NEW DESIGN FOR DRIP IRRIGATION SYSTEM TO MAXIMIZE WATER AND FERTILIZERS USE EFFICIENCY

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ABSTRACT

Maximizing irrigation water use efficiency is a common concept should be used in Egypt due to limited water resources. The experiments were carried out during the two growing seasons 2012 and 2013, at the Research and Production Station, National Research Centre, El-Nubaria Province, El-Behira Governorate, Egypt to evaluate the performance of new design for drip irrigation system compared with two traditional designs to maximize water and fertilizers use efficiency under desert environment conditions. Designs of drip irrigation systems were (1) Design1: drip irrigation system (control), (2) Design2: drip irrigation system with PRD technique (partial root drying; one emitter will irrigate one part of the root system and emitters of other lateral will irrigate other half of root system) with the same direction for main lines and laterals and (3) New design: drip irrigation system with PRD technique with opposite direction for main lines and laterals. The following parameters were studied to evaluate the effect of different irrigation methods on (1) emission uniformity, (2) soil moisture distribution (3) application efficiency (4) Growth characteristics of maize plant (5) yield of maize (6) irrigation water use efficiency of maize "IWUE $_{maize}$". (7) economical evaluation. Statistical analysis indicated that the maximum values of growth, yield, IWUE $_{maize}$ and total income were detected under new design of drip irrigation system with PRD technique with opposite direction for manifolds lines and lateralswhere these values under design 1 were 2.27 Grain Yield (ton/fed.) , 1.25 IWUE maize (Kg_{grain}/m^3_{water}) but it improved under new design 3.97 Grain Yield (ton/fed.) , 2.19 IWUE maize (Kg_{grain}/m^3_{water}).

Keywords: PRD technique, Drip irrigation, Irrigation Water use efficiency, maize cultivation

1 INTRODUCTION

Maximizing irrigation water use efficiency is a common concept used by irrigation project managers; also, the visual quality of the crop yield is the primary criteria on used to assess irrigation systems effectiveness. In recent years, however, growing competition for scarce water resources has led to applying modified techniques for maximizing water use efficiency and improving crop yields and quality, particularly in arid and semi arid regions. Drip irrigation is highly efficient because only the immediate root zone of each plant is wetted (Grabow et. al. 2004). Water supplies are also under pressure from agricultural users and saving of water resources and increasing agricultural productivity per unit of water ("more crop per drop") are becoming of strategic importance for many countries. Nowadays the great emphasis is placed in the area of crop physiology and crop management for dry conditions physiology with the aim to make plants more efficient in water use or to increase in crop water use efficiency (WUE). Many crops have high water requirements and supplemental irrigation is necessary for successful production. The predictions are that the demand for irrigation will increase considerably in years to come to alleviate the consequences of climate change and more frequent and severe droughts, which are expected to become the main limiting factor in agricultural production. (www.cropwat.agrif.bg.ac.rs). With increasing human demand for food more efforts had been done to expand crop cultivation area in sandy soils based on new technologies as new irrigation methods (Girgis 2006). Partial root drying (PRD) the half of the root zone is irrigated, the other half is allowed to dry out. The treatment is then reversed, allowing the previously well-watered side of the root system to dry down while fully irrigated previously dry side. The frequency of the switch is determined according to soil type, genotypes or other factors such as rainfall and temperature. The principle behind PRD is that irrigating part of the root system keeps the leaves hydrated, although exposing the remaining part of the roots to soil drying triggers synthesis and transport of chemical signals from roots to transport of chemical signals from roots to the shoot where they reduce stomata conductance and shoot growth. The PRD irrigation must be switched regularly from switched regularly from one side of the root to the other to keep roots in dry soil alive and fully functional and sustain the supply of root. The time of switching required could present significant difficulty in operating PRD irrigation. Usually in the most applied PRD systems the switching is based on soil water applied PRD systems the switching is based on soil water depletion measured by specific apparatus. (www.cropwat.agrif.bg.ac.rs). The specific objective is study the comparison between three methods to irrigate maize crop to maximize water and fertilizers use efficiency under desert environment conditions in Egypt.

2 MATERIALS AND METHODS

2.1. Description of Study Site

2.1.1. Location and climate of experimental site

Field experiments were conducted during two maize planting seasons from 10 May to 20 September 2012–2013 at the experimental farm of National Research Center, El-Nubaria, Egypt (latitude 30^{o} $30^{\backslash}$ $1.4^{\backslash\backslash}$ N, and longitude 30^{o} $19^{\backslash}$ $10.9^{\backslash\backslash}$ E, and mean altitude 21 m above the sea level) as shown in fig. (1). The experimental area has an arid climate with cool winters and hot dry summers prevailing in the experimental area. The data of maximum and minimum temperature, relative humidity, and wind speed were obtained from "Local Weather Station inside El-Nubaria Farm" .

Figure1. Location of the experimental field in EL-NUBARIA Region, Egypt

2.1.2. Irrigation system

Irrigation system components consisted of control head, pumping and filtration unit. It consists of centrifugal pump with 45 m^3/h discharge and it was driven by electrical engine and screen filter and back flow prevention device, pressure regulator, pressure gauges, flow-meter, control valves. Main line was of PVC pipes with 110 mm in diameter (OD) to convey the water from the source to the main control points in the field. Sub-main lines were of PVC pipes with 75 mm diameter (OD) was connected to the main line. Manifold lines: PE pipes was of 63 mm in diameter (OD) were connected to the sub main line through control valve 2`` and discharge gauge. Emitters, built in laterals tubes of PE with 16 mm diameter (OD) and 50 m in long (emitter discharge was 4 lph at 1.0 bar operating pressure and 30 cm spacing between emitters.

2.1.3. Some physical and chemical properties of soil and irrigation water

Some Properties of soil and irrigation water for experimental site are presented in (Tables 2, 3 and 4).

Table 2. Some chemical and mechanical analyses of soil study site.

Depth	Chemical analysis				Chemical analysis			Texture
	OM (%)	pH (1:2.5)	EC (dSm^{-1})	$CaCO_3$ %	Coarse sand	Fine sand	Silt+ clay	
0-20	0.65	8.7	0.35	7.02	47.76	49.75	2.49	Sandy
20-40	0.40	8.8	0.32	2.34	56.72	39.56	3.72	
40-60	0.25	9.3	0.44	4.68	36.76	59.40	3.84	

OM= organic matter. pH= power of hydrogen EC= Electrical Conductivity

Table 3. Soil water characteristics.

Depth	SP (%)	F.C (%)	W.P (%)	A.W (%)	Hydraulic conductivity(cm/hr)
0-20	21.0	10.1	4.7	5.4	22.5
20-40	19.0	13.5	5.6	7.9	19.0
40-60	22.0	12.5	4.6	7.9	21.0

S.P. = saturation point, F.C. = field capacity, W.P. = wilting point and A.W. = available water.

Table 4. Some chemical characteristics of irrigation water in the open channel at farm study site.

pH	EC (dSm^{-1})	Cations and anions (meq/L)								SAR %
		Cations				Anions				
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}	
7.35	0.41	1	0.5	2.4	0.2	--	0.1	2.7	1.3	2.8

pH= power of hydrogen EC= Electrical Conductivity SAR= Sodium Adsorption Ratio

2.2. Crop Requirements

2.2.1. Irrigation requirements: Seasonal irrigation requirements were estimated. The seasonal irrigation water applied was found to be 1808 m^3/fed./season (where hectare = 2.4 fed.)for drip irrigation system by following equation and as tabulated in table (5):

$$IRg = (ET_O \times Kc \times Kr) / Ei - R + LR \quad (1)$$

Table 5. Estimation of total irrigation requirements for maize per season in EL-NUBARYIA province (average of two seasons, 2012 – 2013)

No.	Items	Growth stages of maize			
		Init.	Dev.	Mid	Late
		12 May – 31May	1 June – 5 July	6 July – 14 Aug.	15 Aug. – 10Sep.
1	ETo (mm/day)	6.3	6.3	5.6	5.0
2	Crop coefficient, Kc	0.7	0.95	1.2	0.48
3	Reduction factor, Kr, %	0.24	0.35	0.82	0.47
4	Emission uniformity, EU	0.9	0.9	0.9	0.9
5	Application efficiency, Ea, %	0.91	0.91	0.91	0.91
6	LR, mm/day	0.03	0.05	0.14	0.03
7	R , mm	0	0	0	0
8	No. of days/ stage	20	35	40	27
9	IRg, (mm/stage)	26	91	275	38
10	IRg, (m^3 / fed. / stage)	111	382	1155	160
11	IRg, (m^3/fed./season)	1808			

*(Hectare =2.4 fed.)****;*** *R=* *water received by plant from sources other than irrigation, mm (for example rainfall)****;*** *IRg = Gross irrigation requirements, mm/day L = Leaching requirement*

2.2.2. Fertilization program, weed and pest control: Fertilization program had been done according to the recommended doses throughout the growing season (2012 - 2013) for maize crop under the investigated irrigation systems using fertigation technique. These amounts of fertilizers NPK (20-20-10), were 80 kg/fed of (20 % N) and 40 kg/fed of (20 % K_2O). While 65 kg/fed of (10 % P_2O_5) in addition to, adding 20 $m^3_{compost}$/ fed. For all plots, weed and pest control applications followed recommendations of maize crop in El-Nobaria, Egypt.

2.3. Experimental Design: Experimental design was evaluation new design for drip irrigation system with two traditional designs. (1) design 1 was drip irrigation system (control), (2)design 2 was drip irrigation system with PRD technique (partial root drying; one emitter will irrigate one part of the root system and emitters of other lateral will irrigate other half of root system) with the same direction for main lines and laterals and (3) New design was drip irrigation system with PRD technique with opposite direction for main lines and laterals. More details for all designs as shown in fig. (4)**.**

2.4. Evaluation Parameters

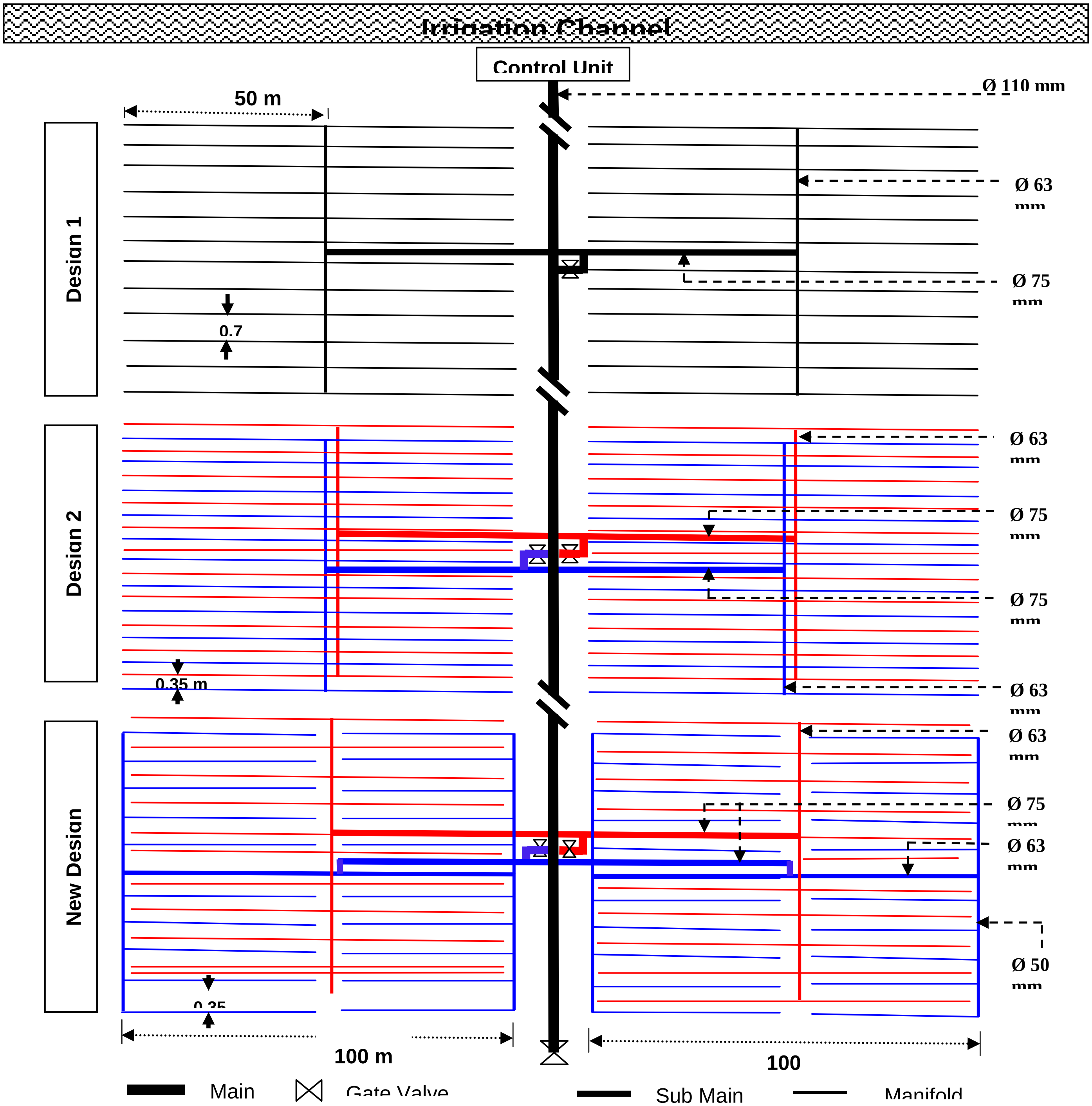
2.4.1. Emission uniformity

emission uniformity (EU) of water was estimated (Marriam and Keller, 1978) along laterals drip irrigation system in every plot area under pressure range of 1.0 bar by using 20 collection cans and following Equation: EU = (qm / qa) 100 ………….. (2)

Where: EU = Emission uniformity, %; qm = the average flow rate of the emitters in the lowest quartile, (l/h); and qa = the average flow rate of all emitters under test, (l/h).

2.4.2. Soil moisture distribution

Soil moisture content was determined according to Liven and Van (1979). The soil samples were taken at maximum actual water requirements by profile probe before and 2 hours after irrigation and from different locations. In the case of 70 cm laterals space the sample locations were at 0, 10, 20, 30 and 35 cm on the X-direction (space between laterals). For each of these locations, soil samples were collected from different depths from soil surface, which were 0, 15, 30 and 45 cm on the Y-direction. By using "contouring program Surfer version 8", we obtained on contouring maps for different moisture levels with depths.



Design 1 = Drip irrigation system (control)
Design 2 = Drip irrigation system with PRD technique with the same direction for manifolds and laterals
New Design = Drip irrigation system with PRD technique with opposite direction for manifolds and laterals

Figure 2. Layout of drip irrigation systems under study

2.4.3. Application efficiency

Application efficiency relates to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field. According to El-Meseery, (2003) application efficiency "AE" was calculated using the following relation:

$$AE = V_s / V_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where: AE = Application efficiency, (%), V_s = Volume of stored water in root zone ($cm.^3$) where:

$$V_s = (\theta_1 - \theta_2) * d * \rho * A \quad \ldots\ldots\ldots\ldots. (4)$$

V_a = Volume of applied water (cm^3), A = wetted surface area ($cm.^2$), d = Soil layer depth (cm), θ_1 = Soil moisture content after irrigation (%), θ_2 = Soil moisture content before irrigation (%), ρ = Relative bulk density of soil (dimensionless). Table (6) show estimation method of application efficiency in the field.

Table 6. Estimation method of application efficiency

Soil depth, cm	θ_1 %	θ_2 %	d, cm	P	A, cm^2	$V_s = (\theta_1 - \theta_2)*d*\rho*A$ cm^3	V_a, cm^3	$AE = V_s/V_a$ $AE = (V_{s1} + V_{s2} + V_{s3})/V_a$
0 -15						V_{s1}		
15 -30						V_{s2}		
30 -45						V_{s3}		

AE = Application efficiency, V_s =Volume of stored water in root zone, V_a =Volume of applied water, A = wetted surface area*, d =Soil layer depth, θ_1 =Soil moisture content after irrigation, θ_2 = Soil moisture content before irrigation, ρ = Relative bulk density of soil (dimensionless). V_{s1}= Volume of stored water in root zone from 0 – 15 cm , V_{s2}= Volume of stored water in root zone from 15 – 30 cm, V_{s3}= Volume of stored water in root zone from 30 –45cm*

2.4.4. Measurements of maize plant growth

Measurements include, plant height (cm), leaf length (cm), leaf area (cm2), number of leaves plant-1 and total chlorophyll content, %.

2.4.5. Yield of maize

At harvest, a random sample of 100 X 100 cm was taken from each plot to determine grain yields in the mentioned area and then converted to yield (ton/fed.).

2.4.6. Irrigation water use efficiency of maize

"$IWUE_{maize}$" was calculated according to James, (1988) as follows: $IWUE_{maize}$ = (Ey/Ir) x100 ……………….. (5)

Where: $IWUE_{maize}$ is the irrigation water use efficiency (kg $_{grain}$ / m^3 $_{water}$), Ey is the economical yield (kg grain /fed.); Ir is the amount of applied irrigation water (m^3 $_{water}$ /fed./season).

2.4.7. Economical evaluation

Total income$^{-\text{ CM more than MC}}$ = Total income - (Costs of all required materials which more than the materials which used in the control treatment) where:

$$\text{Total income}^{-\text{ CM more than MC}} = TI - [(CL/2L_1) + (CP/2L_2) + (CV/2L_3)] \quad \ldots\ldots\ldots\ldots\ldots. (6)$$

CM more than MC: Costs of all required materials which more than the materials which used in the control treatment

TI: Total income = Total yield (ton/fed.)* price of ton

$CL/2L_1$: Costs of laterals/ season, L.E./fed., Lifecycle, L_1= 7 years

$CP/2L_2$: Costs of pipes/season, L.E./fed. Lifecycle, L_2= 25 years

$CV/2L_3$: Cost of valve & elbows /season, L.E./fed., Lifecycle, L_3= 10 years

2.5. Statistical Analysis

Combined analysis of data for two growing seasons was carried out according to Snedecor and Cochran (1980) and the values of least significant differences (L.S.D. at 5 % level) were calculated to compare the means of different treatments.

3 RESULTS AND DISCUSSION

3.1. Emission Uniformity

Emission uniformity "EU" of drip irrigation system is a measure of the uniformity of emissions from all the emission points for field test. Emission uniformity was calculated by dividing average rate of emitter discharge readings of the lowest one-fourth of the field data by average discharge rate of the emitters checked in the field. Fig. (3), table (7) and Fig.(4) showed EU under design 1, design 2 and new design of drip irrigation system. Highest value of EU occurred under new design this may be due to there were two emission points built in laterals and every lateral was opposite direction of the other this mean, one is the lack of a corresponding increase in the other, and this ensures equal distribution of water along laterals, resulting in a high uniformity of distribution under this new design compared with design1 and design 2 **.**

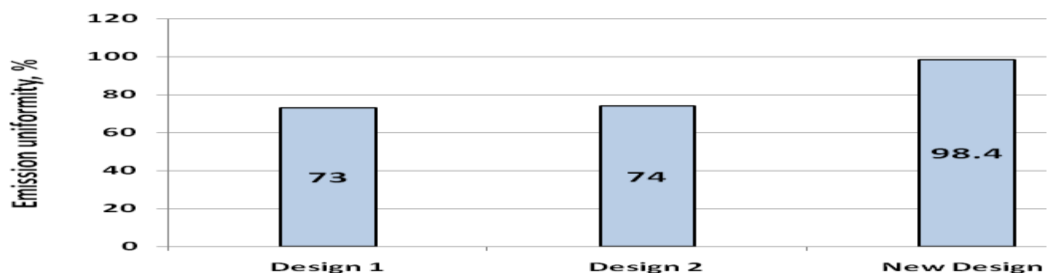


Figure 3. Emission uniformity for three designs under study

Table 7. Emission Uniformity under three designs of drip irrigation systems

Can No.	**Design1**	**Design2**			**New Design**		
	Dripline1 (q_1=l/h)	**Dripline1 (q_1=l/h)**	**Dripline2 (q_2=l/h)**	**Aver. (q_1+q_2)/2**	**Dripline1 (q_1=l/h)**	**Dripline2 (q_2=l/h)**	**Aver (q_1+q_2)/2**
1	5.0	5.2	5.3	5.25	5.2	2.5	3.85
2	4.8	4.8	4.9	4.85	4.8	2.5	3.65
3	4.6	4.6	4.7	4.65	4.6	2.6	3.60
4	4.5	4.5	4.6	4.55	4.6	3.0	3.80
5	4.3	4.3	4.3	4.30	4.2	3.1	3.65
6	4.2	4.2	4.3	4.25	4.2	3.1	3.65
7	4.1	4.1	4.2	4.15	4.1	3.1	3.60
8	3.9	3.9	3.9	3.90	3.9	3.4	3.65
9	3.8	3.8	3.8	3.80	3.8	3.5	3.65
10	3.7	3.8	3.7	3.75	3.8	3.7	3.75
11	3.7	3.8	3.7	3.75	3.7	3.8	3.75
12	3.5	3.5	3.4	3.45	3.5	3.8	3.65
13	3.4	3.4	3.4	3.40	3.4	3.9	3.65
14	3.1	3.1	3.1	3.10	3.1	4.1	3.60
15	3.0	3.1	3.0	3.05	3.1	4.2	3.65
16	3.0	3.0	3.0	3.00	3.0	4.3	3.65
17	2.8	3.0	2.8	2.90	3.0	4.5	3.75
18	2.7	2.7	2.7	2.70	2.7	4.6	3.65
19	2.5	2.5	2.7	2.60	2.5	4.8	3.65
20	2.3	2.4	2.5	2.45	2.4	5.1	3.75
Aver. qm	2.66			2.73			3.62
Aver. qa	3.65			3.69			3.68
EU,% = (qm/ qa)*100	73			74			98.4

Aver. qm: the average flow rate of the emitters in the lowest quartile, Aver. qa: the average flow rate of all emitters under test, EU: Emission uniformity, %;

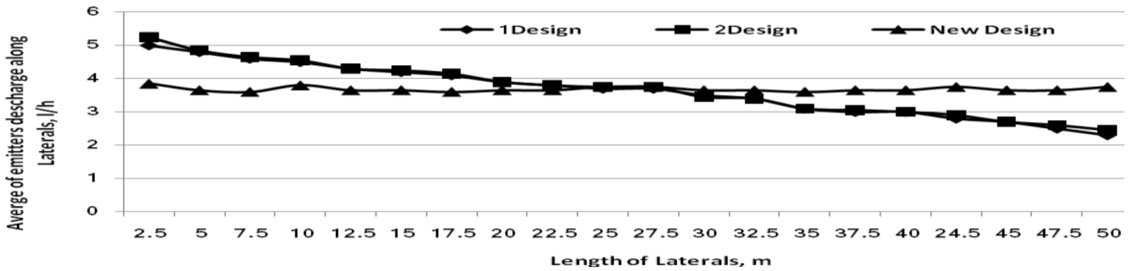


Figure 4. The relation between length of laterals and average of emitters discharge along laterals

3.2. Soil Moisture Distribution

Figs. (5,6 and 7) represented soil moisture distribution and wetted soil volume (more than or equal 100 % from field capacity) in root zone " $WSV_{\geq 100\%FC}$ ". $WSV_{\geq 100\%FC}$ in root zone was determined by calculating the wetted soil volume surrounded by contour line 12 which approximately representing the field capacity. $WSV_{\geq 100\%FC}$ in the root zone increased under new design compared design1 and design2 this may be increasing of emission points through two laterals especially if these points built in two laterals with opposite direction. Under new design occurred highest value for $WSV_{\geq 100\%FC}$ in the root zone hence, decreasing from drought stress inside root zone along laterals and this will create a healthy environment for plant growth.

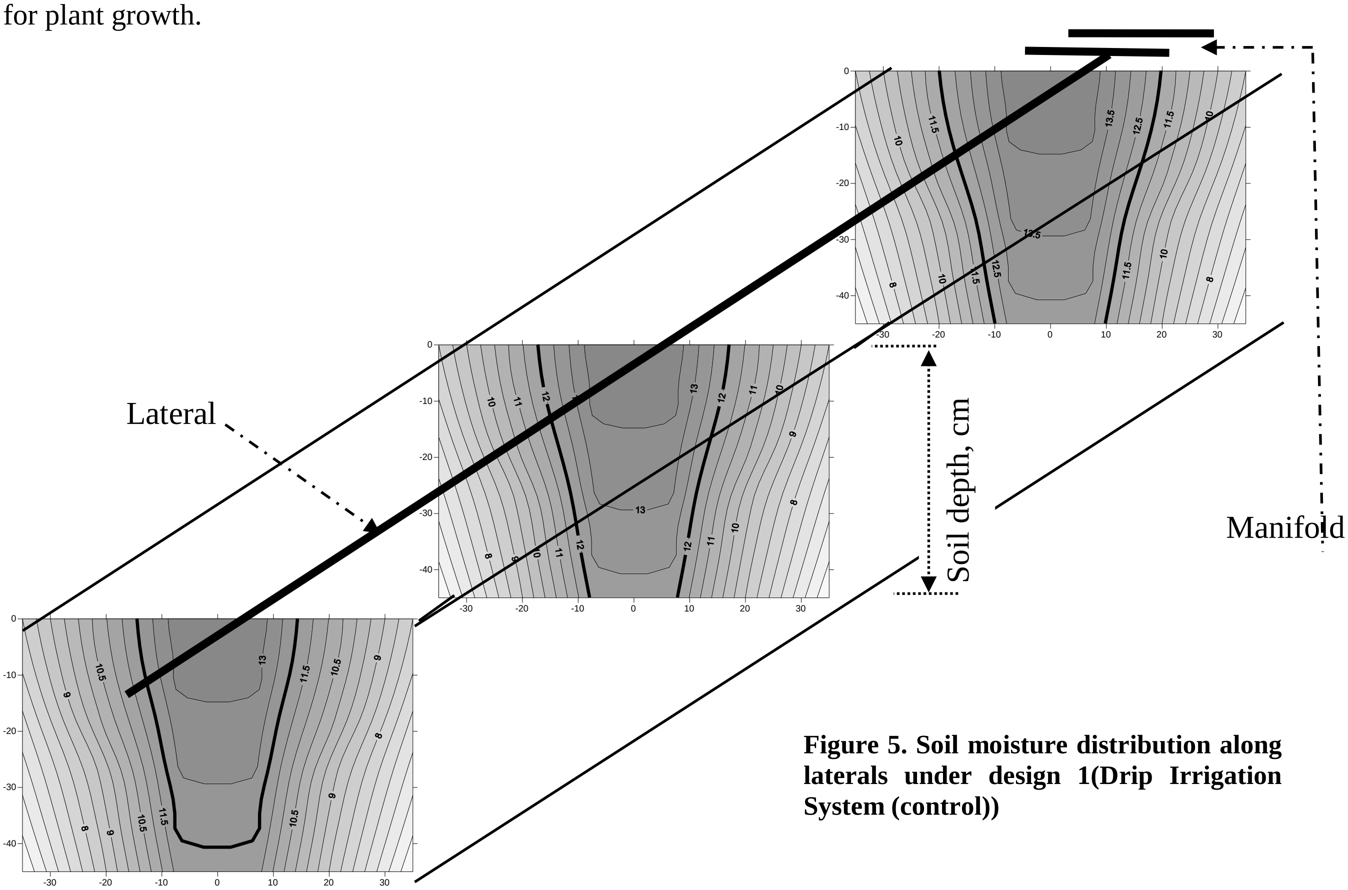


Figure 5. Soil moisture distribution along laterals under design 1(Drip Irrigation System (control))

3.3. Application Efficiency

Application efficiency, "AE" was calculated by dividing the volume of stored water in root zone by the volume of applied water so, increasing of $WSV_{\geq 100\%FC}$ in the root zone increased from AE. Fig. (8) and tables (8,9 and 10) indicated that maximum value of AE occurred under new design compared with design1 and design2 this due to two reasons, first of all, most of irrigation water stored in effective root zone and this is due to increasing number of emission points which increased from $WSV_{\geq 100\%FC}$ in the root zone and the second reason was equality in the applied water volume along laterals.

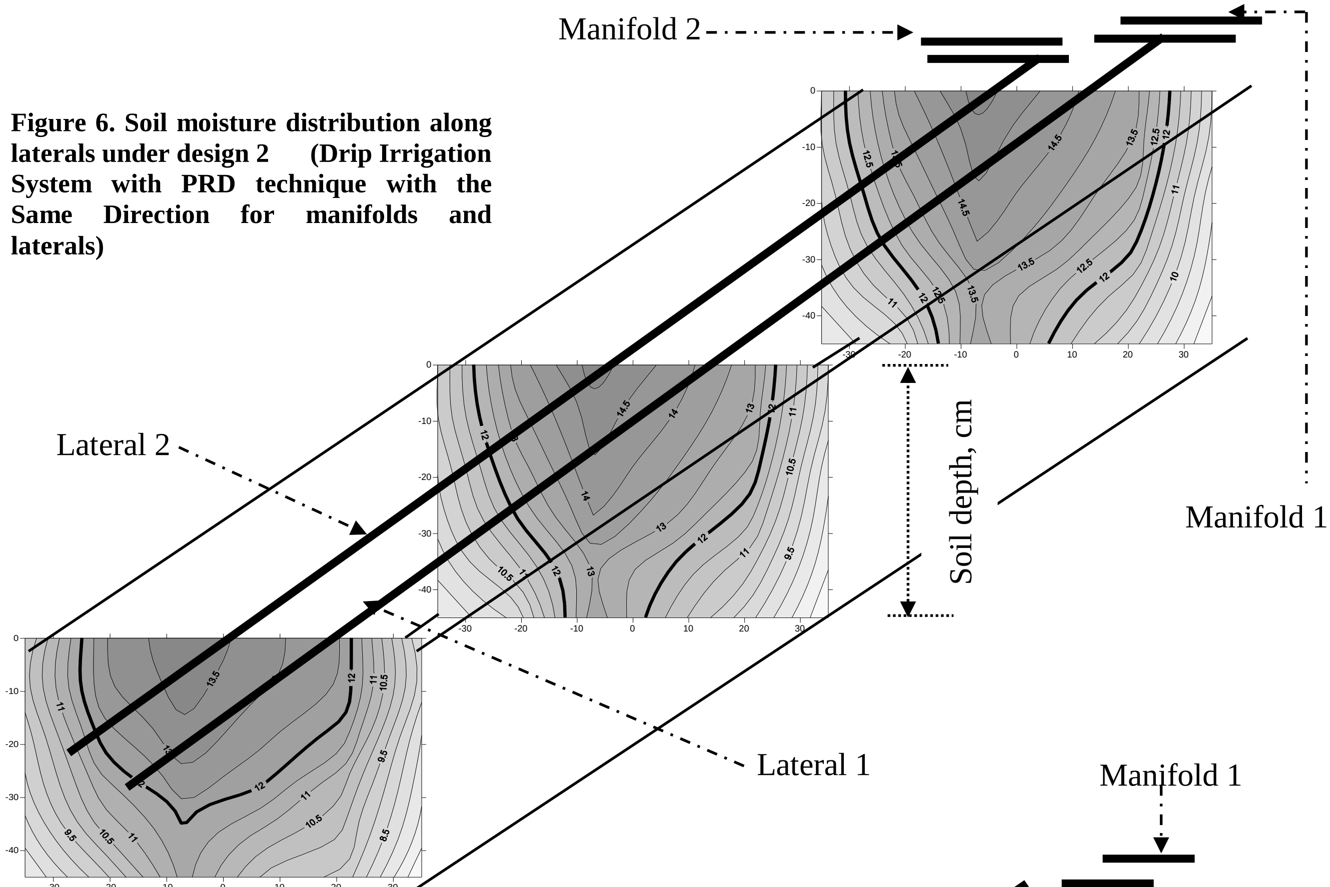


Figure 6. Soil moisture distribution along laterals under design 2 (Drip Irrigation System with PRD technique with the Same Direction for manifolds and laterals)

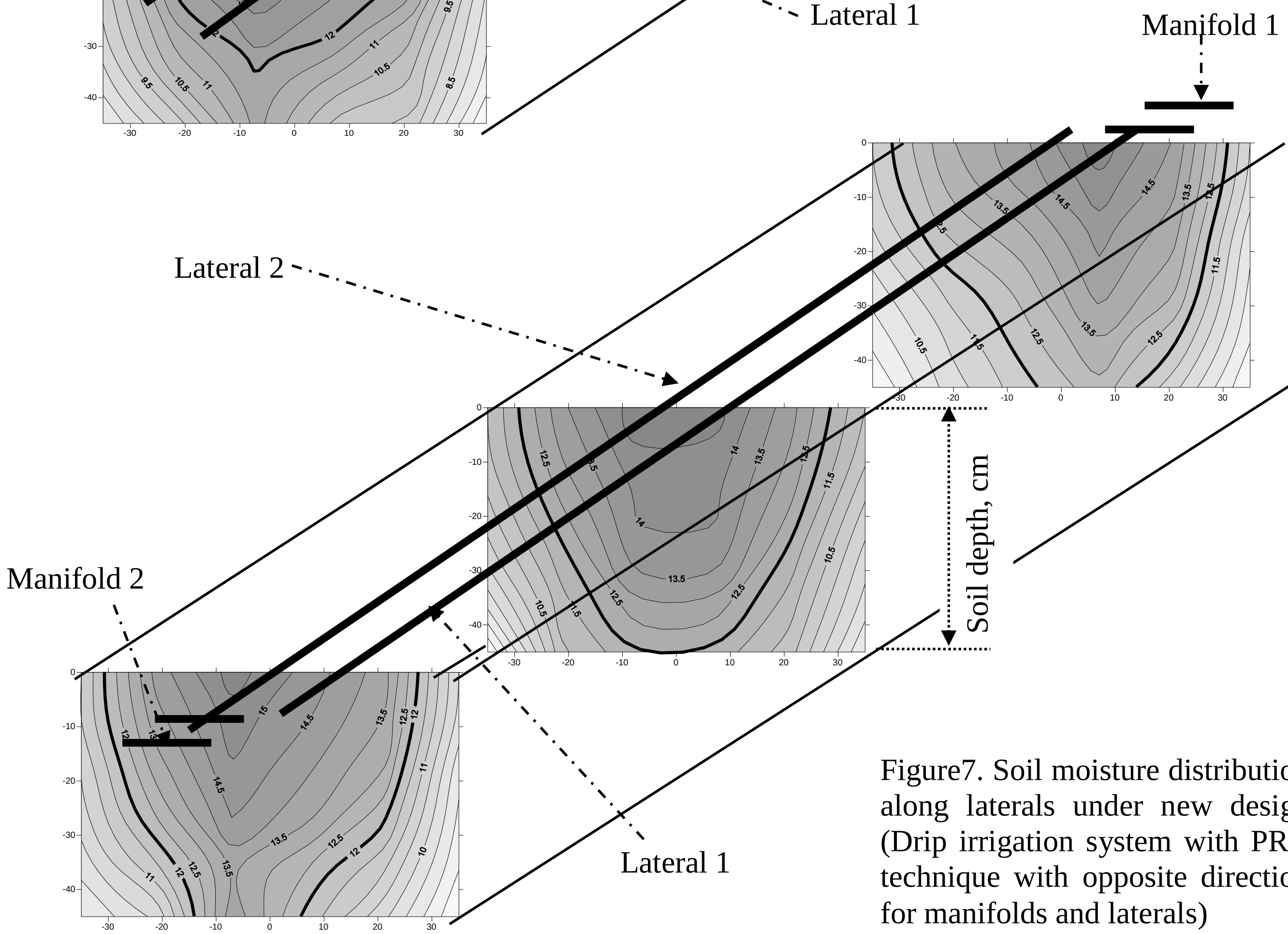


Figure7. Soil moisture distribution along laterals under new design (Drip irrigation system with PRD technique with opposite direction for manifolds and laterals)

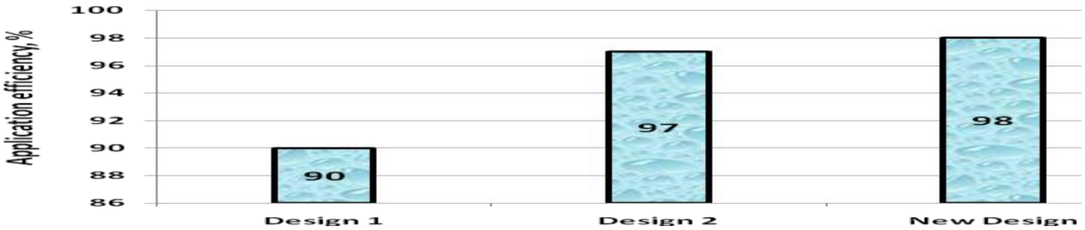


Figure 8. Application efficiency for three designs under study

Table 8. Application efficiency at peak actual water requirements under design1

Soil depth, cm	θ_1 %	θ_2 %	d, cm	P	A, cm^2	$V_s=(\theta_1-\theta_2)*d*\rho*A$ cm^3	V_a, cm^3	$AE = V_s/V_a$ $AE = (V_{s1}+V_{s2}+V_{s3})/V_a$
0 -15	12.7	8.0	7.5	1.4		V_{s1} = 1036		
15 -30	11.5	7.0	7.5	1.5	1470	V_{s2} = 744	2886	
30 -45	10.6	6.0	7.5	1.6		V_{s3} = 811		90

*A= 30 cm*70 cm *0.7(Percentage of wetted surface area for one plant) = 1470 cm^2 Va = 1443*2(Irrigation every 2 days) = 2886 cm^3*

Table 9. Application efficiency at peak actual water requirements under design 2

Soil depth, cm	θ_1 %	θ_2 %	d, cm	P	A, cm^2	$V_s=(\theta_1-\theta_2)*d*\rho*A$ cm^3	V_a, cm^3	$AE = V_s/V_a$ $AE = (V_{s1}+V_{s2}+V_{s3})/V_a$
0 -15	14.5	8.5	7.5	1.4		V_{s1} = 1323.00		
15 -30	12.0	9.0	7.5	1.5	2100	V_{s2} = 708.75	2886	
30 -45	11.0	8.0	7.5	1.6		V_{s3} = 756.00		97

*A= 30 cm*70 cm *1(Percentage of wetted surface area for one plant) = 2100 cm^2 Va = 1443*2(Irrigation every 2 days) = 2886 cm^3*

Table 10. Application efficiency at peak actual water requirements under new design

Soil depth, cm	θ_1 %	θ_2 %	d, cm	P	A, cm^2	$V_s=(\theta_1-\theta_2)*d*\rho*A$ cm^3	V_a, cm^3	$AE = V_s/V_a$ $AE = (V_{s1}+V_{s2}+V_{s3})/V_a$
0 -15	15.2	9.6	7.5	1.4		V_{s1} = 1234.80		
15 -30	13.3	9.2	7.5	1.5	2100	V_{s2} = 968.63	2886	
30 -45	11.5	9.0	7.5	1.6		V_{s3} = 630.00		98

*AE = Application efficiency, V_s =Volume of stored water in root zone, V_a =Volume of applied water, A = wetted surface area , d =Soil layer depth, θ_1 =Soil moisture content after irrigation, θ_2 = Soil moisture content before irrigation, ρ = Relative bulk density of soil (dimensionless). V_{s1}= Volume of stored water in root zone from 0 – 15 cm , V_{s2}= Volume of stored water in root zone from 15 – 30 cm, V_{s3}= Volume of stored water in root zone from 30 – 45cm, A= 30 cm*70 cm *1(Percentage of wetted surface area for one plant) = 2100 cm^2 Va = 1443*2(Irrigation every 2 days) = 2886 cm^3*

3.4. Growth Characteristics of Maize Plant

Table (11) indicated that improving of all growth characteristics of maize plant under new design with significant deference's with design1 and design2 this may be due to increasing of emission uniformity and improving of soil moisture distribution inside root zone in addition to increasing of AE along laterals hence, created a healthy environment for plant growth. **3.5. Yield of maize**

The main goal from any development in agriculture is increasing the yields. Yield of maize was studied under three designs of drip irrigation systems. Data in fig.(9) and table (11) represented the grain yield of maize under these designs. Maximum value of yield was occurred under new design with significant deference's with other designs and this may be due to equality the volume of irrigation water and fertilizers along laterals hence, increasing the yield under the new design compared with other designs.

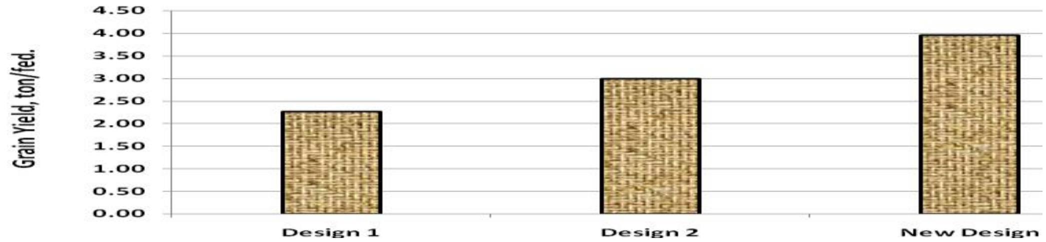


Figure 9. Grain yield for three designs under study

3.6. Irrigation water use efficiency of maize

Irrigation water use efficiency "IWUE" is an indicator of effectiveness use of irrigation water unit for increasing crop yield. Irrigation water use efficiency of maize "IWUE $_{maize}$" was calculated by dividing total yield by total applied irrigation water during the growth season of maize plant. Fig. (10) and table (11) With the stability of the amount of irrigation water for the three designs IWUE $_{maize}$ took the same trend productivity where the maximum value of IWUE $_{maize}$ was under new design.

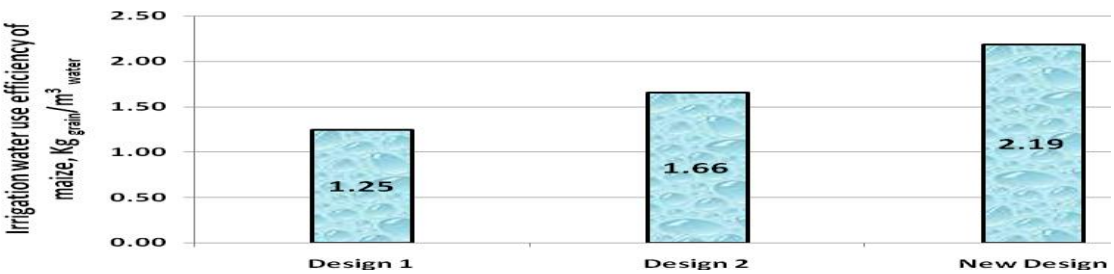


Figure 10. Water use efficiency of maize for three designs under study

Table 11. Effect of new design for drip irrigation system on maize plants growth, grain yield and irrigation water use efficiency of maize" IWUE $_{maize}$".

Designs	Growth Characteristics of maize plant					Grain Yield, ton/fed.	IWUE $_{maize}$, Kg $_{grain}$/m^3 $_{water}$
	Leaf area, cm^2	Plant height, cm	Leaf length, cm	No. of leaves per plant	Chlorophyll content, %		
Design 1	462.33 c	183.33 c	58.00 c	14.67 c	27.67 c	2.27 c	1.25 c
Design 2	484.33 b	192.33 b	65.67 b	16.33 a	33.67 b	3.00 b	1.66 b
New Design	526.00 a	199.00 a	72.00 a	16.67 a	44.67 a	3.97 a	2.19 a

3.7. Economical evaluation

There were three designs for drip irrigation system and every design has a deferent cost so, calculating the total revenue after subtracting the costs of all required materials which more than the materials which used in the control treatment was the only economical parameter which used in this study. Costs of all materials which more than the materials which used in the control treatment did not affect the significant differences between the values of total revenue. Although increasing the cost of new design but also this design achieved the highest yield compared with design1 and design2. The large increase of the differences between the total revenue was not affected by the high cost of the new design for a drip irrigation system.

Table 12. Total costs of all required materials more than materials of control treatment

Evaluation Parameter	Items	Design 1 (Control)	Design 2	New Design
Total income, L.E./ fed.	Total yield(ton/fed.)	2.27	3.00	3.97
	Price of ton, L.E.	2500	2500	2500
	Total yield (ton/fed.)* price of ton, L.E.	5675	7500	9925
Costs of laterals/season, L.E./fed.	Total length of laterals, m/ fed.	0	6000	6000
	Costs of laterals, L.E.= 15 * 320 L.E.	0	4950	4950
	Lifecycle, years	7	7	7
	CL/2L	0	354	354
Costs of pipes/season, L.E./fed.	Total length of pipes, m /fed. (PVC, Ø75 mm)	0	100	100
	Total length of pipes, m /fed. (PVC, Ø63 mm)	0	84	200
	Total length of pipes, m /fed. (PVC,Ø 50 mm)	0	0	168
	Costs of pipes, L.E./ m (PVC, Ø75 mm)	7	7	7
	Costs of pipes, L.E./m (PVC, Ø63 mm)	5.5	5.5	5.5
	Costs of pipes, L.E./m (PVC, Ø50 mm)	3.5	3.5	3.5
	Lifecycle, years	25	25	25
	CP/2L	0	23	48
Cost of valve & elbows /season, L.E./fed.	No. of valves	0	1	1
	Cost of valve & elbows, L.E.($3^{//}$ PVC)	250	250	350
	Lifecycle, years	10	10	10
	$3^{//}$ PVC & elbows	0	25	35
Installation costs, LE/season	Installation costs/2L	0	15	40
Total income^{-} $_{CLP}$, L.E./fed.		**5675 c**	**7083 b**	**9448 a**

L: Lifecycle; PVC: Poly Vinyl Chloride L.E.: Egyptian Pond; CL: Costs of laterals

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