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SUNFLOWER CROP RESPONSE TO FURROW IRRIGATION INFLOW RATE AND TILLAGE SYSTEM

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ABSTRACT

The response of sunflower crop to furrow irrigation inflow rate and tillage system was investigated during summer growing season 2006. The experiments were conducted in clay soil. The furrow irrigation inflow rates were 1.16, 2.42 and 3.34 lit/sec. Meanwhile, the tillage system included (1) chisel plow one pass followed by disk harrow two passes, (2) chisel plow two passes followed by disk harrow one pass and (3) chisel plow three passes followed by disk harrow one pass. The results showed that there was significant effect of tillage system and furrow irrigation inflow rate on sunflower seed yield, plant height, head diameter, thousand seed mass and water use and application efficiency. However, the highest seed yield (1.44 t/fed) was obtained by combination of tillage system (chisel plow three passes followed by disk harrow one pass) and 3.34 lit/sec furrow irrigation inflow rate. Water use efficiency increased from 0.598 to 0.655 kg/m^3 as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing the soil with chisel plow three passes followed by disk harrow one pass. Water application efficiency increased from 74.9 to 80.9% as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing soil with chisel plow two passes followed by disk harrow one pass. Mathematical model was derived from experimental data to get the sunflower seed yield in easy way by multiple regression analysis as function of soil mean weight diameter, plowing depth and furrow irrigation inflow rate with R^2 of 0.95. Finally, the results of this research could help in planning, design and management of surface irrigation schemes in clay soils.

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INTRODUCTION

Sunflower is one of the most important annual crops in the world grown for edible oil (de la Vega and Hall, 2002) and for vegetable oil (Allen et al., 1983). So, it is recommended to increase the planting area of sunflower in Egypt. The production and planted area of sunflower in Egypt were 47.31×10^3 ton and 47857 feddan, respectively during season 2004 with average yield of 0.99 ton/fed (Arab Organization for Agricultural Development, 2005).

As our agricultural land and water resources are becoming more limited, conservation is becoming an increasingly important topic. There are different ways to conserve water. One of these ways is by improving soil properties using alternative cropping systems and using different farming practice systems. Researchers are interested to determine whether practice-farming systems have a negative, positive, or no effect on sunflower crop yield and water efficiency under surface irrigation method in clay soil. One main reason for the increased production of sunflower is its adaptability to dry land conditions, thanks to early sowing, short growing cycle and high rooting depth (Monotti, 2004). There are, however, also other technical and economical reasons: sunflower is an excellent preceding crop for wheat; all cropping practices can be easily mechanized; the high price of grain, at least until recent years (Monotti, 2004).

Seedbed preparation and irrigation are major factors in crop production. So, it is recommended that more care should be taken in selecting the proper tillage system and irrigation method for crop production. Many different tillage systems can be used effectively for sunflower production as mentioned by numerous studies in Egypt and around the world. Each tillage system depends on many factors such as availability of the tillage machine, type of soil…etc. On the other hand, sunflower has well-developed root systems, deep plowing is necessary (Botta et al., 2006). However, deep tillage and/or mulching helped the crop to use water efficiently by increasing the depth and density of rooting in production of sunflower crop (Gajri et al., 1997).

Attia et al. (1994) mentioned that irrigation interval and plant density had significant effect on sunflower yield in calcareous soil. El Biely (1995) reported that the moldboard plow gave the highest yield (0.934 t/fed) of sunflower crop compared with the chisel and rotary plows. Bonari et al. (1996) observed that sunflower yields were affected by tillage systems when weather conditions were favorable, the lowest yields being observed with disk harrowing. Kassab (1997) studied the effect of different tillage systems as chisel plow one pass, chisel plow two passes and rotary plow on sunflower yields and water utilization and use efficiency. Results of his research showed that chisel plow two passes gave the highest values of water utilization efficiency of 0.510 kg/m^3, water use efficiency of 0.660 kg/m^3 and sunflower yield of 1.22 t/fed.

Nasr et al. (1998) studied the effect of six-seedbed preparation systems of sunflower crop production in clay loam soil. The results reveled that the tillage system consisted of chisel plow two passes followed by tooth harrow, land leveler and ridger gave highest value of seed yield production (1.13 t/fed). Taieb (1998) evaluated three tillage systems in clay loam soil for producing sunflower crop (pioneer variety). The tillage system consisted of moldboard plow followed by scraper gave the highest seed yield of sunflower (1.41 t/fed) compared to chisel plow one pass followed by scraper (1.17 t/fed) and rotary plow only (1.14 t/fed).

Kassem (2000) showed that the growth of sunflower plant, the crop yield and the water use efficiency were affected by irrigation method. However, in furrow irrigation method, the amount of applied water was higher and it was 112.9 cm/season compared to drip and subsurface irrigation methods. Helmy et al. (2000) found that the sunflower yield was 1.14 t/fed when using canal irrigation water with furrow irrigation and 3087 m^3/fed/season of applied water in sandy loam soil. Badawy et al. (2001) investigated different seedbed preparation systems on sunflower yield (Helianthus variety) produced in clay soil. They found that the highest seed yield (1.29 t/fed) was obtained using moldboard plow followed by disk harrow followed by leveler. Their results reveled that maximum crop water use efficiency was 0.640 kg/m^3 under the same tillage system.

Yehia (2002) showed that the highest seed yield was 1.90 t/fed when soil was prepared by moldboard plow followed by disk harrow and the planting of sunflower seeds was achieved manually. El Berry et al. (2003) indicated that the average irrigation applied water was 2556 m^3/fed/season by the surface irrigation when planting sunflower crop (Euroflor variety) in sandy soil. Average water use efficiency was 0.561 kg/m^3 and the yield was 1.42 t/fed. Sayed et al. (2004) indicated that the applied irrigation water varied from 2200 to 1300 m^3/season for furrow irrigation method during planting sunflower crop using saline water in calcareous soils. Metwalli et al. (2004) indicated that in sandy clay loam soil, the subsoiling depth of 65 cm and the distance between shares of 2×2 m gave the highest yield (1.34 t/fed) of sunflower crop compared to 55 and 45 cm subsoiling depth.

Sunflower is generally considered drought-resistant, but significant reduction in yield has been observed due to water stress. This is because the water requirements of sunflower are higher than for other crops. Water availability is one of the agronomic factors that can influence the production and quality of sunflower oil (Santonoceto et al., 2003).

Good soil drainage is required for sunflower production. Excess water is detrimental to sunflower and the number of irrigations required depends upon environmental conditions particularly rainfall and the rate of evaporation (Putnam et al., 1990).

Abd El Rahaman (1985) indicated that water use efficiency increased as the irrigation discharge increased. For the irrigation discharge of 4 lit/sec, the water use efficiency recorded the highest value (2.95 kg/m^3) under 0.2 % soil slope compared to other irrigation discharges of 2 and 3 lit/sec that gave 2.32 and 2.67 kg/m^3 of Egyptian clover in alluvial clay loam, respectively. Abo El Kheir et al. (1999) showed that decreasing the water supply to sunflower plants by extending the interval between successive irrigations led to a progressive significant reduction in seed yield. Morsi (2001) indicated that the water use efficiency decreased as the irrigation discharge increased. For irrigation discharges of 1.95, 4.26, 6.20 and 8.50 lit/sec, the water use efficiency recorded 0.886, 0.886, 0.840 and 0.818 kg/m^3, respectively for corn crop in clay soil under any of furrow length of 40, 60, 80 and 100 m.

El Saadawy (2004) indicated that the applied water decreased as the irrigation discharge increased. For the irrigation discharge of 2 lit/sec, the water use efficiency recorded the highest value for any of the used tillage systems compared to other irrigation discharges of 1.5 and 3 lit/sec.

Kadayif and Yildirim (2000) indicated that the highest sunflower seed yields were obtained when adequate irrigation water was applied during the total growing season. Erdem et al. (2006) showed that irrigation levels significantly affected seed yield of sunflower crop. Nasseri and Fallahi (2007) mentioned that the relationships between crop yield and water applied such as water use efficiency and water production were necessary for application in planning, design and management of irrigation schemes. The objectives of this research were:

1. To study the effect of furrow irrigation inflow rate with the combination of selected tillage systems on sunflower crop yield and some growth components, applied water and water application efficiency and water use efficiency.
2. To derive mathematical model describing sunflower seed yield in easy way as function of soil weight mean diameter, plowing depth and furrow irrigation inflow rate.

MATERIALS AND METHODS

Site and treatments:

The field experiments were carried out in the farm of Rice Mechanization Center, Meet El-Deepa, Kafr El-Sheikh Governorate during summer of growing season of 2006. The field experimental area was 1.157 feddan and it divided into three main plots, each one had area of 0.386 feddan with 30-meter length and 20 meter width. Land leveling was carried out using laser controlled equipment with a certain slope 0.15% for field experimental area. Twenty-seven furrows were constructed in each plot. The furrow spacing was 60 cm apart in order to suit the water flow rates. All furrows in all plots were blocked-end. Different implements were used during seedbed preparation. The characteristics of these implements are shown in Table (1). After conducting tillage, traditional land leveling was done for all treatments.

Table (1): Characteristics of implements used in this research.

Implement	Rated width	Tilling depth	Mass	No. of shares	Working speed	Remarks
	(cm)	(cm)	(kg)	(---)	(km/h)	
Chisel plow	175	20	400	7	3.2	El Behera Rau mounted and hitched by Deutz tractor.
Disk harrow	320	20	1000	36 disk	4.5	Trailed, double acting, four groups, diameter of disks were 57 and 59 cm on front and rear groups, respectively and hitched by New-Holland tractor.
Leveler	300		770	-----	3.5	Trailed scraper with pneumatic 4 tires (16× 650/6), cutting depth changed by the hydraulic cylinder and hitched by Deutz tractor.
Ridger	180		400	3	3.5	Mounted and hitched by Nasr tractor.
Tractors	-----	-----	-----	-----	-----	Deutz (110 hp).
	-----	-----	-----	-----	-----	New-Holland (165 hp).
	-----	-----	-----	-----	-----	Nasr (65 hp.)

Planting sunflower seeds variety (Sakha 53) was practiced manually at rate of 5 kg/fed in the middle of the furrows with one plant per hill. Spacing between hills was 60 cm. This variety needs about 105 days to maturity. The distance between seeds was 20 cm apart along the furrow. All the plots were ridged with three unit ridges. No-tillage system (control treatment) was not conducted due to this system gave lowest seed yield of sunflower in previous study (Badawy et al., 2001) and limited experimental area.

Sunflower furrows were irrigated by using three different spiles* size diameters. These diameters were 45.5, 60.15 and 70 mm, which gave three different furrow irrigation inflow rates (*Q1*, *Q2* and *Q3*, respectively) based on changes of water heads over the center of spiles.

Split-plot design was used with two replicates. Meanwhile, tillage systems were as follows:

- Chisel plow one pass followed by disk harrow two passes (*T1*).
- Chisel plow two passes followed by disk harrow one pass (*T2*).
- Chisel plow three passes followed by disk harrow one pass (*T3*).

Nine treatments were laid out in completely randomized blocks with spilt-plots design with two replicates. Treatment combinations comprised three levels of tillage system and three levels of furrow irrigation inflow rate. The main plots were assigned for the three tillage systems. Meanwhile, furrow irrigation inflow rates were randomly distributed in the sub plots.

Field measurements:

Soil weight mean diameter (clod size) was determined after preparing soil with tillage systems using set of sieves having square holes according to Van Bavell (1949). The set of sieves consisted of 75, 50, 25, 19, 15.5, 6.3,4 and 2 mm mesh. The soil sample represents an area of about 50×50 cm taken from three locations at the head, middle and tail of the experimental field to determine particle size distribution. Meanwhile, three samples at two depths were obtained from the experimental field before tillage using standard steel core to determine soil bulk density and soil moisture content. Soil moisture content was determined by the standard oven method by drying soil samples in oven at 105^{o}C for 24 hours. All soil characteristics were obtained according to Black et al. (1965). Average of some soil characteristics at the experiment site are shown in Table (2).

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*Spile: Conduit, made of lath, pipe, or hose, placed through ditch banks to transfer water from an irrigation ditch to a field (ASABE Standards, 2006).

Table (2): Average of some soil characteristics at the experiment site.

Soil depth	Particle size distribution			Texture class	Soil bulk density	Soil moisture content
	Sand	Silt	Clay			
(cm)	(%)	(%)	(%)		(g/cm^3)	(%, d.b)
0-15	20.9	24.3	54.8	Clay	1.16	19.2
15-30	23.7	21.1	55.2	Clay	1.25	17.3
30-45	20.1	22.3	57.6	Clay	1.31	16.3
45-60	18.1	20.7	61.2	Clay	1.34	15.8

Five samples were taken randomly from each plot to determine plant height, head diameter, thousand seed mass and seed yield. Standard management practices were implemented regarding fertility; pest and seeding date. Four irrigations were applied during sunflower growing season. During irrigation, advanced water in furrows was watched until reaching water to the end of furrows. At this moment, the supplying irrigation water source to the plot was closed and the irrigation time was recorded by digital stopwatch. Plowing depth was measured manually. Forward speed of each operation was determined by recording time required to cover distance of 10 m in the middle of experiments plots. The average working speed of each operation is shown in Table (1).

Data analysis:

The field data were analyzed statistically using SAS program (SAS, 1986) using ANOVA procedure. The different furrow irrigation inflow rates namely *Q1*, *Q2* and *Q3 (lit/sec)* were calculated by the following equation (Michael, 1978):

$$Q = 0.61 \times 10^{-3} a \times \sqrt{2gH} \quad \text{..(1)}$$

Where '*H'* is water head above the center of spiles (*cm*) and '*a'* is the area of cross-section of the orifice of the spiles (cm^2) and '*g'* is acceleration due to gravity ($981\ cm/sec^2$).

The volume of water applied to the plot (*V, lit*) during each irrigation period was determined by the following equation:

$$V = n \times Q \times t \quad \text{..(2)}$$

Where 't' is the time required to irrigate the plot (*sec*), 'Q' is the furrow irrigation inflow rate *(lit/sec/furrow)* and 'n' is number of furrows.

Water use efficiency (*WUE, kg/m^3*) could be calculated according to James (1988) as follows:

$$WUE = \frac{Y(kg/fed)}{AW(m^3/fed/season)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where *Y* is seed yield and *AW* is applied water during growing season. However, the applied water (*AW*, m^3/fed/season) was calculated as follows:

$$AW = \sum_{i=1}^{i=4} V\,(lit/season) \times \left[\frac{4200\,(m^2/fed)}{1000\,(lit/m^3 \times 600\,m^2}\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Water consumptive use was estimated for the 60 cm soil depth according to Israelson and Hansen (1962) as follows:

$$WCU = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} \times D \times \rho \times 42 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where '*WCU*' is amount of water consumptive use (*m^3/fed/season*), θ_1 and θ_2 are soil moistures before and after irrigation (%, d.b), respectively, *D* is soil depth (15 *cm*) apart, ρ is soil bulk density for the specific soil layer (*g/cm^3*), 42 is conversion unit and subscript i = 4 means four irrigations.

Water application efficiency (*Ea, %*) could be calculated according to Michael (1978) :

$$Ea = \frac{WCU}{AW} \times 100 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Multiple linear regression analysis was performed using the data analysis tool within Microsoft Excel package. The multiple linear regression analyses was performed on values obtained from field data to establish a mathematical relationship for estimating the seed yield of sunflower crop (*Y, t/fed)*, dependent variable, as a function of the three main independent variables including: soil mean weight diameter (*X1, mm*), plowing depth (*X2, cm*) and furrow irrigation inflow rate (*X3, lit/sec*). The mathematical relationship has the following form:

$$Y = \beta_0 + \beta_1 \times X1 + \beta_2 \times X2 + \beta_3 \times X3 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where β_0, β_1, β_2 and β_3 are regression coefficients. Meanwhile, coefficient of determination (R^2) was used as a criterion of robusting of the mathematical model of the seed yield of sunflower crop.

RESULTS AND DISCUSSION

The average furrow irrigation inflow rate was determined based on different water heads above spiles during irrigation periods. The average values of Q1, Q2 and Q3 were 1.16, 2.42 and 3.34 lit/sec, respectively. Analysis of data showed that the tillage systems had significant effect on soil weight mean diameter and plowing depth (data not included).

Figure (1) depicts the obtained soil weight mean diameters and plowing depths as a result of tillage systems in this research. It is clear that the tillage system 'T1' had higher soil weight mean diameter of 25.15 mm and lower plowing depth of 13.6 cm. Meanwhile, the tillage system 'T3' had higher plowing depth of 25.9 cm and medium soil weight mean diameter of 17.44 mm. Also, the tillage system 'T2' had lower soil weight mean diameter of 14.77 mm and medium plowing depth of 17.2 cm.

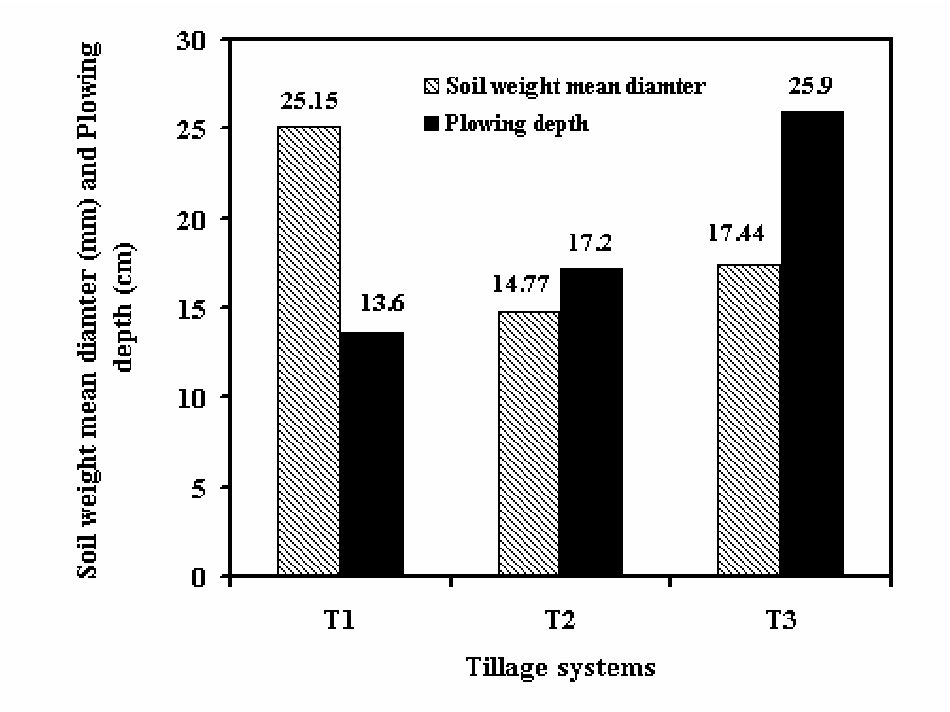

Fig. (1): Obtained soil weight mean diameters and plowing depths as a result of tillage systems.

The analysis of variance given in Table (3) shows that differences in seed yield, plant height, head diameter, thousand seed mass , water use efficiency and water application efficiency are highly significant ($P\leq 0.01$) among tillage systems. Also, differences in water consumptive use are significant ($P\leq 0.05$) among tillage systems. Meanwhile, differences in applied water and average irrigation time of four irrigations during growing season are not significant ($P\leq 0.05$) among tillage systems.

Differences in seed yield, plant height, head diameter, thousand seed mass, water use efficiency, water application efficiency, applied water and average irrigation time of four irrigations during growing season are highly significant ($P\leq 0.01$) among furrow irrigation inflow rates, Table (3). Meanwhile, differences in water consumptive use are significant ($P\leq 0.05$) among furrow irrigation inflow rates.

Differences due to interactions among tillage systems and furrow irrigation inflow rates are significant with the exception of those in head diameter, applied water, average irrigation time of four irrigations during growing season and water consumptive use.

Effect of combination among tillage systems and furrow irrigation inflow rates on seed yield, plant height, head diameter, thousand seed mass, water use efficiency, water application efficiency, applied water, irrigation time of four irrigations during growing season and water consumptive use is shown in Table (4). The highest value of seed yield was 1.44 t/fed. It was due to combination between higher furrow irrigation inflow rate (3.34 lit/sec) and tillage system 'T3'. This result may be due to more uniformity of water distribution in that plot and improvement of soil aeration conditions. At any tillage system, the seed yield and water use efficiency had higher values when higher furrow irrigation inflow rate 'Q3' was applied, Table (4), compared to other furrow irrigation inflow rates. However, the obtained higher values of the seed yield and water use efficiency for tillage system 'T3' compared to other tillage systems may be because the uniformity distribution of water in the root zone when higher plowing depth (25.9 cm) was applied at medium soil weight mean diameter (17.44 mm).

Table (3): Summary of the analysis of variance for the effect of tillage systems and furrow irrigation inflow rates on seed yield, plant height, head diameter, thousand seed mass , water use efficiency, water application efficiency, applied water, average irrigation time of four irrigations during growing season and water consumptive use.

Source of variation	DF	Seed yield (t/fed)	Plant height (cm)	Head diameter (cm)	Thousand seed mass (g)	Water use efficiency (kg/m^3)	Water application efficiency (%)	Applied water (m^3/fed/season)	Average irrigation time + (min)	Water consumptive use (m^3/fed/season)
Tillage system (T)	2	**	**	**	**	**	**	N.S.	N.S.	*
Furrow irrigation inflow rate (Q)	2	**	**	**	**	**	**	**	**	*
T×Q	4	**	*	N.S.	**	**	*	N.S.	N.S.	N.S.

* and ** significant at the 5% and 1% level of probability, respectively. N.S. = not significant.

+ average irrigation time of four irrigations during growing season.

Table (4): Effect of combination among tillage systems and furrow irrigation inflow rates on seed yield, plant height, head diameter, thousand seed mass , water use efficiency, water application efficiency, applied water, average irrigation time of four irrigations during growing season and water consumptive use.

Tillage system	Furrow irrigation inflow rate	Seed yield (t/fed)	Plant height (cm)	Head diameter (cm)	Thousand seed mass (g)	Water use efficiency (kg/m^3)	Water application efficiency (%)	Applied water (m^3/fed/season)	Average irrigation time + (min)	Water consumptive use (m^3/fed/season)
T1	Q1	1.16	134.2	14.4	57.3	0.490	67.5	2377	45.4	1604
T1	Q2	1.25	146.5	14.3	60.8	0.560	72.6	2233	20.3	1620
T1	Q3	1.29	147.5	14.8	64.5	0.589	75.3	2193	14.5	1651
T2	Q1	1.33	157.4	16.0	68.8	0.580	74.9	2287	43.7	1714
T2	Q2	1.35	159.4	16.1	77.9	0.609	76.1	2213	20.1	1685
T2	Q3	1.36	167.6	17.0	81.3	0.623	80.9	2184	14.4	1767
T3	Q1	1.38	162.5	16.8	87.3	0.598	71.9	2309	44.1	1661
T3	Q2	1.42	165.5	17.0	87.6	0.634	74.6	2240	20.4	1670
T3	Q3	1.44	177.2	17.7	94.6	0.655	78.9	2204	14.5	1739

+ **average irrigation time of four irrigations during growing season.**

Increasing soil weight mean diameter from 14.77 mm to 25.15 mm (i.e. 70 %) results in decreased water application efficiency by 5.4 % at ‘Q3’ furrow irrigation inflow rate. Also, increasing plowing depth from 13.6 cm to 25.9 cm (i.e. 48 %) results in increasing water application efficiency by 4.8 % when higher furrow irrigation inflow rate was applied. Meanwhile, increasing furrow irrigation inflow rate from 1.16 to 3.34 lit/sec (i.e. 189 %) increasing seed yield by 11, 2 and 5% and this increasing when conducting seedbed preparation by tillage systems ‘T1’, ‘T2’ and ‘T3’, respectively.

Water use efficiency increased from 0.598 to 0.655 kg/m^3 as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing the soil with tillage system ‘T3’, Table (4). Meanwhile, water application efficiency increased from 74.9 to 80.9% as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing soil with tillage system ‘T2’, Table (4).

The values of applied water of four irrigations had no big differences among tillage systems. However, the tillage systems ‘T1’, ‘T2’ and ‘T3’ gave average values of 2268, 2228 and 2251 m^3/fed/season of applied water of four irrigations, respectively, Table (4). Meanwhile, the values of applied water of four irrigations had differences among furrow irrigation inflow rates. However, the furrow irrigation inflow rates ‘Q1’, ‘Q2” and ‘Q3’ gave average values of 2324, 2229 and 2194 m^3/fed/season of applied water of four irrigations, respectively, Table (4).

Higher furrow irrigation inflow rate ‘Q3’ gave higher water application efficiency, Table (4), at any tillage system. This result agreed with Kassem and El Khatib (2000) who mentioned that increasing furrow irrigation inflow rate from 0.7 to 2.1 lit/sec results in increasing water application efficiency from 67.22 to 71.6% at furrow length 50 m in clay soil. However, the higher values of water application efficiency mean less deep percolation losses below sunflower root zone and less furrow tail water.

There are differences among tillage systems for values of water application efficiency, Table (4). However, the tillage system 'T2' gave higher values at any furrow irrigation inflow rates. This result may be due to that tillage system 'T2' had suitable combination between soil mean weight diameter (14.77 mm) and plowing depth (17.2 cm) and in this case less deep percolation occurred.

Table (5) shows values of regression coefficients of sunflower seed yield model. It is shown that the soil weight mean diameter is inversely proportional to sunflower seed yield and this result was in agreement with El Marazky (2005). Plowing depth is directly proportional to sunflower seed yield and this result is in agreement with El Biely (1995). Meanwhile, furrow irrigation inflow rate is directly proportional to sunflower seed yield and this result was in agreement with El Sharkaway et al. (2005).

Figure (2) illustrates comparison between the predicted and observed sunflower seed yield. By examining Fig. (2), it is relatively easy to visually verify that the obtained model from multiple linear regressions is performing well. The sunflower seed yield is more sensitive to furrow irrigation inflow rate. The obtained statistical model for sunflower seed yield (Y, t/fed) is as follows:

$$Y = 1.197 - 0.007 \times X1 + 0.01 \times X2 + 0.035 \times X3 \qquad R^2 = 0.95$$

Table (5): Values of regression coefficients of sunflower seed yield model (Eq.7).

Independent variables	Regression coefficients	Value
Intercept	β_0	1.197
Soil weight mean diameter (mm)	β_1	-0.007
Plowing depth (cm)	β_2	0.01
Furrow irrigation inflow rate (lit/sec)	β_3	0.035

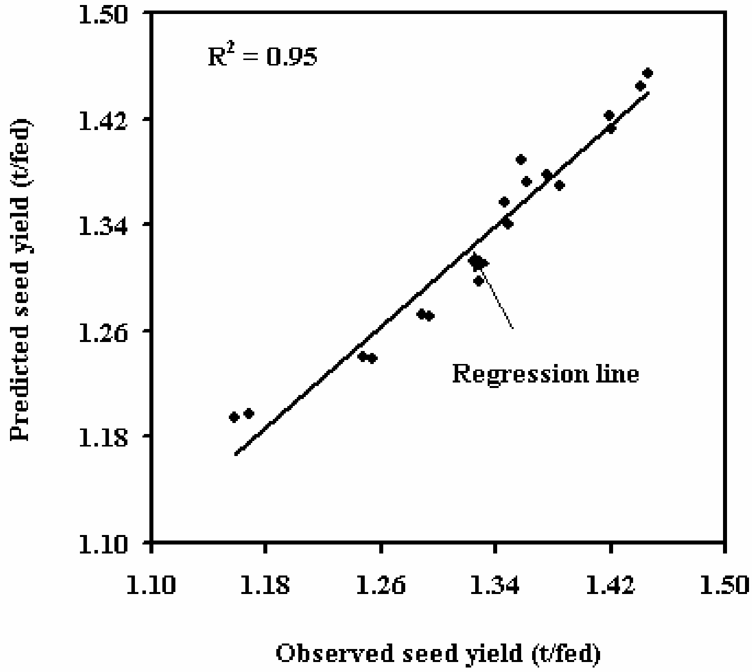

Fig. (2): Comparison between the predicted and observed sunflower seed yield.

CONCLUSION

Conclusions can be summarized in the following points:

1. There was significant effect of tillage systems and furrow irrigation inflow rates on sunflower seed yield, plant height, head diameter, thousand seed mass and water use and application efficiency.
2. The highest seed yield of 1.44 t/fed was observed for combination of tillage system (chisel plow three passes followed by disk harrow one pass) and 3.34 lit/sec furrow irrigation inflow rate.
3. Water use efficiency increased from 0.598 to 0.655 kg/m^3 as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing soil with chisel plow three passes followed by disk harrow one pass.

4. Water application efficiency increased from 74.9 to 80.9% as furrow irrigation inflow rate increased from 1.16 to 3.34 lit/sec when preparing soil with chisel plow two passes followed by disk harrow one pass.
5. Increasing soil weight mean diameter from 14.77 mm to 25.15 mm results in decreased water application efficiency by 5.4 % when higher furrow irrigation inflow rate (3.34 lit/sec) was applied.
6. Increasing plowing depth from 13.6 cm to 25.9 cm results in increasing water application efficiency by 4.8 % when higher furrow irrigation inflow rate (3.34 lit/sec) was applied.
7. The results of this research could help in planning, design and management of surface irrigation schemes in clay soils.

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الملخص العربي

استجابة محصول عباد الشمس لمعدل سريان مياه الري بالخط ومنظومة الحراثة

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الهدف من هذه البحث هو دراسة تأثير منظومة الحراثة ومعدلات سريان مياه الري بالخط علي إنتاجية محصول عباد الشمس المنزرع في أرض طينية، وكذلك كفاءة الاستفادة وإضافة المياه، حيث أن عباد الشمس محصول زيتي هام يزرع في مناطق مختلفة بمصر. وأجريت التجارب في مركز ميكنة الأرز ، ميت الديبة، محافظة كفر الشيخ خلال صيف 2006. تمت الزراعة يدويًا والمسافة بين الخطوط 60سم والمسافات بين النباتات داخل الصف 20 سم، وطول الخط 30 متر. وكانت أهم النتائج المتحصل هي:

1. وجد تأثير معنوي لكل من منظومة الحراثة ومعدلات سريان مياه الري بالخط على إنتاجية المحصول ومكوناته وكفاءة استخدام وإضافة المياه. وأن منظومة الحراثة باستخدام محراث حفار ثلاثة أوجه مرور فوق سطح التربة يليه مشط قرصي وجه واحد أعطت أفضل إنتاجية لمحصول عباد الشمس عند ري المحصول بسريان مياه داخل الخط مقداره 3.34 لتر/ث.
2. زادت كفاءة استخدام المياه من 0.598 إلى 0.655 كجم/م^3 عند زيادة سريان المياه من 1.16 إلى 3.34 لتر/ث عند منظومة الحراثة باستخدام المحراث الحفار ثلاثة أوجه مرور فوق سطح التربة يليه مرور المشط القرصي وجه واحد.
3. زادت كفاءة إضافة المياه من 74.9 إلى 80.9% عند زيادة سريان المياه من 1.16 إلى 3.34 لتر/ث عند منظومة الحراثة بمرور المحراث الحفار وجهان فوق سطح التربة يليه مرور المشط القرصي وجه واحد.
4. تم الحصول على معادلة بالارتداد الخطي المتعدد يمكن من خلالها التنبؤ بإنتاجية محصول عباد الشمس إذا زرع في أرض طينية وذلك من خلال معرفة القطر المتوسط لحبيبات التربة الناشئ من منظومات الحراثة، وعمق الحرث و مقدار سريان المياه داخل الخط في حدود قيم هذه المتغيرات أثناء إجراء البحث.
5. يمكن الاستفادة من النتائج عند تخطيط، تصميم، إدارة نظم الري السطحي لزراعة محصول عباد الشمس في أراضي طينية.

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