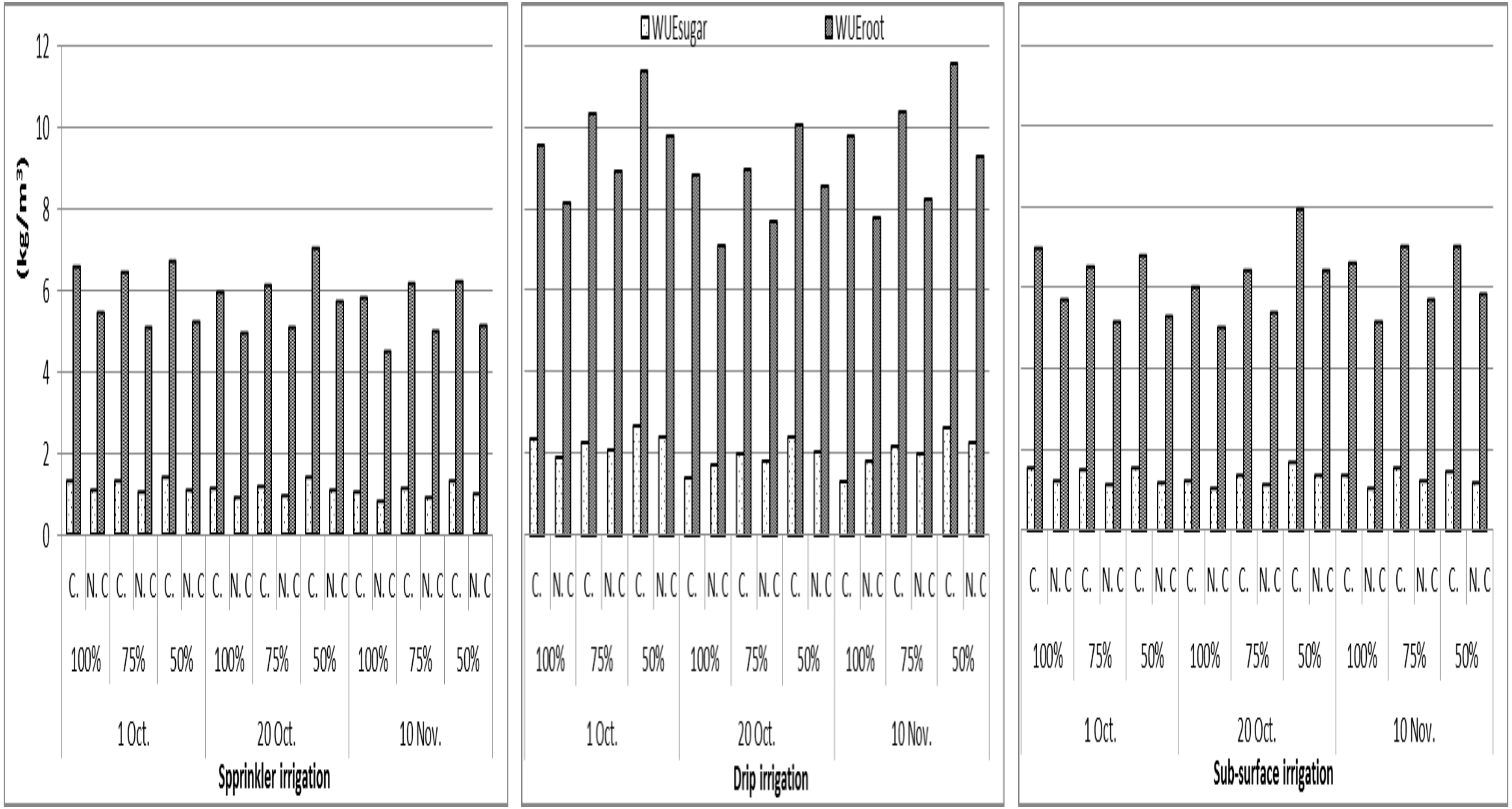

Fig. (5) Effect of irrigation systems on WUE under different treatments.

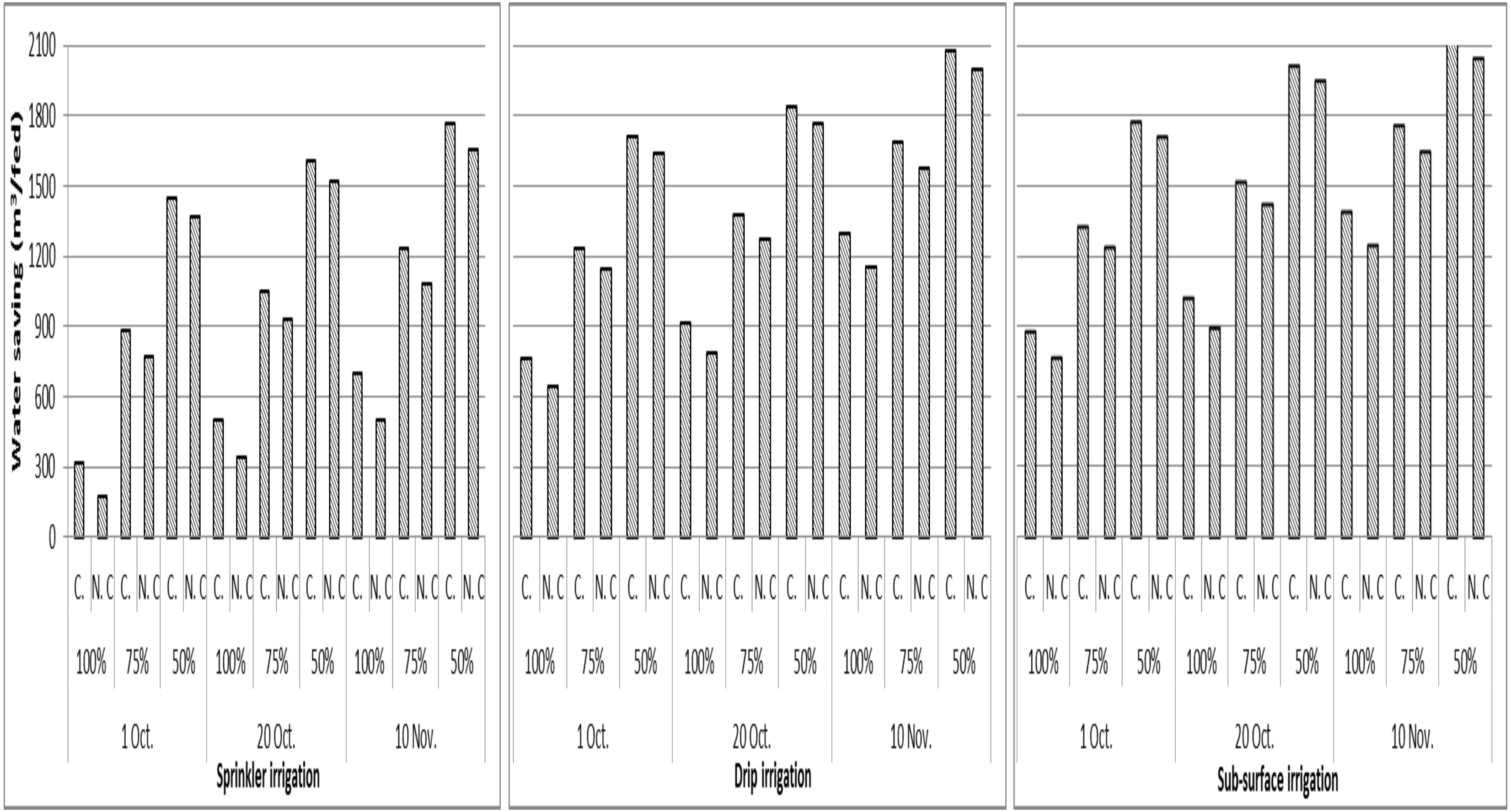

Fig. (6) Effect of irrigation system on water saving under different treatments.

to 10 Nov. decreased root and sugar yields compared with 1 and 20 Oct.

- Also, results indicated, that with using compost the yield of root and sugar and water saving increased comparing with the case of no compost.

Generally, it could be concluded that, under similar conditions, using drip irrigation system, 100% water regime, 1 Oct. planting date and the use of compost to achieve the highest yield, WUE and water saving.

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الملخص العربي

ترشيد المياه باستخدام نظم الرى المختلفة تحت الظروف المصريه

محمد محمد مراد حسن* - السادت ابراهيم علي عبد العال - محمد عنتر محمد مرسى*****

المياه أساس الحياة وهى مورد حيوي يرتكز علية إنتاج الغذاء وتشكل أهم عناصر البيئة كما تلعب دورا رئيسيا في التنمية الصناعية ونظرا لزيادة التوسع في الإنتاج الزراعي لتأمين الاحتياجات الغذائية المتزايدة لسكان مصر ، فان ذلك يتطلب استخدام وادارة جيدة للموارد المائية من اجل زيادة المساحة المروية ، وإن تطبيق تقنيات الري الحديثة يعتبر أحد السبل الهامة في هذا المجال. لذا تتضح اهمية دراسة سبل ترشيد المياه في مصر.

اجريت هذه الدراسة بمحطة تجارب الاحتياجات المائية –وادي النطرون خلال الموسم الزراعي ٢٠١٢/٢٠١١ وذلك لدراسة ترشيد المياه باستخدام نظم الري المختلفة تحت الظروف المصريه.

وكانت عوامل الدراسة هي:-

١) ثلاثة نظم ري مختلفة (الرى بالرش – الرى بالتنقيط – الرى تحت السطحى)

٢) ثلاث مستويات من المياه (١٠٠% - ٧٥% - ٥٠%)

٣) ثلاث مواعيد للزراعة (١ اكتوبر – ٢٠ اكتوبر – ١٠ نوفمبر)

٤) استخدام التسميد بالكمبوست (اضافة – عدم اضافة)

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*** باحث مساعد – معهد بحوث ادارة المياه – المركز القومي لبحوث المياه

وتم قياس الاداء اخذا في الاعتبار كلا من (الاحتياجات المائية – انتاج الجذور – انتاج السكر – كفاءة استخدام المياه – كمية المياه المتوفره) تحت المعاملات المختلفة.

وقد اظهرت النتائج ما يلي:-

١- ان اقل قيم من كميات الري المضافة كانت تحت كلا من الري تحت السطحي مع استخدام مستوي مياه ٥٠% وميعاد زراعة ١٠ نوفمبر مع استخدام الكمبوست. في حين ان اعلي كميات مياه ري مضافة كانت تحت نظام الري بالرش ومعدل اضافة ١٠٠% وميعاد زراعة في ١ اكتوبر مع عدم اضافة كمبوست.

٢- كان اعلي انتاجية لكلا من الجذور والسكر تحت نظام الري بالتنقيط مع استخدام كمية مياه ١٠٠% وميعاد زراعة ١ اكتوبر مع اضافة الكمبوست. علي العكس كانت اقل انتاجية باستخدام الري تحت السطحي مع اضافة ٥٠% من المياه وميعاد زراعة ١٠ نوفمبر وبدون كمبوست.

٣- كانت اعلي قيم لكفاءة استخدام المياه تحت نظام الري بالتنقيط يليه الرش ثم تحت السطحي.

٤- واشارت النتائج الي ان افضل نظام ري استخدم لتوفير المياه كان الري تحت السطحي ثم يليه الري التنقيط ثم الري بالرش تحت جميع المعاملات. واظهرت النتائج ان استخدام الكمبوست يزيد من ترشيد المياه بالمقارنة بعدم اضافته للتربة تحت جميع المعاملات.

وتوصي الدراسة عند زراعة بنجر السكر تحت هذه الظروف يتم استخدام نظام الري بالتنقيط مع استخدام مياه ١٠٠% و ميعاد زراعة ١ اكتوبر مع اضافة الكمبوست بمعدل ٥ طن/فدان لتحقيق اعلي النتائج من حيث الانتاجية وكفاءة الاستهلاك المائي وترشيد المياه.