Plant Archives Volume 20 No. 2, 2020 pp. 8253-8260 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

FIELD EVALUATION OF INNOVATIVE FOLLICULAR DRIPPERS FOR RAISING OF WATER USE EFFICENCY UNDER DESERT CONDITIONS

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Abstract

The trails are conducted in El-Behira Governorate, in the North Coast, Egypt, maize (Zea mays L.) Hybrids (Three Ways Cross 310) is cultivated the space between plant rows is 150 cm and plant is 25 cm apart of plants in sandy soil, all treatments repeated three times under statistical design as Split plot design, under the desert conditions. . For traditional drip irrigation, Gr dripper was used by 8 l/h/m, discharge, and two hoses for one tree row, under surface drip irrigation (SD), subsurface drip irrigation (SSD), Surface innovative porous drippers (SIPD) and Subsurface innovative porous drippers (SSIPD), the flow of SIPD and SSIPD is 1/h/m under operating head 0.5 bar, there are four drippers per meter for all of drip irrigation systems and three amounts of applied water (100%, 75% and 50 of calculated applied water which called WT1, WT2 and WT3 respetivly.). Results show that , the significant positive effects of SSIPD and SSD on the weight of plants and also for WT1 , and for Grain yield (ton/ha) the highest positive values of irrigation systems is 31.7, 28.7, 26.6 and 24.6 ton/ha for SSIPD, SSD, SIPD and SD respectively. And the same values performance for water treatments, the heights significant is for WT1, WT2 and WT3. Receptively. In addition to the interaction of both of irrigation systems and water amounts clears the highest value of grain yield is obtained by (SSIPD, WT1) and the lowest is obtained by (SD, WT3). The highest significant values of both of IWUE and FWUE are obtained for SSIPD and the lowest is for SD, whatever, for the water mounts the highest value is obtained by WT1 and the lowest is by WT3, in the same time, the interaction of both of irrigation systems and water amounts affected on both of FWUE and CWUE, where the highest value is under (SSIPD and WT2), The highest values of total cost of water unite, (LE/m3) and irrigation cost of unite production, (LE/kg) of maize under irrigation systems are obtained by SD, SSD, SIPD and SSIPD resepctivle, where, under and water amounts are obtained by WT3, WT2 and WT1, in the interaction of both of irrigation system and water amounts the highest vaulrs are obtained by SD and WT3. the highest values of Pumping energy requirements, (hp.h) of maize under irrigation systems is for SSIP, SIPD, SSD and SD where for water amounts is WT1, WT2 and WT3 respetivly,

Keywords: Surface-drip, Subsurface-drip, Innovative follicular drippers, WUE, Maize, sand, economic, energy.

Introduction

Water is one of the most dangerous challenges facing sustainable development, especially in arid and semi-arid regions, and that is in the face of the steady increase of population in the world, which necessitates an increase in the demand for food and water, in addition to climate change, so it was necessary to search for innovative solutions based on Nature so that environmental problems do not coalesce, the most important of which is global warming.

The using of sub-surface drip irrigation systems saved water, in these systems the water used direct inside soil layers instead of the surface, where reduced the evaporation losses of water. (Ayars et al. 1999). The soil evaporation is measured in irrigated olive orchards using surface drip, the estimating of seasonal evaporation is 4 - 14% for a mature orchard and 18 - 43 % for young orchard, and this results basically depends on the soil surface wetted using surface drip irrigation. (Bonachela et al. 2001). The water losses by deep-percolation in sandy soil reach to 45% of supplied water. Nassah et al. 2018. Maize is one of the three most important cereal crop species (after wheat and rice). The total area, production and yield in 2002 were138, 755,000 ha producing 602,589,000, (FAO, Production Yearbook 2011). A major shift in global cereal demand is underway, and by 2020, demand for maize in developing countries is expected to exceed demand for both wheat and rice (Pingali and Pandey 2001).

Maize has been reported in the literature as having high irrigation requirements (Rhoads and Bennett 1990; Stone et al. 2001). In arid and semi-arid regions, the daily evapotranspiration rates of maize often exceed 10 mm day)1 for significant time periods (Howell et al. 1995). Furthermore, maize yields are most sensitive to water stress, especially at flowering and pollination stages. For instance, on the other hand, field application efficiency in most traditional irrigation methods is still very low, typically less than 50 % and often as low as 30 % (Molden et al. 1998). Excessive application of water generally entails losses because of surface run-off from the field and because of deep percolation below the root zone within the field. Both run-off and deep percolation losses are difficult to control under furrow irrigation system, where a large volume of water is applied at a single instance. Alternative water application methods such as the drip irrigation method allow for much more uniform distribution as well as more precise control of the amount of water applied and also decrease nutrient leaching (Phene et al. 1994). Drip irrigation is an efficient method for minimizing the water used in agricultural and horticultural crops. However, the method can result in water saving if the correct management procedures are applied (Darusman et al. 1997). Frequency of water application is one of the most important factors in drip irrigation management because of its effects on soil water regime, root distribution around the emitter, the amount of water uptake by roots and the amount of water percolation under the root zone (Coelho and Or 1999, Assouline 2002, Wang et al. 2006). The frequency of water application is one of the most important factors in drip irrigation management. Due to the differences in soil water potential and soil water distribution with depth, grain yield and WUE might differ when the same quantity of water is applied under different irrigation frequencies. Therefore, it is essential to develop the most suitable irrigation schedule for different ecological regions, especially as plant water consumption during plant growth depends mostly on soil and climatic conditions (Nath et al. 2001).

It can saved more water that saved 40% than T2 by 20% especially at SSUD and SUD where the difference was clear when compared to SD and SSD drip irrigation systems. Saving water and nutrient applied in sandy soil, can be saved up to 40% from irrigation water applied and so increasing quantity and quality of yield by good management and using ultra-low flow drip irrigation then having more total economical income. In sandy soil, about 40% of irrigation water applied could be saved and increasing quantity and quality of peach tree. (Omima and El-Hagarey 2014).

Maximal horizontal water distribution, Because the Ultra-Low Drip Emission from "ULDI" emitters is lower - than the soil infiltration capacity, the horizontal water movement to the sides as well as that upwards reaches the maximum distance from the emission point and is wider than with conventional drip irrigation "CDI". Vertical wetting pattern front in sandy soil increased more than vertical in clay with 36.07%, but the horizontal wetting pattern front in clay soil increased more than horizontal in sand with 13.08%. Gilead, G. (2012).By comparing traditional trickle flow 8 L/h and ultra-low rate system 0.4 L/h for the same water quantity 2.4 Liter, wetting pattern front for sand and clay soils at traditional trickle flow were faster than wetting pattern front at ultra-low rate system, which led to a significant loss in the amount of water by deep percolation in a short time, in traditional trickle flow the vertical wetting pattern fronts in sandy soil increase more than vertical in clay with 646.15%, but the horizontal wetting pattern front in clay soil increase more than horizontal in sand with 8.8%. Abdou et al, (2010). The aim of modern irrigation development must be to make the best use of water in conjunction with land and human resources, as well as with all other essential inputs (energy, machinery, fertilizers and pest control measures) so as to enhance and sustain crop production. The selection of an appropriate irrigation technology for any given combination of physical and socio-economic condition involves complex and sometimes conflicting considerations. Where water shortage is acute, the obvious overriding need is to raise the efficiency of water utilization. Where capital is short, the major requirement might be for an irrigation method with minimal de-pendence on capital investment or expensive equipment. In other cases, the deciding factor may be energy require-ments, labour availability or maintenance costs. (FAO, 1997).

List of acronyms and nomenclature

SD	=	Surface traditional drip irrigation system (Gr),
SSD	=	Subsurface traditional drip irrigation system (Gr),
SSIPD	=	Subsurface Innovative porous drippers,
SIPD	=	Surface Innovative porous drippers,
WT_1	=	100% of calculated applied water,
WT_2	=	75% of calculated applied water,
WT_3	=	50% of calculated applied water,
Ws	=	water consumptions (m^3/ha)
Ir	=	irrigation requirements (m^3/ha)
FWUE	=	Field Water use efficiency, (kg/m^3),
CWUE	=	Crop Water use efficiency, (kg/m^3),
Er	=	Pumping energy requirements, (hp.h)
ICWU	=	Irrigation Cost of water unite (LE.m^3), and
IPIC	=	Unit production irrigation cost (LE/kg).

The main objective of the present work was to study the field evaluation of innovative porous drippers for raisnig of water use efficency under desert conditions

Material and Method

The trails are conducted in El-Behira Governorate, in the North Coast Egypt, maize (Zea mays L.) Hybrids (Three Ways Cross 310) is cultivated the space between plant rows is 50 cm and plant is 25 cm apart of plants, all treatments repeated three times under statistical design as split plot design, under the desert conditions. The fertilization is conducted according to the recommendation of ministry of agricultural and land reclamation.

All other agriculture practices of cultivation were performed as recommended by normal practices. Chemical properties of the soil of the experiment were analyzed before cultivation according to Chapman and Pratt (1961) and the results are tabulated in Table (1). The permanent wilting point (PWP) and field capacity (FC) of the trial soil were determined according to Israelsen & Hansen (1962). Plant distances were 30 cm apart.

Soil measurements:

The soil samples were taken under three used irrigation systems, by a screw auger at three spaces from beginning of the drip main line, the space between samples were 20 cm, and at three depths (20,40, and 60cm) at two direct X and Y where the horizontal and vertical space of the sample was 20 cm. Samples were analyzed for determining both soil moisture and salt accumulation. The results were drawn by SURFER, ve. 11 under on a color scale for soil moisture 1-50 and for soil salt distribution from1-100, under windows program, and the "Kriging" regression method as the base model for analysis and contour map development.

Irrigation system:

The irrigation system consisted of the following components:

Control head:

Control head consisted of centrifugal pump 5 /5 inch (20m lift and 80 m3/h discharge), driven by diesel engine (50 Hp) for Gr drip, and low-head (ranged from 2 to 5 m overhead) of tank for innovative follicular drippers, pressure gauges, control valves, inflow gauges, water source in the form of an aquifer, main line then lateral lines and dripper lines. For traditional drip irrigation, Gr dripper was used by 8 l/h/m, discharge, and two hoses for one tree row, under surface drip irrigation (SD), subsurface drip irrigation (SSD), Surface innovative porous drippers (SIPD) and Subsurface innovative follicular drippers (SSIPD), the flow of SIPD and SSIPD is 1/h per meter under operating head 0.5 bar, there are two drippers per meter for all of drip irrigation systems more over the irrigation water moves during two filter units, the first one is screen (130 mesh) and the other is gravel filter. and three amounts of applied water (100%, 75% and 50 of Etc)

Innovative follicular (porous) drippers (SIPD)

The Innovative follicular (porous) drippers (SIPD is designed and manufactured from local and environmental materials where the basic components of (PCPD) are pottery discs. It is made from Aswan Clay beside the additional material to result at various porosities and volumes. The composites contain dry powder of organic matter according to (El-Hagarey et al. 2016). Figs 1 and 2.

Fig. 1: Total Surfcae innovative follicular (porous) dring irrigation process in expirments site

Fig. 2: Hoses of innovative follicular (porous) drippers befors installing in expirment site.

Statistical analysis

All the obtained data during the two seasons of study were subjected to analysis of variance method according to (Snedecor and Cochran, 1990). Meanwhile, differences among means were compared using Duncan's multiple range tested at a probability of 5 % level (Duncan, 1955).

All measurements in this study were analyzed using an analysis of variance appropriate for a split plot design with irrigation systems as the main factor, applied water amounts level as the split factor. Mean separation of treatment effects in this study was accomplished using Fisher's protected least significant difference (LSD) test. Probability levels lower than 0.05 were categorized as significant.

Irrigation requirements:

Irrigation water requirements for Maize were calculated according to the local weather station data at El-Behira Governorate, belonged to the Central Laboratory for Agricultural Climate (C.L.A.C.), Ministry of Agriculture and Land Reclamation.

Table1: Some physical and chemical properties of the experimental orchard soil.

Particle size distribution(%)			Texture	EC(ds/m)	pH	Soluble cation meq/L				Soluble Anions meq/L			
Sand	Silt	Clay	Soil			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3	HCO_3	Cl^-	SO_4
91.72	6.15	2.13	sandy	1.99	7.9	6.65	3.40	9.18	0.57	--	3.85	8.30	7.85

Table 2: Some chemical analysis of irrigation water.

characters	pH	EC ds/m	Soluble cation meq/L				Soluble Anions meq/L			
			Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^-	HCO_3^-	CL^-	SO_4^-
value	7.46	1.33	3.00	3.70	6.30	0.32	0.50	2.42	6.40	4.00

Irrigation process was done by calculating crop consumptive use (mm/day) according to Doorenobs, and Pruitt (1977).

$$IR = \left[\frac{K_c \times Et_o \times A \times C_F}{10^7 \times Ea} \right] + LR$$

Where:

IR = Irrigation water requirements, m^3/ha/day.
E to = Potential evapotranspiration, mm day-1
Kc = Crop factor of garlic
A = Area irrigated, (m^2)
Ea = Application efficiency, %.where 60% in modified furrow irrigation.
LR = Leaching requirements.

Table 3: Calculated consumptive use (mm/day) of Maize

Growth stage	month	ETo mm/day	Kc	Etc mm/day	Water consumptions (m^3/ha)
Initial	17/5 to7/6	4.25	0.40	1.7	255
Develop.	8/6 to 7/7	4.5	0.80	3.6	1080
Mid-season	7/7 to 28/7	4.57	1.15	5.3	110
Season end	27/7 to 23/8	4.3	0. 7	3.01	783
Total (Ws)	2228 (m^3/ha/season)				
Total Ir	2451 (m^3/ha/season)				

Table 4: Calculated water amounts versus irrigation systems for maize

Characters	Irrigation requirements per season for ha, (m^3/ha/season)
100% ET_C = (WT1)	2450
75% ET_C = (WT2)	1892
50% ET_C = (WT3)	1335

Measurements and calculations:

Yield and yield attributes:

After physiological maturity, 10 randomly selected plants were harvested from each sub plot for measuring some yield and vegetative parameters are measured such as: Length of plant (m), number of leafs of plant, the weight of the plant (kg), the weight of the ear (g), grain yield (ton/ha) and straw yield (ton/ha). Maize plants were adjusted to a water content of 50 %.

Water use efficiency (kg/m^3):

Crop water use fficency (CWUE) is calculated according to next relationship:

CUWE= (Grain yield (kg/ha))/(Actual requirements water amount (m^3/ha))

Field water use fficency (FWUE) is calculated according to next relationship:

FWUE= grain yield (kg/ha) / Applied water amounts (m^3/ha),

According to (Vites 1962 and Michael, 1978)

Economic efficiency of irrigation systems (EEIS, %)

The economic efficiency of irrigation systems was defined as the percentage of actual yield and typical yield per hectare.

EEIS= (Actual yield (kg/ha))/(Typical yield (kg/ha))

Economic and Cost Feasibility analysis:

Cost analysis to evaluate surface and subsurface drip irrigation systems comparing with surface and subsurface innovative follicular drip irrigation systems, cost analysis were computed according to Worth and Xin (1983), Fixed and operation costs are calculated according to market price level of 2019 for equipment and operating irrigation process, cost analysis is based on one hectare.

Energy analysis

Pumping energy requirements:

Energy requirements and energy-applied efficiency (EAE) were determined for drip irrigation systems according to Batty et. al.,(1975),by following formula :

- Power consumption use for pumping water (Bp) was calculated ,as follows:

$$Bp = \frac{Q \times TDH \times Yw}{Ei \times Ep \times 1000}$$

Where:

Bp	=	Power conumption for pumping water (Hp)
Q	=	Total system flow rate (m^3/h)
TDH	=	Total dynamic head (m)
E_i	=	Total system efficiency

Pumping energy requirements (Er) (kW.h) was calculated as follows:

$$Er = Bp * H$$

Where:

H = Irrigation time per season (h).

Results

Soil moisture distribution under irrigation systems:

Figure 3 cleared that the highest homogeneous of soil moisture patterns are under SSIPD, SIPD and SSD respectively. It’s important to clear that after two hours of irrigation process the applied water of traditional drip irrigation is more than applied water in IPD irrigation system, where the last one support the ultra-low flow, the traditional dripper flow is 4 l/h, 1 bar operating pressure where, innovative porous drippers flow 0.4 l/h, 0.4 operating pressure. This technique support water saving specially in sandy soil, which has a poor water hold capacity, so whatever the water application is increase and the irrigation hours decrease, a much amount of water will losses by deep-percolation, and the against behavior, more over the water losses by evaporation, it’s crystal cleared in soil moisture patterns after 10 hours of irrigation process finishing.

The subsurface irrigation system is the best for the Egyptian climate according to the high temperature and less humidity which encourage to the evaporation losses from plants and soil surface. It means that so by burring the drip tube, the water move down and little up by capillary which is so weak in sandy soil, so losses by evaporation decrease without any additions or more costs. The highest yield is occurred not only under surface drip irrigation but also with the good management and scheduling of irrigation process. It's noticeable that the highest yield and quality under (SSIPD) then (SSD) had significant difference due to the excessive water in WT1 which cause the nutrient losses by deep percolation and seepage to the underground layer which reduce the planet usage of nutrient. On the contrary WT2 the exactly perfect water amount under these conditions and give plant more time and chance to have the benefits of nutrients. Whatever, buried hoses need more costs for buried tubes but it's still economic according to the high yield and quality income. Fig (3).

Surface drip irrigation is the common systems in Egypt according to the beginning of drip use and for ease and spread among farmers, it's can note that the excessive water under the emmiter verticaly especially when the water amount increasing, which lead to loss water and nutrients by percolaion in addtion to pollute the underground water by N and pesiticides.

As to progressive soil layer, (0– 60 cm) water was moving descending with continuous augmentation in its esteems achieving the majority of moisture content 18.03% for 100 cm soil profundity. Such decrease in the water content in the upper layers 0– 20 cm and the continuous augmentation in its incentive inside the layers 20– 40 cm can be for the most part credit to the variety in the aggregate potential.

Previously, the soil moisture contents increases with the soil depth increament according to the water move direction under gravity and there is evaporation losses, for that the best systems is subsurface drip irrigation under good management and scheduling without excessive water, ubsurface drip irrigation is for cold or in good climate zone which not encourage the evaporation. Fig (3).

Some morphological characterizes and yield of Maize:

The data illustrated in table (5) showed the significant differences of plant and yield parameter response to the irrigation systems and applied water amounts,

Length of plant: there is no noted significant differences of length of plants under irrigation system and the same under water treatments, this due to plant availability to adapted to the environmental conditions, whatever in interaction of irrigation systems and water amounts, the lowest significant values are recorded for WT3 (50% of ETc) under the surface drip and surface innovative porous drippers.

Number of leafs: it can be noted there is a very low significant deference’s values of plants leafs number under the water amount, on other hand there is any significant influences of irrigation systems or interaction of irrigation system and water treatments.

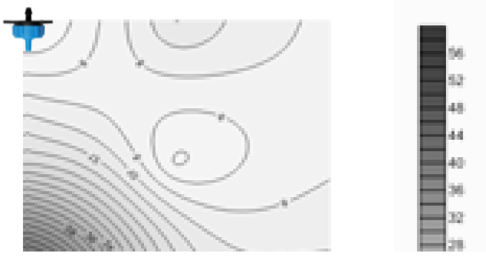
The weight of the plant (kg): Data clear that the significant positive effects of SSIPD and SSD on the weight of plants and also for WT1 , by the same token the positive affect of interaction between both of irrigation system and water amounts, but it’s important to clear that there is no significant between WT1 and WT2 under SSIPD, SIPD, SSD and SD.

The weight of the ear (g): the highest positive significant values are under WT1, WT2 and WT3 respectively, and for irrigation systems highest positive values is for SSIPD, SSD, SIPD and SD respectively, by the same token in the interaction between both of irrigation systems and water amounts.

Grain yield (ton/ha): the highest positive values of irrigation systems is 31.7, 28.7, 26.6 and 24.6 ton/ha for SSIPD, SSD, SIPD and SD respectively. And the same values performance for water treatments, the heights significant is for WT1, WT2 and WT3. Receptively. In addition to the interaction of both of irrigation systems and water amounts clears the highest value of grain yield is obtained by (SSIPD, WT1) and the lowest is obtained by (SD, WT3)

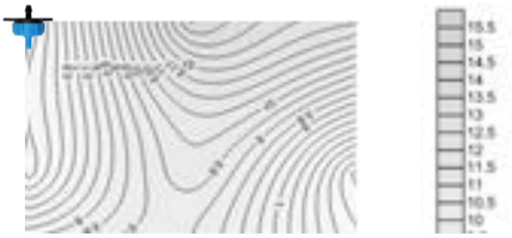
Straw yield (ton/ha): By the same token, the highest positive significant value is obtained by SSIPD and WT3 where the lowest significant values are obtained by (SD, WT3).

The water stress affected negatively on yield and some morphological parameters according to the limitation of plant availability of elements adsorption and physiological process such as photosynthesis and carbohydrate formation, because of water stress and the increasing of soil solution as results to water reduction. These results are agreed with Porro and Cassel (1986), El-Ganayni et al. (2000) and Asch et al. (2001). Table (5).



The soil moisture distribution under SSIPD

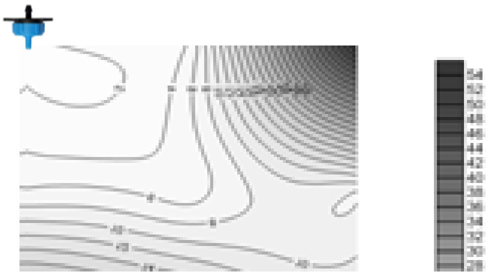
The soil moisture distribution under SIPD



The soil moisture distribution under SSD

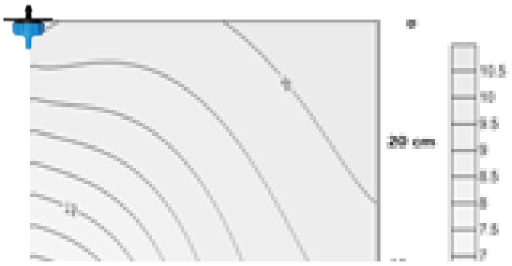
The soil moisture distribution under SD

2 hours after irrigation process



The soil moisture distribution under SSIPD

The soil moisture distribution under SIPD



The soil moisture distribution under SSD

The soil moisture distribution under SD

10 hours after irrigation process

Fig 3: Soil moisture distribution under various irrigation systems

Water use efficiency (kg/m^3):

Figures in tables (6 and 7) showed that, the highest significant values of both of IWUE and FWUE are obtained for SSIPD and the lowest is for SD, whatever, for the water mounts the highest value is obtained by WT1 and the lowest is by WT3, in the same time, the interaction of both of irrigation systems and water amounts affected on both of FWUE and CWUE, where the highest value is under (SSIPD and WT2) where, the lowest value in under (SD and WT3), these differences are due to the poor hold capacity of sand soil, which expose applied water to losses by deep-percolation to the lower layers of soil beyond the active root zone because the amount of water applied moreover, reaching to underground water which cause a pollution to underground water by the chemical and pesticides additions. It's noted that the lower amounts of water have a high value of FWUE and CWUE so it must be not less the typical economic grain yield per hectare. The last results are agree with Oktem et al. (2003) and Wan and Kang (2006). Howell et al. (1997), Camp et al. (1989), The difference refers to save water and nutrients losses by deep-percolation and evaporation, according to (Lubars, 2008), and allowing of opportunity for plant at more time to absorb nutrients and water beside have a good environment to process of photosynthesis and respiration Which reflects positively on the amount of crop. Tables (6,7)

Economic efficiency of irrigation systems (EEIS, %):

Economical irrigation efficiency is an important engineering term that involves understanding soil and agronomic sciences to achieve the greatest benefit from irrigation process. The enhanced understanding of irrigation efficiency can improve the beneficial use of limited and declining water resources needed to increase and improve crop and food production from irrigated lands.

The highest significant values of EEIS for irrigation systems are obtained by (SSIPD, SSD, SIPD and SD) respectively, on the other hand, the heights significant values for water amounts are obtained by (WT1, WT2 and WT3) respectively.

Generally, the highest values of EEIS were under SSIPD and SSD irrigation systems followed by SIPD and SD irrigation systems. Table (8).

Table 5: some yield parameters of maize under irrigation systems and water amounts

	Length of plant (m)				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT_1	4.2167 A	4.1833 A	3.9167 AB	4.1667 A	4.1208 A
75%, WT_2	4.2000 A	4.0667 A	3.9000 AB	4.3333 A	4.1250 A
50%, WT_3	3.9833 AB	3.9000 AB	3.7333 AB	3.1000 B	3.6792 B
Means	4.1333 A	4.0500 A	3.8500 A	3.8667 A	
	Number of leafs of plant				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT_1	16.000 A	16.667 A	17.000 A	17.000 A	16.667 A
75%, WT_2	16.333 A	16.667 A	16.667 A	16.333 A	16.500 A
50%, WT_3	16.000 A	16.333 A	16.667 A	16.333 A	16.333 A
Means	16.111 B	16.556 AB	16.778 A	16.556 AB	
	The weight of the plant (kg)				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT_1	2.343 BCDE	2.5743 AB	2.4500 ABC	2.7000 A	2.5169 A
75%, WT_2	2.083 DEF	2.233 BCDE	2.323 BCDE	2.423 ABCD	2.2658 B
50%, WT_3	1.837 FG	2.067 EFG	1.7333 G	2.16 CDEF	1.950 C
Means	2.0878 C	2.2914 B	2.1689 C	2.4300 A	
	The weight of the ear (g)				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT_1	460.00 BC	605.43 A	495.00 B	650.00 A	552.61 A
75%, WT_2	465.33 BC	504.50 B	506.67 B	514.50 B	497.75 B
50%, WT_3	303.33 D	323.33 D	330.00 D	423.33 C	345.00 C
Means	409.56 C	477.76 B	443.89 BC	529.28 A	
	Grain yield (ton/ha)				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT_1	27.600 BC	36.326 A	29.700 B	39.000 A	33.157 A
75%, WT_2	27.920 BC	30.270 B	30.400 B	30.870 B	29.865 B
50%, WT_3	18.200 D	19.400 D	19.800 D	25.400 C	20.70 C
Means	24.573 C	28.665 B	26.633 BC	31.757 A	
	Straw yield (ton/ha)				
	SD	**SSD**	**SIPD**	**SSIPD**	**Means**
100%, WT1	140.6 BCDE	154.46 AB	147.00 ABC	162.00 A	151.01 A
75%, WT2	125.0 DEF	134.0 BCDE	139.4 BCDE	145.4 ABCD	135.95 B
50%, WT3	110.2 FG	124.0 EFG	104.00 G	130 CDEF	117.05 C
Means	125.27 C	137.49 B	130.13 C	145.80 A	

Table 6: Crop water use efficiency of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT_1	12.400 F	16.300 BC	13.300 EF	17.500 AB	14.875 B
75%, WT_2	14.767 CDE	16.000 BCD	16.067 BCD	16.300 BC	15.783 A
50%, WT_3	13.633 EF	14.500 DE	14.833 CDE	19.033 A	15.5 AB
Means	13.600 C	15.600 B	14.733 B	17.611 A	

Table 7: Field crop water use efficiency, (kg/m^3) of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT1	11.133 F	14.667 BC	12.000 EF	15.767 AB	13.392 B
75%, WT2	13.26 CDE	14.400 BCD	14.433 BCD	14.667 BC	14.192 A
50%, WT3	12.233 EF	13.033 DE	13.333 CDE	17.133 A	13.933 AB
Means	12.211 C	14.033 B	13.256 B	15.856 A	

Table 8: Economic efficiency of irrigation systems, (EEIS %) of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT_1	71.53 BC	94.13 A	77.00 B	101.07 A	85.933 A
75%, WT_2	72.37 BC	78.47 B	78.80 B	80.03 B	77.417 B
50%, WT_3	47.20 D	50.27 D	51.33 D	65.83 C	53.658 C
Means	63.700 C	74.289 B	69.044 BC	82.311 A	

Economic and Cost Feasibility analysis:

According to statistical analysis, it's crystal clear that there's a significant influence of irrigation systems and applied water amounts on irrigation cost of water unite and irrigation cost of unite production of wheat crop. Tables. 9 and10.

The highest values of total cost of water unite, (LE/m^3) and irrigation cost of unite production, (LE/kg) of maize under irrigation systems are obtained by SD, SSD, SIPD and SSIPD resepctivle, where, under and water amounts are obtained by WT3, WT2 and WT1, in the interaction of both of irrigation system and water amounts the highest vaulrs are obtained by SD and WT3. The lowest annual cost of IPD due to the lowes price of IPD hoses where the diamter of IPD hoses is 8 mm, on the other side, the diamter of traditional common drip is 16 mm, by othe means the price of traditoonal hose equal twice the price of IPD hoses, moreover, the price of porous drippers is very sheap according to it's manufactured fro enviornmenta local materials. Which affected on fixed costs. Morover the opertaing pressure of IPD is less that tradtional dripper by 60% which affect on the energy and operating costs. In addition to the highe grain yield of full water amounts. Because the initial installation costs of drip irrigation are high, field crops together with vegetable in crop rotation, which needs more studies, would be one of the most significant factors in reducing the high overall investment costs of drip irrigation when it is used for field crop production. Tables (9,10).

Table 9: Total cost of water unite, (LE/m^3) of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT_1	0.9500 C	0.90 C	0.7367 C	0.7300 C	0.8292 C
75%, WT_2	1.2167 B	1.1867 B	0.9100 C	0.9000 C	1.0533 B
50%, WT_3	1.7500 A	1.7500 A	1.3200 B	1.3200 B	1.5350 A
Means	1.3056 A	1.2789 A	0.9889 B	0.9833 B	

Table 10: Irrigation cost of unite production, (LE/kg) of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT1	0.0850 D	0.0657 E	0.0610 E	0.0463 F	0.0645 C
75%, WT2	0.0937 BC	0.0853 CD	0.0650 E	0.0640 E	0.0770 B
50%, WT3	0.1427 A	0.1340 A	0.1000 B	0.0777 D	0.1136 A
Means	0.1071 A	0.0950 B	0.0753 C	0.0627 D	

Energy analysis

Data are tabulated in Table (11) clear the highest values of Pumping energy requirements, (hp.h) of maize under irrigation systems is for SSIP, SIPD, SSD and SD where for water amounts is WT1, WT2 and WT3 respetivly, thereason of the pumping highest energy opf IPD acording to the increasing of operating hours but in larg scale it can be the same of toal operating hours for allover the farm, and this nagtive infulence will not be according to the saving of operating pressure head. By the same token, for the interaction between both of irrigation systems and water amounts the highest values of energy requirment are obtained by SSIPD and WT3.

The operating pressure is the pressure required at the entrance to each subunit for the emitters to operate effectively and water to be uniformly distributed. The required pressure is defined by the choice of emitter and the subunit pipe network design. Pipelines are designed to distribute water to the emitters with controlled pressure losses so that water can be uniformly applied throughout the subunit. Operating pressures can be minimized by selecting emitters that operate at low pressures. According to (Smajstrla et al.2009 and Daniel H. 1997). Table.(11).

Table 11: Pumping energy requirements, (hp.h) of maize under irrigation systems and water amounts

	SD	SSD	SIPD	SSIPD	Means
100%, WT_1	110.40 D	110.40 D	421.57 A	421.57 A	265.98 A
75%, WT_2	85.68 E	85.68 E	325.47 B	325.47 B	205.58 B
50%, WT_3	60.48 F	60.48 F	229.71 C	229.71 C	145.10 C
Means	85.52 B	85.52 B	325.58 A	325.58 A	

Conclusions

Innovative follicular (porous) drip irrigation systems, saved water, nutrients and energy specially it is buried under soil surface and it's will introduce a new methods to save soil and water resources by using innovative solution based nature. The highest significant positive values of maize yield and morphological parameters are obtained under subsurface innovative follicular (porous) drip irrigation systems

Irrigation efficiency is an important engineering term that involves understanding soil and agronomic sciences to achieve the greatest benefit from irrigation. The enhanced understanding of irrigation efficiency can improve the beneficial use of limited and declining water resources which is needed to enhance crop and food production from irrigated lands. Ultra-low flow technologies are important methods of irrigation to water management that save it from loss by runoff in heavy soils or deep percolation in sandy soils.

There was high gradation for CWUE and FWUE under various water amounts; WT1 water treatment had a higher value than WT2 and WT3 under various drip irrigation systems. According to the used water amount, WT1 saved more water that saved 50% than WT2 by 25% especially at SSIPD and SSD where the difference was clear when compared to SD and SIPD drip irrigation systems.

Saving water and nutrient applied in sandy soil, can be saved up to 40% from irrigation water applied and so increasing quantity and quality of yield by good management and using ultra-low flow drip irrigation then having more total economical income.

In sandy soil, about 40% of irrigation water applied could be saved and increasing quantity and quality of peach tree (like maize physical characteristics and fruit chemical characteristics) by good management and using IPD which supports ultra-low flow drip irrigation. Also avoid the common problems which result from exceeded irrigation like water table rise, aqua fire pollution by loss of nutrients and chemical additions, nutrients and water loss by deep-percolation, non-ideal grow environment to plant due to non-maintain of air balance, and appearance of soil hardpan. On the other side, the innovative porous drippers which support ultra low flow must have a good management for preventing the soil salinity.

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