EFFECT OF IRRIGATION SYSTEMS ON COTTON AND TOMATO PRODUCTIVITY GROWN UNDER DIFFERENT INTERCROPPING PATTERNS

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ABSTRACT

The field experiments were conducted during summer season of 2009/2010 in Agricultural Experimental Farm, at in Kafrelshiehk University to study the effects of irrigation system on crops, under different intercropping of cotton and tomato.,

The main results could be summarized as follows

- *Drip irrigation system increased seed cotton yield by about of 30.4% and 27.78% compared with furrow irrigation and the perforated pipes respectively, where the average value of seed cotton yield for drip irrigation system was 6.48 kentar♣/feddan.*
- *Increasing ridges length tended to decrease both of cotton and tomato yield for furrow irrigation but increasing length of ridges tended to increase tomato yield under perforated pipes and drip irrigation system.*
- *Using perforated pipes and drip irrigation had developed the water application efficiency compared with traditional furrow irrigation because they used less irrigation water, increase amount of water stored in root zone (saved of irrigation water) and gave a highest value of production.*
- *The highest value of water distribution efficiency was 97.3% using drip irrigation with 25 m ridges length and cotton plants were grown on the two sides of the ridges and tomato plants in the middle of the same ridges.*

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♣ 1 kentar = 157.5 kg

- *Traditional furrow irrigation gave lowest value of water use efficiency, because drip irrigation and perforated pipes used less amount of irrigation water and gave the highest value of crop yield.*

INTRODUCTION

Cotton is the most important fiber crop used for making textile materials. It can be used in making a wide range of products, from diapers to explosives, than any other fiber. Cotton still ranks as a major source of national income of Egypt. The Egyptian economy is heavily dependant on cotton production. Cotton crop takes comparatively long time in the field, about seven months. Intensive cropping requires farmers to look for suitable crops to grow with cotton without reducing its final yield in order to avoid risks of bad yield and/or severe fluctuations prices. Tomato is one of the most important vegetable crop in Egypt. It's grown all year round in Egypt. However, production faces some problems in summer season due to high temperature and insect born viruses diseases prevailing in these months. The main effect of adverse weather conditions was found on flowering and fruit set.

El-Habbak (1980) found that intercropping cotton and soybean produced Land Equivalent Ratio (LER) value of 0.95 on the average of the two successive seasons 1977 and 1978, indicating a disadvantage for intercropping cotton and soybean was 0.87 and 0.69 in 1982 and 1983, respectively, showing negative effect for intercropping. Higher yield in terms of total biomass and grain production per unit area in a given season without the use of costly inputs under intercropping system is attributed to better use of growth resources namely, light, moisture and nutrients *Sivakumar and Virmani, (1980*). *Abou-Zahra (1983)* found that intercropping cotton and soybean in alternate single rows produced 8-9% increase in land use efficiency. Water application efficiency is one of the most important criteria that used to describe field irrigation efficiency. The water application efficiency is the ratio between water storage in the root zone to total water applied. The high water application efficiency means that less deep percolation below the crop root zone and less tail water of furrow *Samani et al. (19*85). Cotton being a long duration crop having slow growth in the early growth stages is ideally suited for intercropping. Short duration legume crops can be grown conveniently as intercrops in cotton. The practice of intercropping in cotton increases the yield and stabilizes return *Mukherji et al., (1987). Chartzoulakis and Michelakis. (1990*) reported that, the total amount of water applied under drip irrigation for cucumber was 366 mm and the average fruit yield per plant was 4.38 kg and the water use efficiency was 27.7 kg/m^3. *Kamel et al. (1990)* revealed that efficiency of land use reached maximum (1.44) when two rows of maize were alternated with four rows of soybean in intercrop patterns. On the other hand, increasing the alternating rows of maize in the intercrop patterns contributed lower advantage in land use (1.17). *Kusumo and Sutater (1993)* reported that intercropping potato with maize increased land productivity as measured by land equivalent ratio. *Morris and Garrity (1993)* stated that increasing productivity of intercropped soybean and maize over the sole crop has been attributed to better use of solar radiation. They added that water capture by intercrops is higher by about 7% compared by sole crop. Their results indicated that water utilization efficiency of intercrops was higher by about 18% compared by sole crop. Under soybean/maize intercropping systems, soybean yield tends to be lower and maize yield tends to be higher *Ghaffarzaeh et al., (1994). Patel et al. (1995)* reported that cotton intercropped with soybean, blackgram and greengram gave numerically 141, 108 and 100 kg ha^{-1} more cotton equivalent yield than cotton alone. *Sharma et al. (1995*) examined new multiple systems for higher production and profit. They reported that among eight intensive annual cropping systems, relay cropping of maize and potato followed by wheat gave the highest productivity. Irrigation management consists of determining when to irrigate, and how much water to apply at each irrigation during each growth stage of plant and operation of irrigation system. *Satao et al. (1996*) reported that the treatment having one row of soybean (60 cm x 7.5 cm) in between uniform rows of cotton (60 cm x 30 cm) recorded higher LER of 1.55 than either of sole crops (LER 1.0). The benefits like reduced water use, earliness, improved lint quality, fewer pesticide applications and better use of solar radiation were reported in intercropping of soybean in cotton *Weir, (1997). Barhom, (2001*) indicated that, the biological basis for intercropping involves complementarily of resources used by the two crops. His results indicated that, water use efficiency was the highest under soybean/maize intercropping, compared with sole maize and sole soybean. *Abdel-Aal and Zohry (2003*) gained more benefit when intercropped tomato with maize. They found that marketable tomato increased as a result of maize shadow and indicated also saving water and increased land use productivity per unit area. *Vedprakash et al. (2005)* reported that relay intercropping of hybrid tomato and French bean in maize resulted remarkable improvement in land equivalent ratio (1.93 and 1.98) compared to sole maize. *Birabal (2006)* reported that on sandy loam soils of Madhya Pradesh, all the intercropping treatments resulted in significantly higher LER as compared to the sole crop. Intercropping of maize + pigeonpea (2:2) recorded the highest LER (1.59) followed by maize + pigeonpea in 1:1 row ratio (1.56). *Sharma et al. (2006)* reported that tomato intercropped with French bean (grain purpose) gave the maximum yield (15.8 t.ha-1) and was at par with those of tomato and cabbage with vegetable purpose French bean (15.52 and 15.57 t.ha-1, respectively) and sole tomato (15.58 t.ha-1) but significantly higher than the sole crop of major cash crops viz., pea (12.39 t.ha-1), potato (5.54 t.ha-1) and carrot (10.19 t.ha-1). *Dağdele et al (2009)* studied the effects of different drip irrigation regimes on water use efficiencies (WUE). The results demonstrated that irrigation of cotton with drip irrigation method at 75% level (T75) had significant benefits in terms of saved irrigation water and large WUE indicating a definitive advantage of deficit irrigation under limited water supply conditions. In an economic viewpoint, 25.0% saving in irrigation water (T75) resulted in 34.0% reduction in the net income. However, the net income of the T100 treatment is found to be reasonable in areas with no water shortage.

The objectives of the present work to evaluate and investigate irrigation water management for cotton and tomato grown under different intercropping patterns.

MATERIALS AND METHODS

The present field experiments were carried out in the experimental farm of faculty of Agriculture, Kafrelsheikh University, Egypt, during agricultural season 2009/2010. The experimental treatments were arranged in a split-split plot design with three replicates. The experimental site was ploughed three times by using chisel plough. Calcium super phosphate was added during seed-bed preparation at the rate of 100 kg / fed.. The other agricultural practices were done according to the common recommendations. Cotton variety Giza 88 extra long-staple was planted manually during end of April, 2009. The plots were irrigated immediately after sowing then the tomato plants (Hybrid Alissa F1) were planted on the same day. Tables 1 indicates some physical properties for different layers of experimental soil and water characteristics according to the standard procedures described by Black (1965) .

Table (1) : Some physical properties for different layers.

Profile Depth cm	**Mechanical analysis**			**Texture**	**Soil water characteristic**			
	Sand %	**Silt %**	**Clay %**	**class**	**Field Capacity %**	**Wilting Point %**	**Available Water %**	**Bulk Density g / cm^3**
0 - < 15	**15.50**	**25.69**	**58.81**	**Clay**	**40.5**	**25.1**	**21.4**	**1.16**
15 – < 30	**22.53**	**26.16**	**51.31**	**Clay**	**39.9**	**21.5**	**18.4**	**1.20**
30 – < 45	**18.90**	**29.47**	**51.63**	**Clay**	**38.5**	**20.8**	**17.7**	**1.25**
45 - 60	**20.62**	**28.67**	**50.71**	**Clay**	**36.4**	**19.6**	**16.8**	**1.30**
Mean	**19.39**	**27.50**	**53.11**	**Clay**	**38.83**	**21.8**	**18.6**	**1.23**

The present study was included the following :-

A) Irrigation systems (main – plots) :

Three irrigation systems were used in this work :

1) Traditional furrow irrigation. It used as a control treatment .
2) Furrow irrigation using perforated tubes : The perforated tubes system consisted of 2 inch diameter made from PVC. These perforated pipes were drilled with a 22 mm drill at 1.2 m distance apart to use for every ridges . These tubes were connected together with their couplers . The end of each tube was equipped with a plug .
3) Drip irrigation: It consisted of PVC pipes (50 mm inside diameter) as a main line; one inch of PVC pipes (25 mm inside diameter) as a sub main line and 16 mm inside diameter of PE pipes as a lateral line. Drippers (GR) were put on lateral lines every 25 cm with 4 l/h flow rate.

The network of irrigation system included centrifugal pump with 5 hp (3.68 kw) gasoline engine its discharge 900 l/h; screen filter 250 mesh; several valves to control pressure head and water flow and pressure gauges.

B) Ridges length (sub-plots):

Three different of ridges lengths were used 15; 20 and 25 m .

C) Intercropping patterns (sub sub – plots) :

The experiment included 5 treatments which were the combination of intercrop components and 2 pure stands treatments of both species. The five treatments were:

T_1: Intercropping tomatoes with cotton by planting cotton on ridges 1.2 m wide in hills spaced 25 cm apart on one side of the ridge and planting tomatoes on the other side of the same ridge in hills 50 cm apart, i.e. growing 28000 cotton plants + 7000 tomato plants/fed. (50 % cotton + 100 % tomatoes). as shown in Fig. (1).

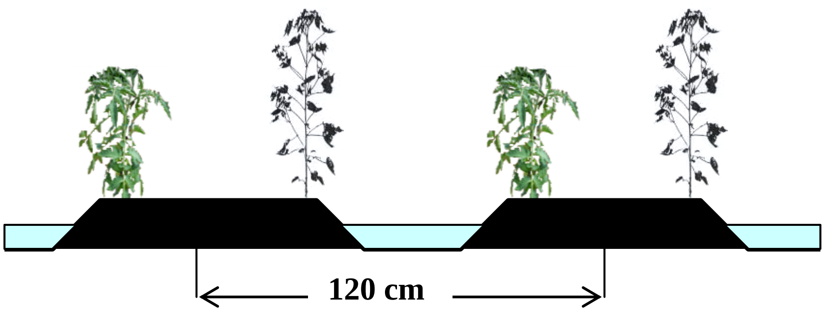


Fig. (1): Schematic diagram of intercropping patterns, cotton and tomato.

T_2: Planting cotton as pure stand on the two sides of the ridges in hills 25 cm apart. Thinning was carried out and two plants were left per hill at a density of 56000 plants/fed. (100% cotton) as shown in Fig. (2).

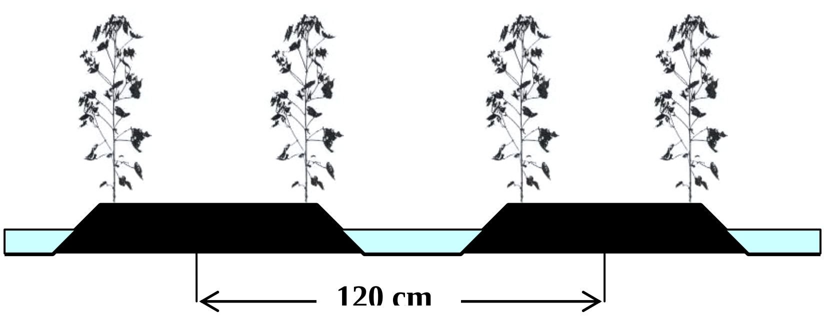


Fig. (2): Schematic diagram of intercropping patterns, pure cotton.

T_3: Planting tomatoes as pure stand on the one side of the ridges in hills spaced 50 cm apart at a density of 7000 plants/fed. (100% tomato) as shown in Fig. (3).

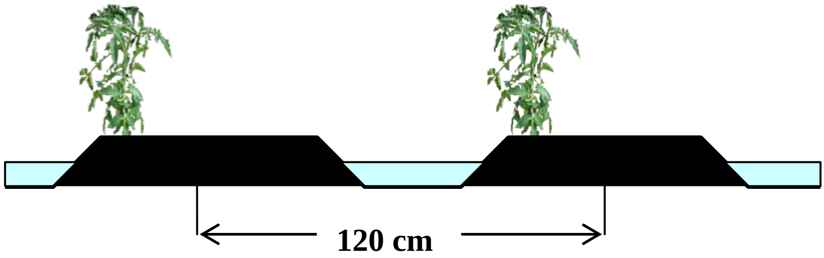


Fig. (3) : Schematic diagram of intercropping patterns, pure tomato.

T_4: Intercropping tomatoes with cotton by planting cotton on the two sides of the ridges in hills 25 cm apart and planting tomato plants in the middle of the same ridges in hills spaced 50 cm apart, i.e. growing 56000 cotton plants + 7000 tomato plants/fed. (100% cotton + 100 % tomatoes). as shown in Fig. (4).

T_5: Intercropping tomatoes with cotton by planting cotton and tomatoes together on the two sides of the same ridge (alternative) in hills spaced 50 cm apart for both cotton and tomatoes, i.e. growing 14000 cotton plants + 7000 tomato plants/fed. (25 % cotton + 100 % tomatoes). as shown in Fig. (5).

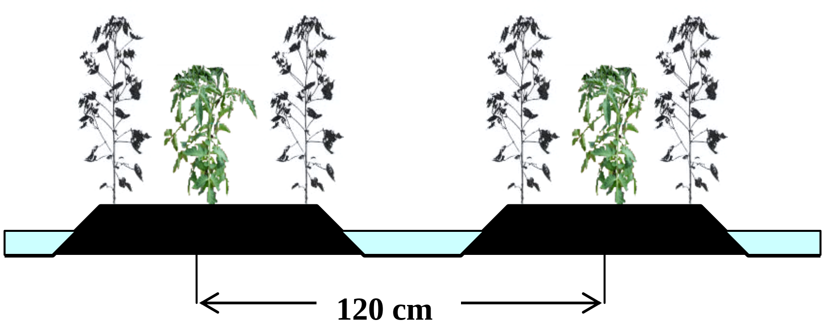


Fig. (4) : Schematic diagram of intercropping patterns, cotton – tomato – cotton.

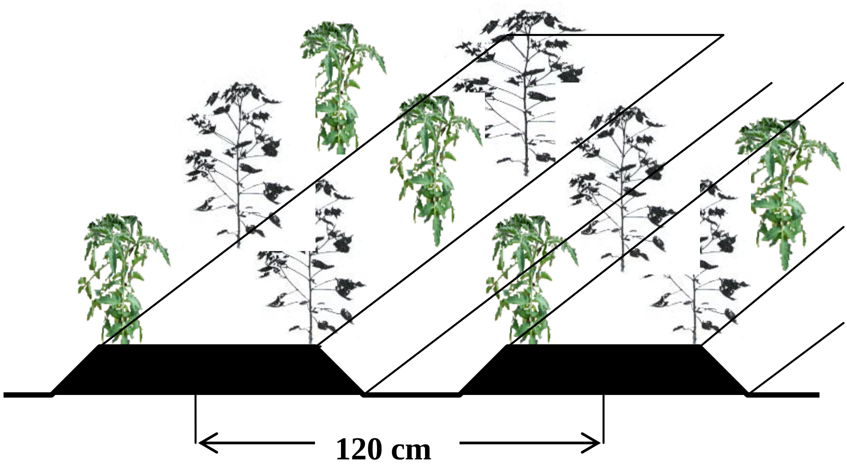


Fig. (5) : Schematic diagram of intercropping patterns, cotton and tomato (alternative).

Estimated characters:

The yield of two inner ridges was determined for each crop and a sample of five plants were taken at random from each crop to estimate the following characters :

Cotton : seed cotton yield kentar/fed.

Tomato : tomato yield Mg/fed.

Land equivalent ratio (LER)

Intercropping advantages were evaluated by calculating the land equivalent ratio; (*Willey, 1985*) :

LER = amount of monoculture land needed to produce same yield as intercrop. LER was determined according to the following formula :

$$LER = \frac{Y_{ab}}{Y_{aa}} + \frac{Y_{ba}}{Y_{bb}} \quad \text{...(1)}$$

Where :

Y_{ab} = seed cotton yield in mixtures.

Y_{ba} = tomato yield in mixtures

Y_{aa} = seed cotton yield in pure stand.

Y_{bb} = tomato yield in pure stand.

Efficiencies:

Water Use Efficiency (WUE) :

Water use efficiency was determined according to the following equation according to *Hansen et al. (1980)* :

$$\text{Water Use Efficiency} = \frac{\text{Seed cotton yield (kg/fed.)}}{\text{Applied water (} m^3 \text{/fed.)}}; \quad kg/m^3 \text{ ....(2)}$$

Water distribution efficiency (Ed) :

It was calculated according to James (1988) as follow:

$$E_d = \left(1 - \frac{d}{y}\right) * 100 \text{ ....(3)}$$

Where :

d =Average of soil water depth stored along the furrow during the irrigation. it was calculated from three points along the furrow run , cm and

y = Average numerical deviation from d . cm .

Water application efficiency (Ea) :

Application efficiency is the ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation applied water . it was calculated for the 60 cm soil depth according to *Michael (1978)* and *James (1988*) as follow :

$$E_a = \frac{W_s}{W_f} * 100 \text{ ....(4)}$$

Where *:*

E_a = Water application efficiency, %

W_s = Amount of water stored in the root zone, m^3 and

W_f = Amount of water added to each plot, m^3 .

The studied characters included: Seed cotton yield (kantar/feddan) (S.C.Y.) boll mass (B.M), lint percentage (L.P), seed index (S.I), span length (S.L) at 2.5% and 50%, hair weight (H.W), micronaire reading (Mic.) and yarn strength (Y.St).

Amount of irrigation water requirement :

Water requirement for cotton and tomato crops was calculated as follow :

Crop water requirements,(ET_c):

It was calculated from the following equation (*Ismail, 2002* in arabic):-

$$\mathbf{ET_c = K_c*K_r*ET_o} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \mathbf{(5)}$$

Where :-

ET_c = Crop water requirements, mm/day

K_c = crop factor (1.0, 1.15 and 0.75 for the initial stage; mid-season stage and late stage, respectively according to (*Ismail, 2002* in arabic).

K_r = reduction factor (it is depending on distance between laterals, emitter discharge and soil texture (*Sakla, 1991* in arabic). Its value equal one in the present study).

ET_o= reference evapotranspiration, mm/day, which was calculated depending on climatic data. The climatic data was collected from Sakha Weather Station for the period of May to September, 2009

Applied irrigation water,(AIW):

For each irrigation time, the amount of the applied irrigation water was calculated according to the following equation:

$$AIW_m = \frac{\sum_{i=1}^{i=n} ET_{crop}}{E_a(1-Lr)} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ \mathbf{(6)}$$

Where:-

m = irrigation number;

n = soil layer number;

Ea = designed water application efficiency, which was 0.85 in the present study according to (*Ismail, 2002* in arabic), and

Lr = leaching requirement, which was 10% from ET_c in the present study.

Seasonal applied irrigation water was calculated from the sum of AIW_m

A crop coefficient values for cotton and tomato crops was used according to the different growth stages of crop according to FAO (1984). Values of Kc and water consumptive use for different growth stages are presented in Tables (2) and (3) .

Evapotranspiration of cotton crop was calculated using CROPWAT COMPUTER PROGRAM depending on the average of climatic data according to Penman-Monteith method. Climatic data were obtained from Sakha Weather Station for the period of May to September, 2009 and summarized in Table (4). Soil samples were taken for estimating the actual water consumptive use from four depths (0 – <15, 15 – <30, 30 – <45 and 45 – 60 cm) after 5 hours from irrigation and before the next irrigation throughout each growth stage.

Table (2) : Calculated water consumptive use for cotton crop.

Growth stages	ET_o (mm/day)	K_c	ET_{crop} (mm/day)	ET_{crop} (mm/stage)
initial				
21/5/2009-31/5/2009	4.71	0.8	3.77	37.7
1/6/2009-11/6/2009	5.39	0.8	4.31	43.1
Flowering & squaring				
12/6/2009-30/6/2009	5.39	1.15	6.20	111.6
1/7/2009-16/7/2009	5.29	1.15	6.08	91.27
17/7/2009-23/7/2009	5.29	1.15	6.08	36.48
24/7/2009-31/7/2009	5.29	1.15	6.08	42.56
1/8/2009-13/8/2009	4.39	1.15	5.05	60.6
Harvesting				
14/8/2009-13/8/2009	4.39	0.7	3.07	52.19
1/9/2009-10/9/2009	4.06	0.7	2.84	25.56
Total ET_{crop} (mm/season)				501.06

Table (3) : Calculated water consumptive use for tomato crop

Growth stages	ET_o (mm/day)	K_c	ET_{crop} (mm/day)	ET_{crop} (mm/stage)
initial				
21/5/2009-31/5/2009	4.71	0.7	3.30	33.00
1/6/2009-11/6/2009	5.39	0.7	3.70	37.70
Flowering & fruiting				
12/6/2009-30/6/2009	5.39	1.1	5.93	106.74
1/7/2009-16/7/2009	5.29	1.1	5.82	87.30
17/7/2009-23/7/2009	5.29	0.8	4.23	25.38
Harvesting				
24/7/2009-31/7/2009	5.29	0.8	4.23	29.61
1/8/2009-13/8/2009	4.39	0.8	3.51	42.12
14/8/2009-20/8/2009	4.39	0.8	3.51	24.57
Total ET_{crop} (mm/season)				386.42

Table (4) : Climatic data for the period of May to September, 2009.

Reference Evapotranspiration ET_o according to Penman-Monteith							
Country : Egypt Altitude : 20 meter				Meteo Station : Sakha Coordinates : 30.00 N.L 30.00 E.L			
Month	**Temperature**		**Relative Humidit**	**Solar Radiation**	**Wind speed**	**Sunshine Hours**	**ET_o**
	Max K (°C)	**Min K (°C)**	**%**	**Mj/m²/day**	**Km/ day**	**h/day**	**mm/day**
May	**304.1 (31.1)**	**287.1 (14.1)**	**54.22**	**24.1**	**129.0**	**9.57**	**4.71**
June	**305 (32.0)**	**290 (17.0)**	**57.55**	**26.15**	**129.0**	**10.75**	**5.39**
July	**307 (34.0)**	**292 (19.0)**	**63.15**	**25.52**	**112.32**	**10.49**	**5.29**
August	**306.5 (33.5)**	**291.3 (18.3)**	**67.24**	**24.23**	**112.32**	**10.24**	**4.39**
September	**305.9 (32.9)**	**290.3 (17.3)**	**71.29**	**21.21**	**95.04**	**9.46**	**4.06**
Mean	**305.7 (32.7)**	**290.1 (17.1)**	**62.69**	**24.24**	**115.54**	**13.7**	**4.77**

Measurements:

Irrigation water flow rate:

Volumetric method was done to measure flow rate for furrow and perforated tubes irrigation methods. The time required to fill a known volume container (20 liters) was measured. Also, the time required to reach the water to the end of the furrow was calculated in each treatment.

Soil moisture content:

Moisture distribution in root zone under emitter along the lateral line in drip irrigation system was determined at different distances from emitter (under the emitter, 6.25, and 12.5 cm along the lateral line at different depth, (0 – <15, 15 – <30, 30 – <45 and 45 – 60 cm). In case of perforated tubes and furrow irrigation systems moisture content was determined at three locations (the beginning , the middle and the end of the furrow) at the same previous soil depth. Samples were immediately transferred in tightly closed cans of aluminum to laboratory to be weighted and dried in electric oven at 105 °C for 24 hours.

Crop Productivity:

The yield of each treatment picked and the average yield per plant was multiplied by number of plants per feddan .

RESULTS AND DISCUSSIONS

Seed cotton yield:

Fig. (6) shows the effect of ridges length and intercropping systems on seed cotton yield under different irrigation systems. The results demonstrated that drip irrigation system increased seed cotton yield by about of 30.4% and 27.78% compared with furrow irrigation and the perforated pipes respectively, where the average value of seed cotton yield for drip irrigation system was 6.48 kentar/feddan.

Increasing the length of ridges tended to decrease the seed cotton yield for furrow irrigation the highest value of seed cotton yield was obtained with 15m length of ridges. But the seed cotton yield increased by increasing the length of ridges under perforated pipes and drip irrigation system the highest value of seed cotton yield was obtained with 25m length of ridges. The highest seed cotton yield value was 10.76 kentar/feddan that obtained using drip irrigation system, 25 m ridges length and intercropping tomatoes with cotton by planting cotton on the two sides of the ridges and planting tomato in the middle of the same ridges. The lowest seed cotton yield value was 1.59 kentar/feddan that obtained using furrow irrigation system, 25 m ridges length and intercropping tomatoes with cotton by planting cotton and tomato planted together on two sides of the same ridge (alternative).

The statistical analysis showed that the irrigation system, length of ridge and the intercropping systems had a highly significant effect on seed cotton yield, while their interaction had no significant on seed cotton yield.

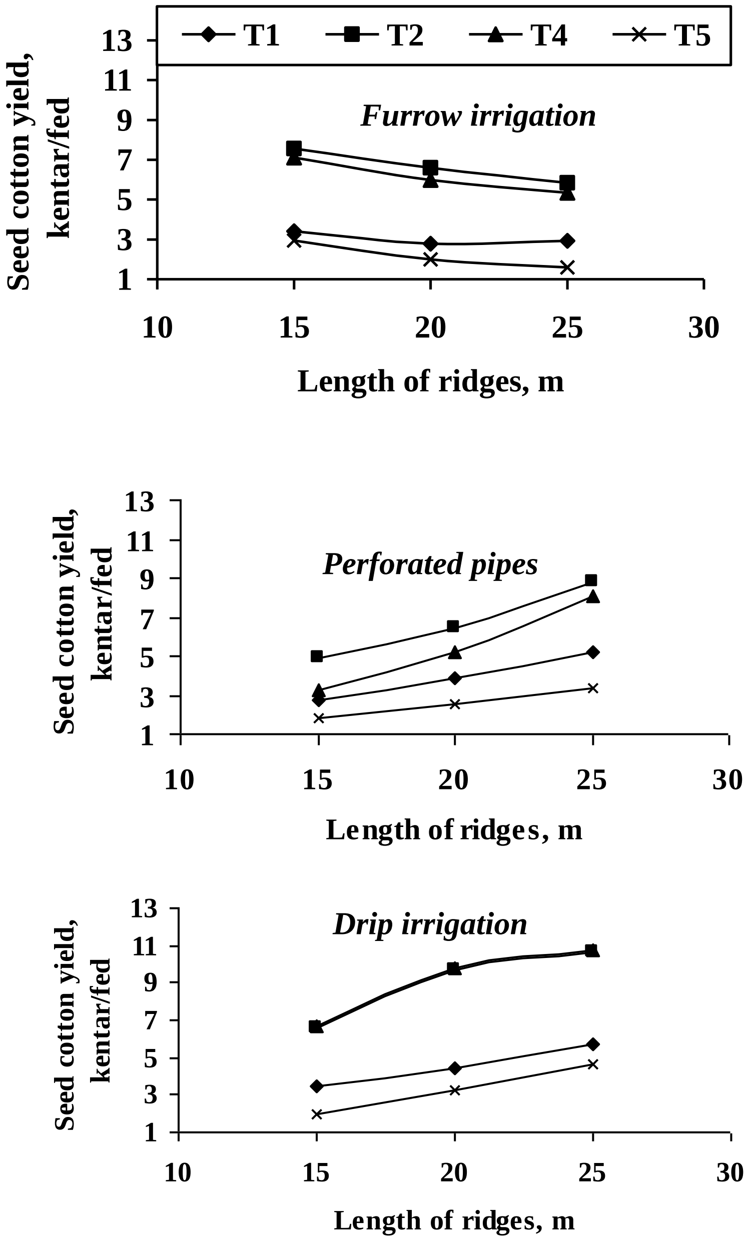


Fig. 6 : Effect of ridges length and intercropping patterns on seed cotton yield under different irrigation systems.

Tomato yield, (Mg) :

Fig. (7) shows the tomato yield at the end of the growing season. The results demonstrate that drip irrigation system increased tomato yield by 32.15% and 7.22% compared with furrow irrigation and the perforated pipes respectively, where the average value of tomato yield for drip irrigation system was 15.167 Mg/fed. The results indicated that increasing length of ridges tended to decrease the tomato yield for furrow irrigation but increasing length of ridges tended to increase tomato yield under perforated pipes and drip irrigation system. Drip irrigation system gave the highest value of tomato yield which was 22.898 Mg/fed using 25 m ridges length and tomato crop planted alone on one side of ridges(pure tomato). The lowest tomato yield value was 4.846 Mg/fed that obtained using furrow irrigation system with 25 m ridges length and tomato planted together on two sides of the same ridge (alternative).

Water application efficiency, (WAE) :

Using perforated pipes and drip irrigation had developed the water application efficiency compared with traditional furrow irrigation because they used less irrigation water, decrease loss irrigation water in root zone and gave a highest value of production as shown in Figs (8 and 9). The water application efficiency for the perforated pipes and drip irrigation system were increased by 45.7% and 79.2% compared with furrow irrigation, where the average value of water application efficiency for traditional furrow irrigation was 51.07% . The highest value of water application efficiency was 95.1% using drip irrigation with 25 m length of ridges and cotton plants were grown on the two sides of the ridges and tomato plants were grown in the middle of the same ridges. The worst water application efficiency value was 39.87% using traditional furrow irrigation with 25 m ridges length and cotton and tomato crops were grown together two sides of the same ridge (alternative). Increasing ridges length tended to decrease the water application efficiency for traditional furrow irrigation. But the water application efficiency increased by increasing the ridges length under perforated pipes and drip irrigation system.

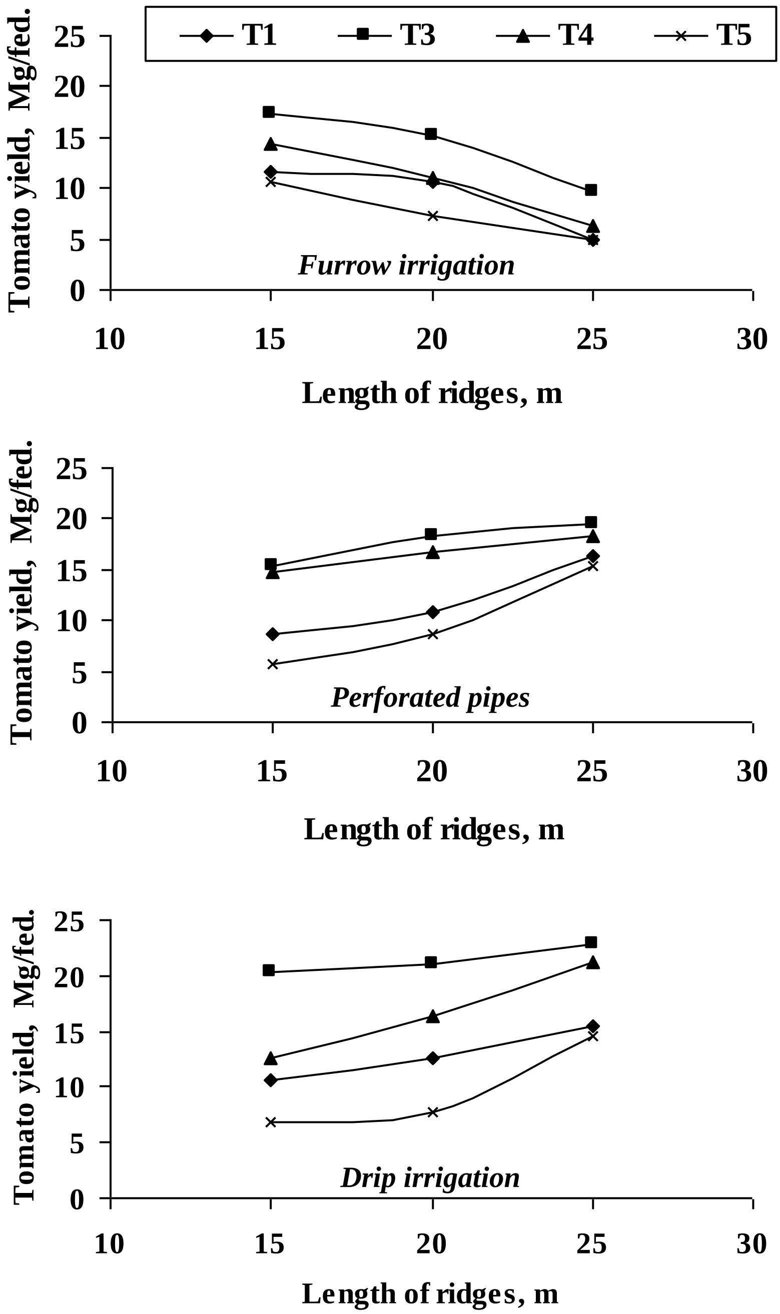


Fig. 7 : Effect of ridges length and intercropping patterns on tomato yield under different irrigation systems .

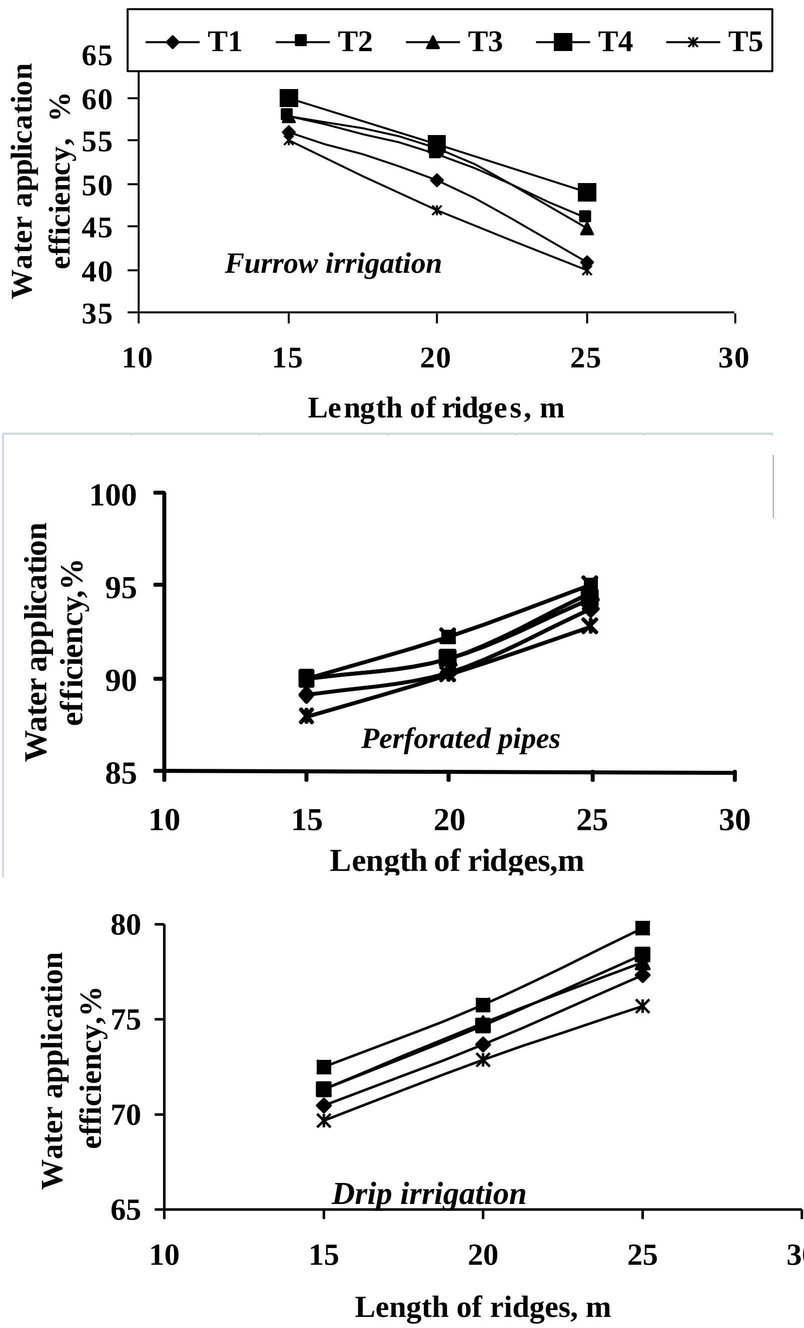


Fig. 8 : Effect of ridges length and intercropping patterns on water application efficiency under different irrigation systems .

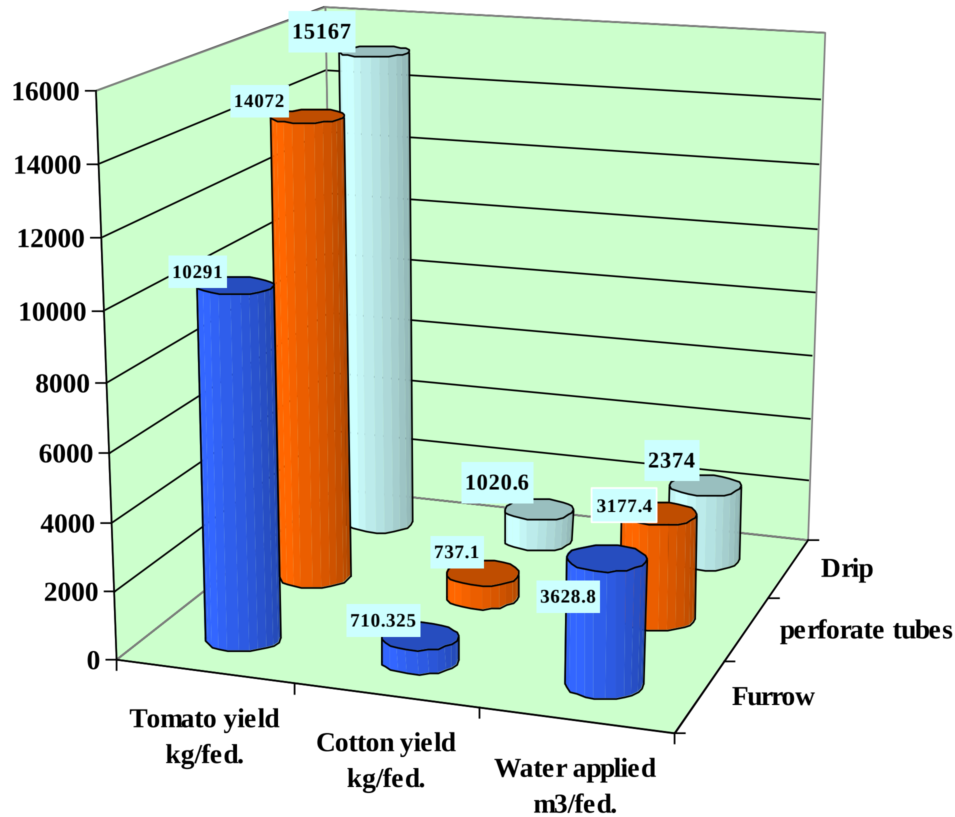


Fig. 9: Tomato yield; cotton yield and amount of irrigation water applied under different irrigation systems .

The statistical analysis showed that the irrigation systems, ridges length, intercropping system and their interaction had a highly significant effect on water application efficiency. This may be due to the least percentage of water loss occurred under trickle irrigation system, less water is lost resulting from direct evaporation and deep percolation. The results from the present study was agreement with that obtained by *El-Marazky 1996* .

Water distribution efficiency, (WDE) :

The perforated tubes pipes were more suitable in these case to improve water distribution in the surface irrigation method .The distribution efficiency describes water distribution along the irrigation furrow. High value of water distribution efficiency means that the different sections of the field received similar application depths, low value imply that some areas of a field receive more than other areas James (1988) .

The results indicated that drip irrigation system had developed water distribution efficiency compared with traditional furrow irrigation and perforated pipes irrigation as shown in Fig. (10). Water distribution efficiency for drip irrigation system was increased by 50.4% and 15.8% compared with traditional furrow irrigation and perforated pipes respectively, where the average value of water distribution efficiency for drip irrigation system was 92.33%. The highest value of water distribution efficiency was 97.3% using drip irrigation with 25 m ridges length and cotton plants were grown on the two sides of the ridges and tomato plants in the middle of the same ridges. The worst water distribution efficiency value was 49.13% using traditional furrow irrigation with 25 m ridges length and cotton and tomato plants were grown together two sides of the same ridge (alternative). Increasing ridges length tended to decrease the water distribution efficiency for traditional furrow irrigation. But the water distribution efficiency increased by increasing ridges length under perforated pipes and drip irrigation system.

The statistical analysis showed that the irrigation systems, ridges length, intercropping system and their interaction had a highly significant effect on water distribution efficiency.

Water use efficiency, kg/m^3 :

Water use efficiency is the ratio of seed cotton yield and tomato yield (kg) to the total amount of applied water. The maximum value of water use efficiency means that less amount of irrigation water and highly yield (*Michael,1978*).

Figure (11) illustrates the effect of ridges length and intercropping systems on water use efficiency under different irrigation systems. The results indicated that drip irrigation system recorded highly crop yield followed by perforated pipes.

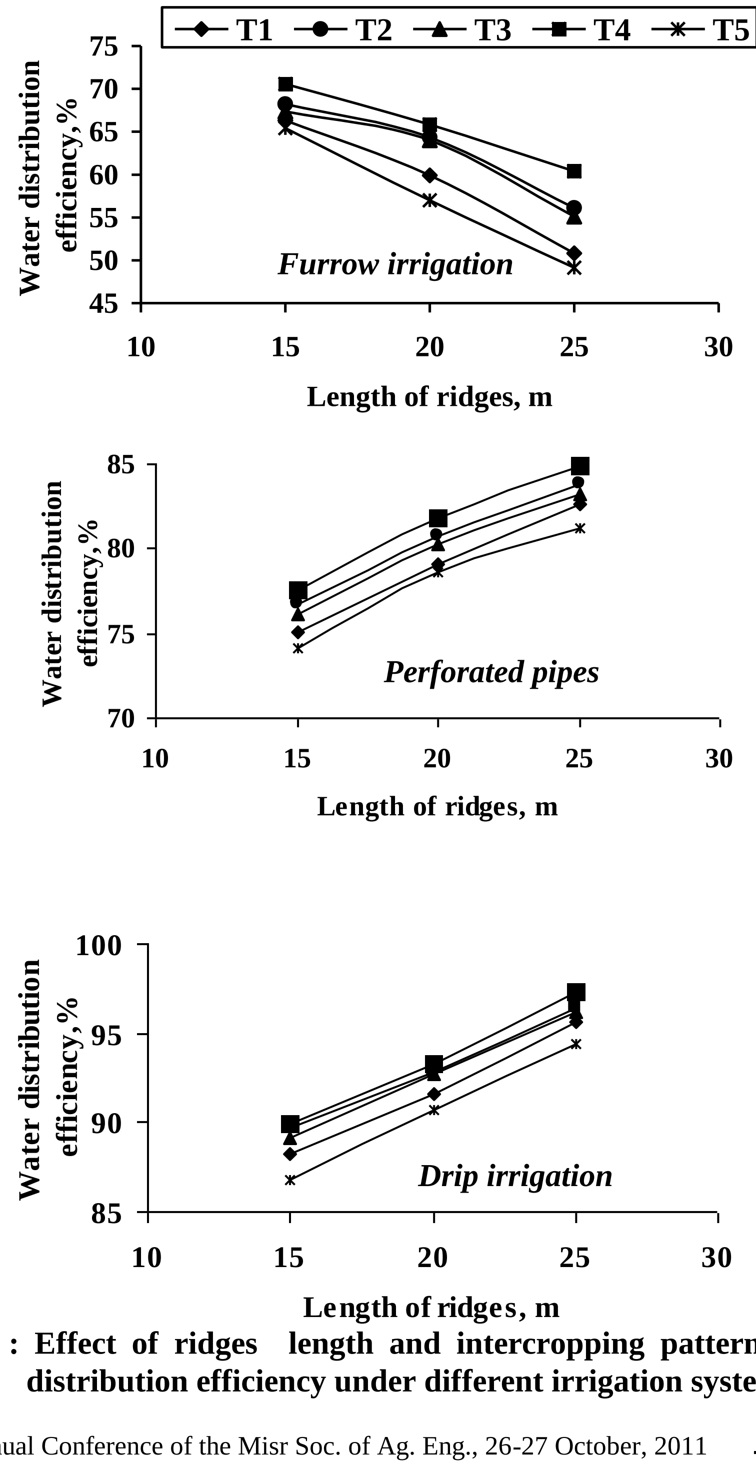
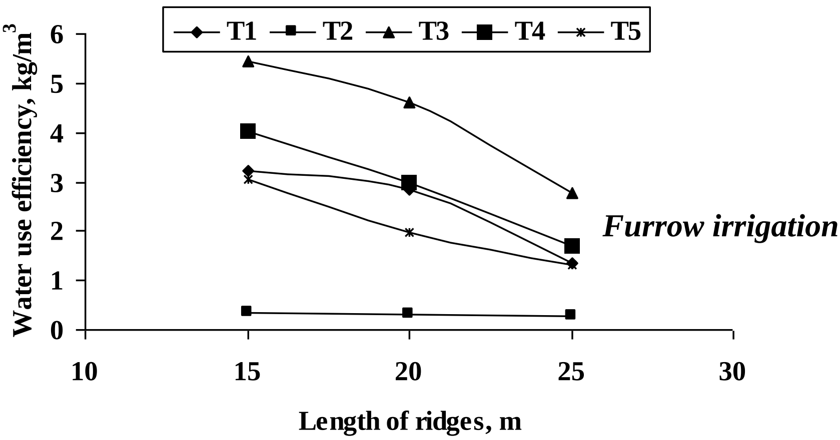
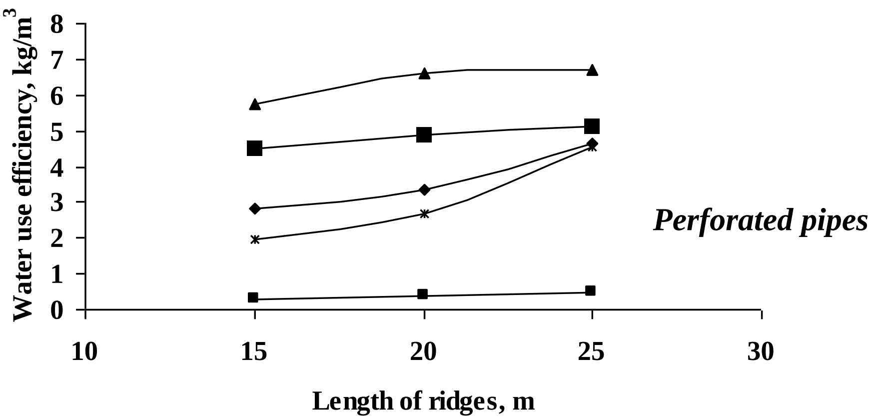


Fig. 10 : Effect of ridges length and intercropping patterns on water distribution efficiency under different irrigation systems .


T1
T2
T3
T4
T5
Water use efficiency, kg/m3
6
5
4
3
2
1
0
10
15
20
25
30
Length of ridges, m
Furrow irrigation


Water use efficiency, kg/m3
8
7
6
5
4
3
2
1
0
10
15
20
25
30
Length of ridges, m
Perforated pipes

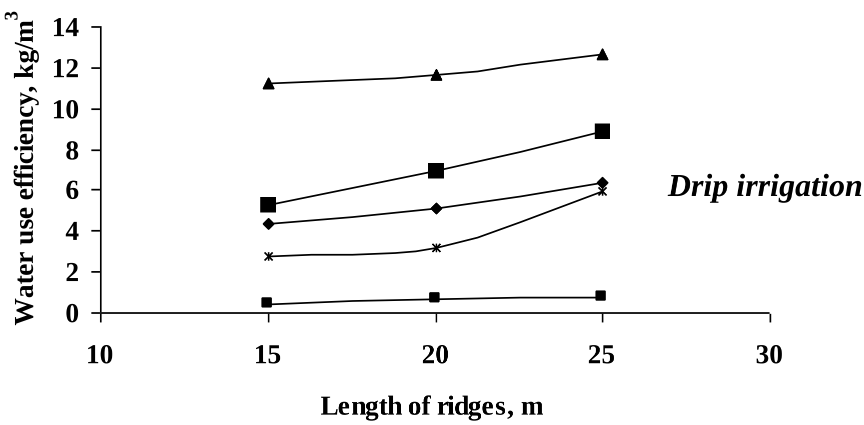

Water use efficiency, kg/m3
14
12
10
8
6
4
2
0
10
15
20
25
30
Length of ridges, m
Drip irrigation

Fig. 11 : Effect of ridges length and intercropping patterns on water use efficiency under different irrigation systems.

Traditional furrow irrigation gave lowest value of water use efficiency, because drip irrigation and perforated pipes used less amount of irrigation water and gave the highest value of crop yield. The results demonstrate that traditional furrow irrigation system decreased the water use efficiency by 29.47% and 53.96% compared with the perforated pipes and drip irrigation system respectively, where the average value of the water use efficiency for drip irrigation system was 5.43 kg/m^3. Increasing ridges length tended to decrease the water use efficiency for traditional furrow irrigation but water use efficiency was increased by increasing ridges length for perforated pipes and drip irrigation. The highest water use efficiency value was 8.89 kg/m^3 obtained by using drip irrigation system with 25 m ridges length and cotton crop was planted on the two sides of the ridges and tomato crop in the middle of the same ridges. The lowest water use efficiency was 1.31 kg/m^3 using traditional furrow irrigation system with 25 m ridges length and cotton and tomato crops were planted together on the two sides of the same ridge (alternative).

The statistical analysis showed that the irrigation systems, ridges length and the intercropping systems had a highly significant effect on water use efficiency, while their interaction had no significant effect on water use efficiency.

Land Equivalent Ratio (LER) :

Data presented in Fig. (12) shows that the perforated pipes recorded highly crop yield followed by drip irrigation system as compared with traditional furrow irrigation. The results demonstrated that Land Equivalent Ratio value was increased by about of 8.33% and 6.06% for perforated pipes compared with traditional furrow and drip irrigation system respectively, where the average value of the Land Equivalent Ratio for perforated pipe was 1.32. The obtained data indicated that increasing ridges length tended to decrease the Land Equivalent Ratio for traditional furrow irrigation but its value was increased by increasing ridges length under perforated pipes and drip irrigation system. The highest Land Equivalent Ratio value was 1.96 that obtained by using drip irrigation system with 25 m ridges length

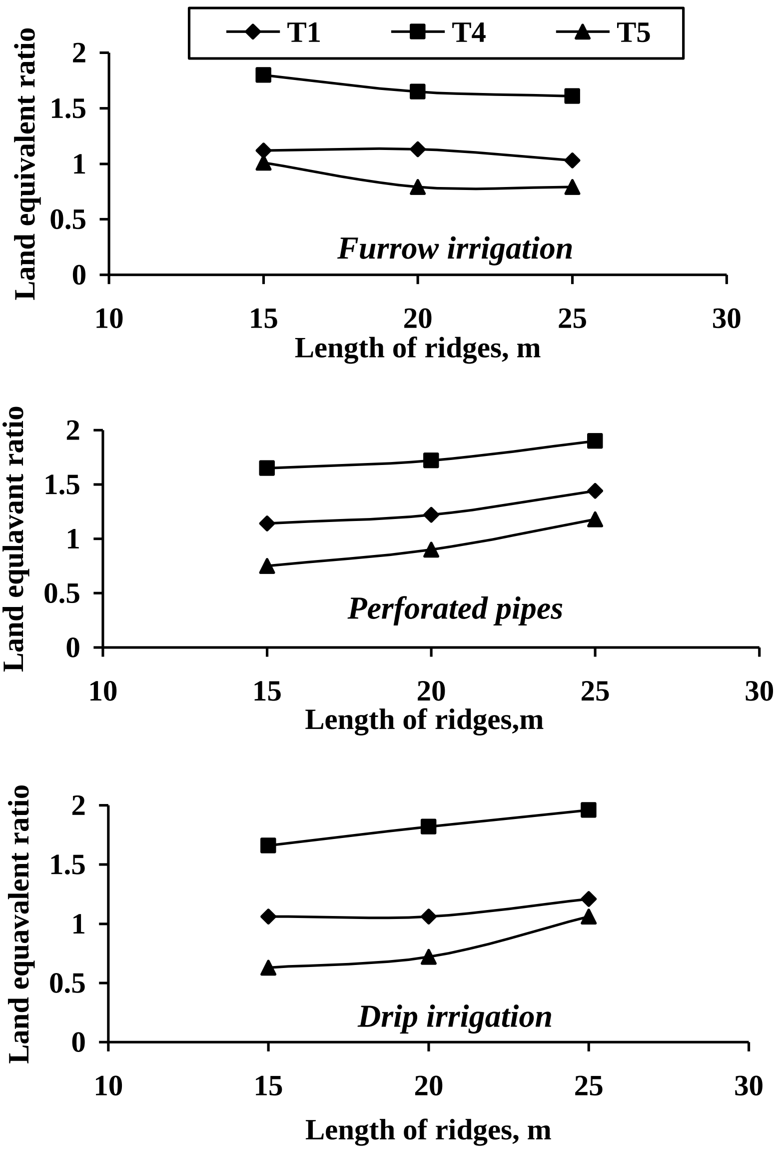


Fig. 12 : Effect of ridges length and intercropping patterns on land equivalent ratio yield under different irrigation systems.

and cotton crop was planted on the two sides of the ridges and tomato crop the middle of the same ridges. The lowest Land Equivalent Ratio was 0.63 that obtained with drip irrigation system using 15 m ridges length and cotton and tomato crops were planted together on the two sides of the same ridge (alternative).

It could be concluded that intercropping cotton and tomato produced yield advantage and proved promising. The highest LER value was obtained under intercropping system 100% : 100%.

CONCLUSION

Increasing crops productivity and saving irrigation water are two interrelated issues raising a lot of concern these days in Egypt. Intercropping pattern is generally more productive than reference sole crop. Five cotton/tomato intercropping patterns were tested for its productivity and three irrigation treatments tested for its water use efficiency. Results showed that intercropping at 2:1 cotton/tomato pattern is the most productive system, compared with the other four patterns. Furthermore, the highest values of water use efficiency and land equivalent ratio were obtained under drip irrigation system; 25 m ridges length and cotton crop was planted on the two sides of the ridges and tomato crop the middle of the same ridges..

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<u>**الملخص العربى**</u>

تأثير نظم الري على إنتاجية محصولي القطن والطماطم التي تزرع تحت أنماطِ تحميل مختلفة

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أجريت التجارب الحقلية بالمزرعة البحثية بكلية الزراعة جامعة كفر الشيخ في موسم ٢٠٠٩ / ٢٠١٠ وكان الهدف من البحث هو دراسة وتقييم إدارة مياه الري باستخدام نظم ري مختلفة لتحسين كفاءة استخدام مياه الري وذلك بزيادة إنتاجية محصولي القطن والطماطم عند زراعتهما مع أنماط مختلفة من التحميل .واشتملت الدراسة على العوامل التالية:

١- نظم الري : اشتملت الدراسة على ثلاث نظم ري مختلفة هي : الري بالخطوط (التقليدي) – الري باستخدام الأنابيب المثقبة – الري بالتنقيط.
٢- طول الخط (المصطبة) : استخدم ثلاثة أطوال مختلفة هي : ١٥ - ٢٠ - ٢٥ متر وكان عرض الخط ثابت ويساوي ١.٢ متر.
٣- نمط التحميل : حيث استخدم في الدراسة خمسة أنماط مختلفة للتحميل هي : زراعة القطن على الريشتين بدون تحميل طماطم – زراعة ريشة قطن و الريشة الأخرى طماطم – زراعة الريشتين قطن وفي المنتصف زراعة طماطم – زراعة جوره قطن وجوره طماطم بالتبادل على نفس الريشة – زراعة ريشة طماطم و ترك الريشة الأخرى بدون زراعة أو تحميل.

وكانت أهم النتائج المتحصل عليها هي كالأتي : -

- استخدام الري بالتنقيط أدى إلى زيادة محصول القطن بحوالي ٣٠.٤ % و ٢٧.٧٨ % مقارنة بالري بالخطوط التقليدي أو باستخدام الأنابيب المثقبة في الري بالخطوط حيث كان متوسط الإنتاجية للقطن باستخدام الري بالتنقيط ٦.٤٨ قنطار/فدان .
- أوضحت النتائج أن زيادة طول الخط أدى إلى انخفاض الإنتاجية للمحصولين عند استخدام الري بالخطوط التقليدي ولكن عند استخدام الأنابيب المثقبة أو الري بالتنقيط فانه بزيادة طول الخط أدى إلى زيادة الإنتاجية في المحصولين.

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- استخدام الأنابيب المثقبة كوسيلة لتطوير الري بالخطوط وكذا استخدام الري بالتنقيط وضحت النتائج إن استخدام الطريقتين في الري يؤدي إلى تحسن كفاءة إضافة مياه الري مما يعمل على زيادة كمية المياه المخزنة في مجال الجذور و تقليل الفاقد (توفير مياه الري) مما ينعكس على زيادة الإنتاجية.

- أقصى كفاءة لانتظام توزيع مياه الري كانت ٩٧.٣ % تم الحصول عليها باستخدام الري بالتنقيط وطول خط ٢٥ متر وذلك في نمط تحميل هو زراعة القطن على الريشتين وزراعة الطماطم في منتصف المصطبة.

- أظهرت النتائج أن استخدام الري بالخطوط التقليدي يعطي اقل قيمة من كفاءة استخدام مياه الري وذلك لان استخدام الأنابيب المثقبة و الري بالتنقيط أدى إلى تقليل كمية المياه المضافة.

- وضحت النتائج أن نسبة الأرض المكافئة (LER) زادت بحوالي ٨.٣٣ % و ٦.٠٦ % عند استخدام الأنابيب المثقبة كوسيلة لتطوير الري بالخطوط مقارنة بالري بالخطوط التقليدية و الري بالتنقيط حيث كانت متوسط نسبة الأرض المكافئة باستخدام الأنابيب المثقبة ١.٣٢.