*J. Agric. Sci. Mansoura Univ., 34 (6): 7199 - 7210, 2009*

# COMPARISON OF SOME TYPES OF SURFACE AND DRIP IRRIGATION SYSTEMS ON MAIZE CROP

**Sonbol, H.A.*; E.M. El-Hadidi*; M.M. Saied** and H. M. Abou El-Soud****

*** Soil Dept., Faculty of Agric., Mansoura Univ.**

**** Soil improvement and Conservation Res. Dept., Soil ,Water & Environ. Res. Instit , ARC, Egypt**

## ABSTRACT

A surface drip irrigation using a single lateral (SSDI) or double laterals/plant row (DSDI) , subsurface drip irrigation using single lateral (SSSDI) or double laterals/plant row (DSSDI), gated pipes (GP) and traditional surface irrigation (TSI) were applied with maize (Single Cross,10) during the summer season 2007 at Sakha Agricultural Research Station Farm , Kafr El-Sheikh Governorate, Egypt in order to study the effects of these irrigation systems on maize yield and water use efficiency. Both drip irrigation systems included 16 mm diameter drip-lines, with emitters discharging about 2L/h and spacing 0.5 m. The subsurface drip irrigation system was installed before the crop seeding, where its laterals (16 mm drip-lines), were buried 0.6 m apart at 15cm below soil surface so that they are not affected by the cultivation practices during the current growing season . The aluminum gated pipes (150 mm diameter) were located at the head of the irrigated field and connected directly with the irrigation pump. The experimental layout of irrigation systems included six replications for each of the six irrigation systems .The design of this experiment is randomized complete blocks(RCB).

Water applied was obviously affected by irrigation systems . The DSSDI system was more effective since it received the lowest depth of irrigation water (55.7 cm.) followed by SSSDI (58.7 cm) and DSSDI system (60.1 cm). On the other hand, TSI system received the highest amount of irrigation water (79.4 cm) followed by GP system (72.2 cm). From the statistical analysis of the harvested maize yields, it has been found that their values are significantly different for all irrigation systems. Maize yields are high for GP and SSSDI irrigation systems and varied between 26.6 to 23.85 ardab /fed. for both systems, respectively. On the other hand , the grain yields are low with SSDI and DSSDI systems which varied between 20.14 and 19.04 ardab /fed. for both systems, respectively. The straw yield took the same trend that is found with the grain yield. Water use efficiencies expressing the maize yield per $m^3$ water applied ranged from 0.96 to 1.355 kg/$m^3$ water for TSI and SSSDI systems, respectively. The effect of different irrigation systems on water use efficiency took the following descending order: SSSDI > GT >DSDI >DSSDI > SSDI >TSI systems. Approximately, the same trend was found with irrigation water use efficiency which related to both grain yield and total water consumptive use.

**Keywords**: subsurface drip irrigation, drip irrigation, gated pipes, water depths, maize yield, water use efficiency.

## INTRODUCTION

Population increase and the improvement of living standards brought about by development will result in a sharp increase in food demand during the next decades. Most of this increase will be met by the products of irrigated agriculture. At the same time, the water input per unit irrigated area will have to be reduced in response to water scarcity and environmental concerns. Water productivity is projected to increase through gains in crop yield and reductions in irrigation water. In order to meet these projections, irrigation systems will have to be modernized and optimized. So, Egypt has to improve irrigation techniques and find out the possible ways for rationalize irrigation water. Pressurize irrigation systems (surface or subsurface drip) and the improved surface irrigation using gated pipes are a relatively new method, which has been considered to be proper irrigation systems, which have to be applied for irrigating field crops in old valley where land texture is often clay. Also water is considered the major constraint for any policy to increasing agriculture productivity, since the person's supply of water is seemed to be constant with the time, water demand is augmenting to face the increasing in population, thus it was necessary to control and manage the available water supply to face overuse problem and minimize water losses to improve irrigation efficiency ( Badawy *, et al* 2001). On the other hand, Hanson and Petterson, (1974) showed that water use efficiencies were highest for surface drip and sprinkler systems with sweet corn comparing with furrow and subsurface systems. Part of the reduction in the applied water can be achieved by shifting the irrigation system from surface irrigation to drip irrigation systems (on surface or subsurface). The use of subsurface drip irrigation (SSDI) has been motivated by its advantages that include higher crop yields and water application efficiency compared to any other irrigation methods including surface drip irrigation (SDI) (Sakellariou- Makrantonaki *et al*, 2002 and Kalfountzos et al ,2004).The advantages of SSDI comparing with SDI are related to the fact that the wetted soil volume develops closer to the root system while the soil surface remains dry hence evaporation losses from the topsoil are limited or negligible (Phene and Ruskin ,1995). There are also some additional practical advantages associated with SSDI. The relatively dry soil surface under SSDI permits farm equipment access and movement during the whole irrigation period and reduces , significantly weed growth (Solomon , 1993). In addition, the permanent installation of SSDI below the ploughing depth provides saving of the labors cost. Gated pipes system provides more uniform water distribution and reduces the irrigation water application quota and conserve energy without effect on the crop yields. However, the gated pipes irrigation technique is easy to understand, and the system is movable and convenient to operate( Jibin and Foroud , 2007). Abo Soliman *et al* (2005) concluded that irrigation by gated pipes achieved the highest values of maize grain yield and its components followed by minisprinkler and gun irrigation methods . They concluded that , the system efficiency could be arranged in the following descending order as: subsurface drip > surface drip > minisprinkler > gated pipes > gun > floppy > conventional irrigation system.

The aim of the present work is to study the effects of drip irrigation (single or double laterals/plant row),SSDI ,gated pipes and traditional surface irrigation systems on water applied, maize yield and water use efficiency. For this reason, yields of an experimental maize field irrigated by a subsurface drip irrigation systems are compared with those of surface drip irrigation systems as well as with other surface irrigation systems.

## MATERIALS AND METHODS

The experiments were conducted in the farm that belongs to the Soil ,Water & Environment Research Institute at Sakha Agricultural Research Station , Kafr El-Sheikh, Egypt. The 4400 $m^2$ experimental field was divided into six plots to be occupied by the studied irrigation systems (550 $m^2$ for drip systems and 1100 $m^2$ for gated pipes and traditional systems). Each experimental plot was 16 rows, of 0.60 m apart for each (across the crop rows) and 55 m long (along the crop rows). The subsurface laterals were buried at a depth of 0.15 m ,so that they are not affected by plowing and other agricultural practices. The drip irrigation network consisted of a main delivery pipe (63 mm in diameter). The drip laterals were of 16 mm polyethylene pipes with in-line self-regulated emitters with discharge rate of about 2 liter/hr. The gated pipes are 150 mm diameter aluminum pipes with slide gates at 0.75 m spacing (3.0 $m^3$/h discharge for each).The pipes are located at the head of the irrigated field across the furrows and connected directly with the water pump. So, the irrigation systems under this study are:

1. Single surface drip irrigation lateral/crop row ………..(SSDI).
2. Double surface drip irrigation laterals/crop row ……...(DSDI).
3. Single subsurface drip irrigation lateral/crop row …...(SSSDI).
4. Double subsurface drip irrigation laterals/crop row…..(DSSDI).
5. Gated pipes…………………………………… ...........(GP).
6. Traditional surface irrigation as a control....……… ……(TSI).

Maize (Zea Mays, var. Single Cross,10) was seeded on 15th July 2007 and harvested on 25th November of the same year. The recommended agricultural practices were applied . The recommended dose of NPK chemical fertilizers for maize were applied ie, 120 kg N /fed. as urea form ,15.5 kg $P_2O_5$ and 24 kg $K_2O$/fed. . All plots were irrigated when 50 % of the available water was depleted using TDR apparatus. The yields of each replication (three crop rows by 2.33 m long) were collected manually and weighted making a total harvested area of 4.2 $m^2$ for each replication (6 replicates).The applied and consumed water, maize yield and its components(number of plant/$m^2$, ear weight ,plant height and leaf area) , and irrigation efficiencies were determined for each irrigation systems. The yield and yield components of maize were subjected to the statistical analysis according to Snedecor and Cochran (1967) and the mean values compared by ( LSD ) test. Water consumptive use (WCU) was calculated according to Israelsen and Hansen (1962) by the following equation :-

$$WCU = \Sigma_i (\Theta_2 - \Theta_1) / 100 * Dbi * Di$$

Where :

WCU = Soil moisture depletion (cm) in the effective root zone(60 cm).

$\Theta_2$ = Soil moisture after irrigation.

$\Theta_1$ = Soil moisture before irrigation.

$Db_i$ = Bulk density (g / $cm^3$).

Di = Depth of soil layer (cm).

I = Number of the soil layer sampled in the root zone depth (cm).

Crop water use efficiency (CWUE) was calculated in kg/$m^3$ for different irrigation systems as follow:

$$CWUE = \frac{Y}{Wcu}$$

Where : Y = grain yield (kg / fed.)

Wcu = total water consumed in $m^3$ / fed.

The field water use efficiency ( FWUE) was calculated in kg/$m^3$ for different irrigation systems to clarify how much kg yield is produced from one cubic meter applied **(**Michael , 1978) as follow:

$$FWUE = Y / Wa$$

Where :

Y = total yield produced (kg / fed.).

Wa = total applied water ($m^3$ / fed.).

Some chemical analysis of soil paste extract were determined according to Black (1965) and some physical properties of soil were determined according to Garcia (1978) .The determined chemical , physical and moisture characteristics of the experimental soil are shown in Tables (1-2).

**Table (1): Soil moisture characteristics of the experimental field.**

| Depth Soil (cm) | Field capacity (%) | Permanent wilting point(%) | Available water(%) | Bulk density(g/cm$^3$) |
|---|---|---|---|---|
| 0-15 | 42.6 | 20.4 | 22.2 | 1.14 |
| 15-30 | 40.0 | 21.4 | 18.6 | 1.19 |
| 30-45 | 39.2 | 22.5 | 16.7 | 1.24 |
| 45-60 | 35.7 | 20.6 | 15.1 | 1.28 |
| Average | 39.4 | 21.2 | 18.2 | 1.22 |

**Table (2): Some physical and chemical properties of the experimental field.**

| Soil depth(cm) | Particle size distribution (%) | | | Texture class | ECe (dS /m) |
|---|---|---|---|---|---|
| | Sand | Silt | Clay | | |
| 0 – 30 | 18.9 | 33.7 | 47.4 | Clayey | 2.48 |
| 30 – 60 | 16.6 | 34.2 | 49.2 | Clayey | 2.36 |
| 60 – 90 | 17.0 | 35.1 | 47.9 | Clayey | 2.68 |

## RESULTS AND DISCUSSION

### 1- Some water relations:

The studied relations with maize crop are recorded in Table (3) and Figs(1-3). The data show that the amounts of water applied with single surface drip lateral/plant row (SSDI), double surface drip laterals/plant row (DSDI), single subsurface drip lateral/plant row (SSSDI), double subsurface drip laterals /plant row (DSSDI), gated pipes (GP) and traditional surface irrigation (TSI) are 62.3, 60.1, 58.7, 55.7, 72.2 and 79.4 cm, respectively. with irrigation application efficiency of 90.0, 90.5, 91.2, 93.5, 82.2 and 75.5 % for the above mentioned irrigation systems, respectively. Also, data indicate that water saving with maize for SSDI , DSDI, SSSDI, DSSDI and GP systems comparing with TSI system are 21.5 ,24.3, 26.1, 29.8 and 9.1 %,respectively. Therefore, the subsurface drip irrigation is preferable than surface irrigation , while using double laterals /plant row is slightly more effective than single lateral in water saving (3.1 and 3.3 %,respectively).

Concerning the water consumptive use, the data revealed that the highest values of water consumptive use by maize plant are obtained with TSI and GP systems (57.6 and 56.7cm , respectively) while the lowest values are recorded with single or double subsurface drip laterals/plant row(50.8 or 49.3 cm, respectively) . The field and crop water use efficiencies which depend on the relation between the yield and the applied water (FWUE) or consumed water (CWUE) are calculated for maize grain yield with different irrigation systems. The highest FWUE and CWUE values are obtained with SSSDI irrigation system(1.35 and 1.56 kg/$m^3$,respectively) and GP irrigation systems (1.23 and 1.56 kg/$m^3$,respectively).

These results in somewhat are in agreement with those obtained by Kalfountzos , *et al*(2004) .

**Table (3): Water applied, stored and consumed and some irrigation efficiencies with maize under different irrigation systems.**

| Irrigation system | Water applied (cm) | Water stored (cm) | Water consumptive use (cm) | Irrigation application efficiency (%) | Grain yield kg/fed | FWUE (kg/$m^3$) | CWUE (kg/$m^3$) |
|---|---|---|---|---|---|---|---|
| SSDI | 62.3 | 56.1 | 53.5 | 90.0 | 2820 | 1.077 | 1.255 |
| DSDI | 60.1 | 54.4 | 51.3 | 90.5 | 2898 | 1.149 | 1.344 |
| SSSDI | 58.7 | 53.5 | 50.8 | 91.2 | 3339 | 1.355 | 1.564 |
| DSSDI | 55.7 | 52.0 | 49.3 | 93.5 | 2665 | 1.140 | 1.286 |
| GP | 72.2 | 59.3 | 56.7 | 82.2 | 3718 | 1.227 | 1.562 |
| TSI | 79.4 | 60.0 | 57.6 | 75.5 | 3197 | 0.958 | 1.322 |
| F test | - | - | - | - | - | ** | ** |
| LSD(0.05) | - | - | - | - | - | 0.086 | 0.07 |
| LSD(0.01) | - | - | - | - | - | 0.116 | 0.10 |

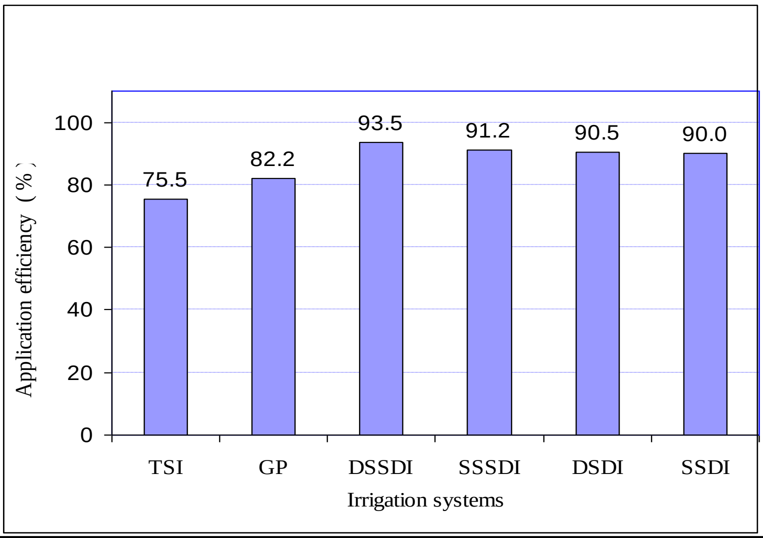



**Fig (1): Irrigation application efficiency with maize as affected by different irrigation systems.**

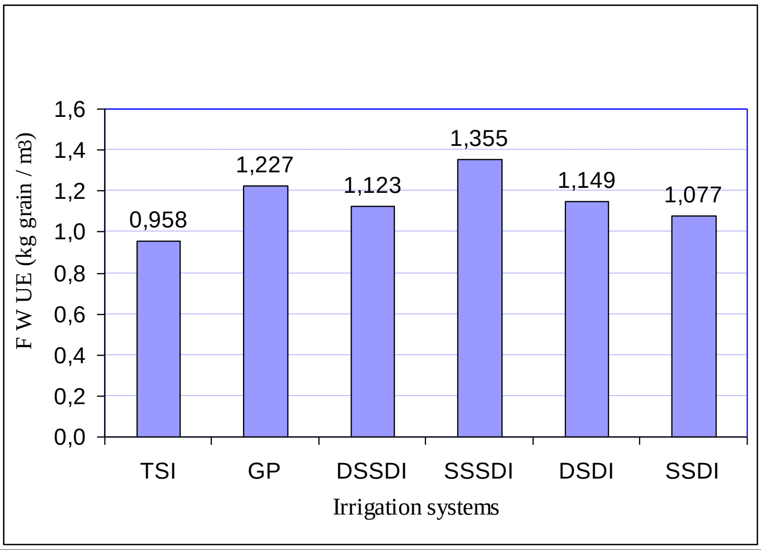



**Fig (2): Field water use efficiency of maize grain as affected by different irrigation systems.**

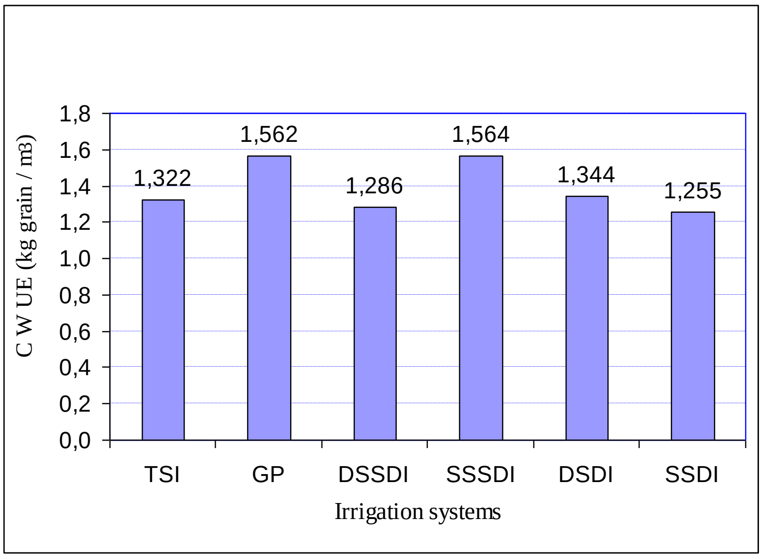



**Fig (3): Crop water use efficiency of maize grain as affected by different irrigation systems.**

**Maize yield and its components:**

The results of maize yield and its components are illustrated in Table (4) and Figs(4-9).The statistical analysis showed a significant effect of irrigation systems on maize yield and its components .The highest straw and grain yields are achieved with GP irrigation system ( 22.48 ton and 26.56 ardab /fed., respectively) followed by SSSDI system (21.06 ton and 23.85 ardab /fed., respectively) .While ,the lowest straw and grain yields are recorded with DSSDI system (15.58 ton /fed. and 19.04 ardab/fed. , respectively). Also, from the statistical analysis, it has been found that the values of the number of plants /m2 ,ear weight , plant height and leaf area are significantly different for all irrigation systems. The highest values of the number plant / m2 , ear weight , plant height and leaf area are obtained with GP irrigation system (11 plant / m2 , 352 gm , 227 cm and 635 cm2 ,respectively) .The lowest values of these parameters are recorded with DSSDI system (7.5 plant / m2 ,265 gm , 209 cm and 476 cm2, respectively).

**Table (4): The yield and yield components of maize as affected by different irrigation systems**

| Irrigation systems | Straw yield (ton /fed) | Grain yield (ardab/fed) | No of Plants /$m^2$ | ear weight (g) | Plant height (cm) | Leaf area ($cm^2$) |
|---|---|---|---|---|---|---|
| SSDI | 15.92 | 20.14 | 8.3 | 295 | 213 | 496 |
| DSDI | 16.49 | 20.70 | 8.8 | 298 | 215 | 511 |
| SSSDI | 21.06 | 23.85 | 10.7 | 336 | 218 | 618 |
| DSSDI | 15.58 | 19.04 | 7.5 | 265 | 209 | 476 |
| GP | 22.48 | 26.56 | 11.0 | 352 | 227 | 635 |
| TSI | 20.63 | 22.84 | 9.5 | 310 | 213 | 513 |
| F test | ** | ** | ** | ** | ** | ** |
| LSD(0.05) | 3.21 | 1.37 | 0.753 | 21 | 5.801 | 62.641 |
| LSD(0.01) | 4.34 | 1.86 | 1.019 | 27 | 7.851 | 84.783 |

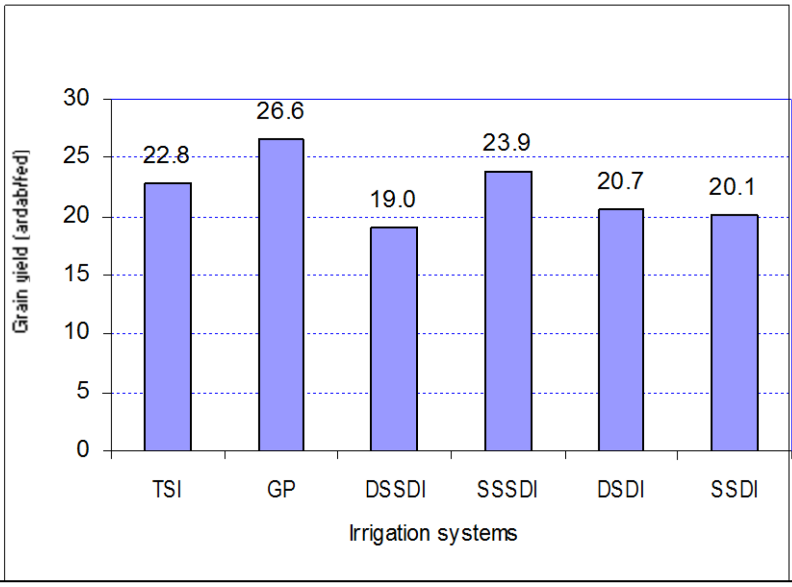
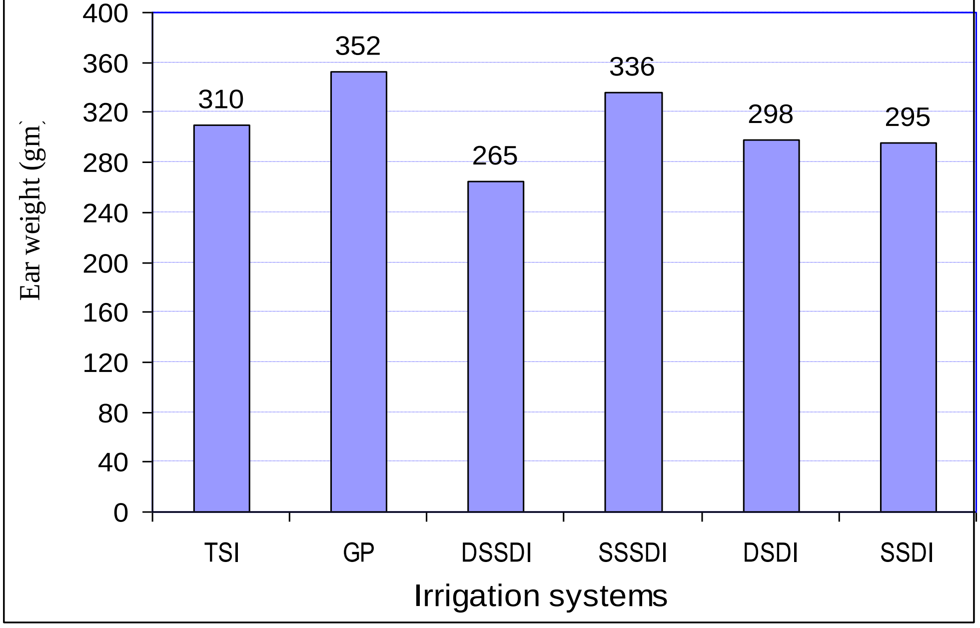



**Fig (4): Grain yield of maize (ardab/fed) as affected by different irrigation systems.**

**Fig ( 6 ):Ear weight(gm) as affected by different irrigation systems.**



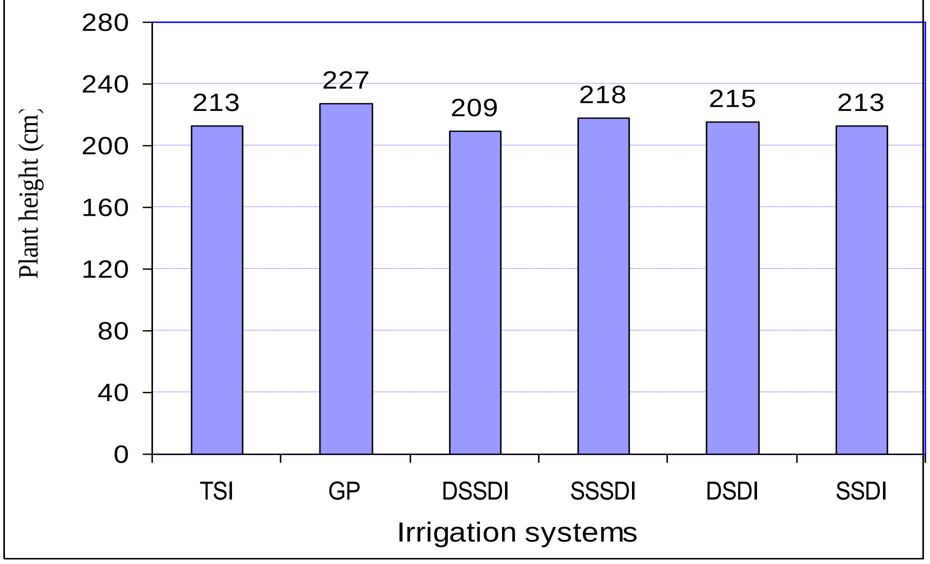
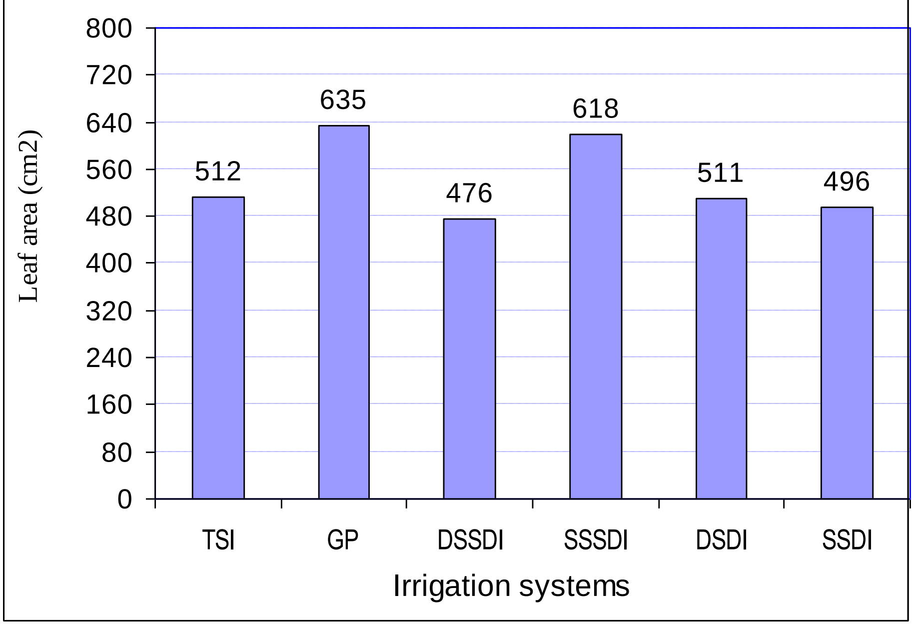




**Fig (7): Plant height(cm) as affected by different irrigation systems.**

Fig ( 8 ):Leaf area (cm$^2$) as affected by different irrigation systems.



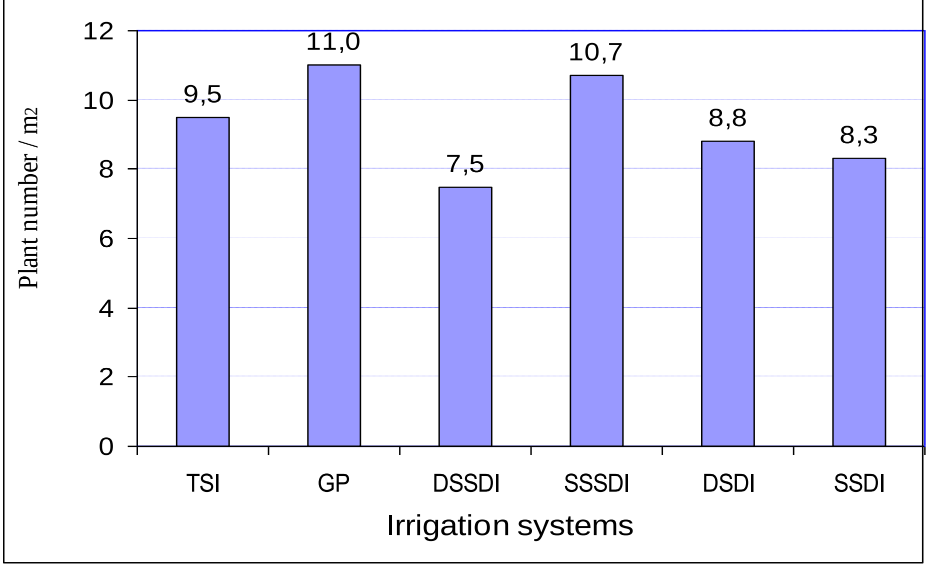




**Fig (9): Plant density(plant /m$^2$) as affected by different irrigation systems.**

## CONCLUSION

Some studies of irrigation researches demonstrated a significant yield and water use efficiency increase for gated pipes and drip irrigation (Abo Soliman,2005 and Jibin and Foroud , 2007).

After one year of experimentation on subsurface, surface drip irrigation and gated pipes applied on maize plantations, the following are concluded:

- Subsurface drip systems (using single or double laterals/plant row) required relatively low volume of irrigation water and have high application efficiency (more than 90 %) , while traditional surface irrigation and gated pipes received higher values of irrigation water with relatively lower application efficiency.
- Maize grain yield are relatively high for single subsurface drip lateral /plant row (SSSDI) and gated pipes(GT) and ranging from 23.85 to 26.56 ardab/fed. for both treatments , respectively.
- The achieved water use efficiencies are relatively high for the two systems(GP and SSSDI) and ranged from 1.23 to 1.36 kg/m3 of water, respectively.
- The subsurface drip irrigation is better than surface irrigation ,and using double laterals /plant row is more effective than single lateral in water saving .

Generally, subsurface drip irrigation is expected to give more valuable results under dry weather conditions and mitigate the adverse effects of water scarcity supporting substantially good yields.

## REFERENCES

Abo Soliman, M. S., H. E. Osman , M. M. Saied and E. H. Omar (2005). Maize, barley production and water use efficiency as influenced by different irrigation methods in Egyptian old land. '' Role and horizons of Agricultural Engineering in the contemporary world''. The 13th Conference of the Misr. Society of Agr. Eng. , 14-15 December (2005).

Badawy., M. E. ; H. A El-khateeb. and M. I. Meleha (2001). Effect of different seedbed preparation on water requirements and sunflower yield. Misr, J. Ag. Eng., July 445-459.

Black, C.A. (1965). Methods of soil analysis. Amer. Soc. Agron.Inc., Madison, Wisconsin, U.S.A.Carter, D.L. (1975). Problems of salinity in agriculture. In:

Garcia, G. (1978). Soil water Engineering Laboratory Manual.Colorado State Univ. Dept. of Agric. and Chemical Engineering. Forcollins, Colorado, 80523.

Hanson, E. G. and T. C. Petterson (1974 ) . Vegetable Production and water use efficiency as influenced by drip, sprinkler, subsurface and furrow irrigation methods. Proc. Sec. Int. Drip Cong. Sandiego, California, USA, pp: 97-102.

Israelsen, O.W and V.E. Hansen (1962). Irrigation principles and practices. 3rd Edit. John Willey and Sons Inc. New York.

Jibin Li and N. Foroud (2007). Evaluation of a gated pipe basin irrigation method in China .http://www.geocities.com/Research Triangle /Thinktank/2097/ gatedpipe .htm 06/04/22

Kalfountzos D., Alexiou I., Kotsopoulos S., Vyrlas P. and S. Kambeli ( 2004). Evaluation of subsurface and surface drip irrigation applied on cotton. Proc. Int. Symposium of EWRA on Water Resources Management: Risk and Challenges for the 21st Century, 2-4 September 2004, Ismir, Turkey, 1: 417-427.

Michael, A.M. (1978). Irrigation theory and practice. Vikas Publishing House, New Delhi.

Phene C.J., and R. Ruskin (1995). Potential of subsurface drip irrigation for management of nitrate in wastewater. In Micro-irrigation for a changing World: Conserving Resources/ Preserving the Environment, ASAE, Proceedings of the 5th International Micro-irrigation Congress, ed. F.R. Lamm, April 2-6, Orlando Florida, 155-167.

Sakellariou-Makrantonaki M., Kalfountzos D. and P. Vyrlas( 2002). Water saving and yield increase of sugar beet with subsurface drip irrigation. Global Nest: The International Journal, 4 (2-3): 85-91.

Solomon K. (1993). Subsurface drip irrigation: Product selection and performance. In Subsurface drip irrigation: Theory, practices and application, eds. Jorgensen, G. S. and K. N. Norum , CATI Publication No. 921001.

Snedecor, O.A,. and W.C. Cochran (1967). Statistical method 6th ,Oxford and IBH. Publishing Co., Calcutta, India.

## مقارنة بعض أنواع نظم الري السطحي والري بالتنقيط على محصول الذرة

**حسين احمد سنبل* ، السيد محمود الحديدي* ، محمود محمد سعيد** و هشام محمود أبو السعود****

*** قسم الأراضي، كلية الزراعة ، جامعة المنصورة**

**** قسم بحوث تحسين وصيانة الأراضي ، معهد بحوث الأراضي والمياه والبيئة، مركز البحوث الزراعية**

طبقت نظم الري بالتنقيط السطحي أو تحت السطحي ( مع استخدام خط أو خطين نقاطات لكل خط نبات) والري السطحي المطور باستخدام الأنابيب المبوبة لمقارنتها بالري السطحي التقليدي من حيث تأثيرها علي كفاءات الري ومحصول الذرة الشامية ( صنف هجين فردي ١٠ ). وقد أقيمت التجربة في موسم ٢٠٠٧ في المزرعة البحثية التابعة لمعهد بحوث الأراضي والمياه والبيئة بمحطة البحوث الزراعية بكفر الشيخ. ولقد استخدم في نظم الري بالتنقيط خطوط نقاطات قطر١٦ مم علي مسافات ٦٠ سم علي سطح التربة أو تحت السطح بعمق ١٥ سم حتى تكون بعيدة نسبيا عن تأثير العمليات الزراعية ( مكافحة الحشائش ... وخلافه ). وكانت النقاطات علي أبعاد ٥٠ سم وتصرف حوالي ٢ لتر/ ساعة لكل منها . والأنابيب المبوبة عبارة عن أنابيب ألمونيوم قطر ١٥٠ مم ذو بوابات قابلة الغلق تصرف كل منها حوالي ٣م$^{٣}$ / ساعة.

وقد وجد أن كميات المياه المضافة تأثرت بطرق الري المختلفة بصورة كبيرة . وقد وجد أن استخدام خطين نقاطات تحت سطحي لكل خط نبات أكثر كفاءة في ترشيد مياه الري حيث استقبلت هذه المعاملة اقل كمية مياه ري ( ٥٥,٧ سم ) يليها خط نقاطات واحد تحت سطحي / خط نبات حيث أضيف ٥٨,٧ سم ثم خطين نقاطات سطحي / خط نبات ( ٦٠,١ سم) مع كفاءة إضافة

مياه الري تتعدى ٩٠%. من ناحية أخري فان اكبر احتياجات مائية كان مع الري السطحي التقليدي ( ٣٣٣٦ م٣ / فدان ) تليها المواسير المبوبة ( ٧٢,٢ سم ) مع كفاءة إضافة ٧٥,٥ و ٨٢,٢% ،على التوالي. وأتضح من التحليل الاحصائى أن هناك تأثير معنوي لطرق الري علي محصول الذرة ومكوناته. وقد أتضح أن محصول الحبوب مرتفع نسبيا باستخدام المواسير المبوبة أو باستخدام خط نقاطات سطحي واحد/ خط نبات حيث كان المحصول ٢٦,٦ ، ٢٣,٨٥ أردب / فدان لكلا النظامين ،علي التوالي بينما كان المحصول منخفضا مع استخدام خط نقاطات واحد سطحي أو مع خطين نقاطات تحت سطحي لكل خط نبات ( ٢٠,١٤ ، ١٩,٠٤ أردب / فدان ، علي التوالي ). وجد أيضا أن محصول القش له نفس اتجاه محصول الحبوب . ولقد تم حساب كفاءة استخدام المياه ويعبر عنه بكمية محصول الحبوب بالكيلو جرام الذي ينتج من متر مكعب مياه ري . وقد تراوحت قيمة كفاءة استخدام المياه على مستوى الحقل (FWUE) بين ٠,٩٦ - ١,٣٥٥ كجم / م٣ مع استخدام الري السطحي التقليدي أو مع استخدام خط نقاطات سطحي واحد/ خط نبات ، علي التوالي. وتأثير طرق الري المختلفة علي كفاءة استخدام مياه الري على مستوى الحقل يأخذ التسلسل التنازلي الأتي:- خط نقاطات تحت سطحي > المواسير المبوبة > خطين نقاطات سطحي > خطين نقاطات تحت سطحي > خط نقاطات سطحي > الري السطحي التقليدي. ونفس الاتجاه تقريبا تحقق مع كفاءة استخدام مياه الري المستهلكة (CWUE).