Plant Archives Volume 20 No. 2, 2020 pp. 9211-9220 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

EVALUATING OF DRIP IRRIGATION SYSTEMS FOR MAXIMIZING WATER USE EFFICACYFOR GARLIC IN DESERTSOILINAL-SADAT AREA IN EGYPT

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Abstract

Two successful seasons (2019-2020) of experiments are conducted in in AlSadat city area, AlMonufia government, Egypt. garlic was cultivated in one hectare under two modern irrigation systems, Buried drip irrigation system (BD), belt-in dripper called in Egypt (Gr), the flow is 4 l/s, 1 bar of operating pressure and 50 cm the length between drippers, there are two Gr hoses all-round the plant row on the soil surface. The last system is the control treatment as a common system in this area; the second system is the Innovative porous drippers, (IPD) which innovated from maturing earth material and expose to engineering designing tests in hydraulics Lab. The typical ultra-low flow is 0.1 l/s, 0.2 low-head operating pressure, the space between drippers is 30 cm. There are two, three and four of hoses all-round the plant row where called IPD_1, IPD_2 and IPD_3, respectively. IPD is buried under the soil surface by 15 cm. The experimental sit soil texture is (Sandy) and soil salinity the water source is aqua fire, Soil, water, yield measurements is done in addition to energy analysis and economic feasibility.

The results show that the irrigation water saving by for garlic, is 72.4%, 58.5%, 45% for IPD_1, IPD_2 and IPD_3, respectively, by the same token the highest yield is 23.5, 21.6, 14.6 and 11.7 ton/ha for IPD_2, IPD_3, IPD_1 and BD, respectively. The highest water productivity for garlic is 12, 11, 8.4, and 2.5 kg/m^3 for IPD_2, IPD_1, IPD_3, and BD respectively and finally the Irrigation Cost of water unite (LE/m^3) is 0.5, 1.32, 0.89 and 0.68 for BD, IPD_1, IPD_2 and IPD_3. The Innovative porous drippers are very economic, ecosystem and saved irrigation water.

Keywords: water, dripper, energy, economic, innovation, garlic, ecosystem

Introduction

It's crystal clear that the most using amount of fresh water is for agriculture, where it's the highest user of water in world water consumption. Agriculture consumed more than 70% and world population increases, which make stress on the necessity of food production increasing, urban increasing, industry increasing, the water scarcity is a becoming an essential issue. (IPCC, 2014). The using of sub surface drip irrigation systems saved water and raise the water use efficiency, in these systems the water used direct inside soil layers instead of surface, and this approach reduce the evaporation losses of water from soil surface. (Ayars et al. 1999). From the many advantages of sub-surface drip irrigation that: the long of hoses lifespan which are protected from sun radiation, in addition to ease the farm practices without any harmful for drip hoses, reduction of weed and fungus diseases. (Moriana et al. 2003; Melgar et al. 2008).The soil surface evaporation is measured in irrigated olive orchards using surface drip irrigation, the estimating of seasonal evaporation is ranged from 4 to 14% for a mature orchard and from 18 to 43 % for young orchard, and this results basically depends on the soil surface wetted using surface drip irrigation.Bonachela et al. (2001). It's recommended to use sub-surface drip irrigation according to reduction of soil surface evaporation comparing with the evaporation rate in the traditional flood irrigation, but it's better than surface drip irrigation without any side effects of crop yield or quality**.** Umair et al. 2019.

Saving water and nutrient applied in sandy soil, can be saved up to 40% of 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 the quantity and quality of peach tree (like fruit physical characteristics and fruit chemical characteristics) by good management and using 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. (Omima and El-Hagarey 2014). Garlic (Allium sativum L.), is a second vital cultivated Allium species after onion worldwide. In Egypt, garlic is a high-value cash crop (Abdel-Razzak and El-Sharkawy, 2013). Egypt ranks the fourth leading country in the world for garlic production (244.626 MT) after China, India and Korea (FAO, 2011, Mansour, 2006, Mansour 2015, Mansour et al. 2015a,b,c,d, Mansour et al. 2016, Mansour et al. 2019a,b,c,d,e and Abou El-Magd et al. 2012). Increasing safe food production is a global demand. Also, increasing yield is the most important agroeconomic goal of farmers. Conventional macro and micro elements fertilization has a superior effect on plant growth and yield, but these are expensive and environmentally hazardous due to leaching out, contamination of the Buried water and water basins and damaging beneficial microorganisms (Hilman and Asandhi, 1987). In Egypt, the average annual area cultivated with garlic varieties was estimated at 29,961 fed (12,584 ha) and the total national production of garlic is about 276,556 tons (Economic Affairs Sector, 2015).

The aim of this investigation is irrigation water saving by the field evaluation of the Innovative porous rippers, (IPD) under operating conditions comparing with the traditional system in the same field Buried soil belt-in dripper (Gr) irrigation system,

Abbreviations and Acronyms

BD	=	Buried traditional drip irrigation system (Gr),
IPD	=	Innovative porous drippers,
IPD_1	=	Two of hoses all-round the plant row, 50% of applied water
IPD_2	=	Three of hoses all-round the plant row, 75% of applied water
IPD_3	=	Four of hoses all-round the plant row, 100% of applied water
W_p	=	Water productivity, (kg/m^3).
W_A	=	Amounts of applied water, (m^3/ha),
Ws	=	Irrigation water saving percentage, (%),
TGY	=	Total grain yield (Mg/ha)(ton/ha).
PP	=	Pumping power, (hp),
Er	=	Pumping energy requirements, (hp.h)
EAE	=	Pumping energy applied efficiency, (kg/hp.h),
IC	=	Initial cost,
F	=	Annual fixed cost (F):
O	=	Operating cost,
EC	=	Energy cost,
TAC	=	Total annual cost (LE/year), and
ICW	=	Irrigation Cost of Water unite (LE.m^3),

Material and Method

Field experimental site:

The Innovative porous drippers, (IPD) was applied irrigation system located at a private farm in in AlSadat city area, AlMonufia government, Egypt. And garlic is cultivated under both of tow irrigation systems, There are two, three and four of hoses all-round the plant row where called IPD_1, IPD_2 and IPD_3, respectively,

Irrigation systems:

The irrigation system consists of the following components:

First: traditional drip irrigation system, Gr drip irrigation system.

Control head consists of centrifugal pump 5/5 inches (6m lift and 50 m^3/h discharge), driven by diesel engine (50 Hp), pressure gauges, control valves, inflow gauge, water source was aquafire. Traditional drip irrigation system (Gr, 4 l/h, 50 cm of length between drippers, operating pressure is 1 bar) is installed in two methods (surface drip and Buried drip).

Second: the Innovative porous drippers, IPD drip irrigation system:

The second system is the Innovative porous drippers, (IPD) which innovated from maturing porous earth material and expose to engineering designing tests in hydraulics Lab. The typical ultra-low flow is 0.1 l/s, 0.2 low-head operating pressure, the space between drippers is 30 cm. the desired IPD flow is selected according to the evaluation of design engineering and hydraulic parameters of IPD, according to (El-Hagarey, 2014 and El-Hagarey, et al. 2016)

Garlic under both of two drip irrigation systems:

Garlic was planted under in one hectare under two modern irrigation systems, Buried drip irrigation system (BD), belt-in dripper, there are two Gr hoses all-round the plant row on the soil surface. The last system is the control treatment as a common system in this area; the second system is the Innovative porous drippers, (IPD. There are one, two and three of hoses all-round the plant row where called IPD_1, IPD_2 and IPD_3, respectively. IPD is buried under the soil surface by 15 cm.

The last hoses distribution is services that the various amount of applied water under IPD systems, where,

IPD_1, IPD_2 and IPD_3 means that there are two, three and four of hoses all-round the plant row, respectively.

The statistical design was completely random blocks.

Irrigation requirements:

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

Irrigation process was done twice per week by calculated crop consumptive use (mm/day) according to Doorenobs and Pruitt (1977).

Water requirements for galricver were calculated according to the following equation as recommended by Keller and Karmeli (1975).

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

Where:

IR	=	Irrigation water requirements, m^3/ha/day.
E to	=	Potential evapotranspiration, mm day-1
Kc	=	Crop factor of garlic
A	=	Area irrigated, (m2)
Ea	=	Application efficiency, %.where 60% in modified furrow irrigation.
LR	=	Leaching requirements.

Crop factor of garlic was used to calculate Etcrop values, according to FAO,(1984).

Irrigation water saving percentage

Water saving was estimated according to the following equation

Water saving, (Ws) = (If – In) / If x 100

Where:

I_n	=	Irrigation water requirements, m^3/ha/day. Water use for control treatment (m^3/ha), and
I_f	=	Potential evapotranspiration, mm day^{-1}

Fertilization program:

For garlic, the amount of fertilizers were applied according to the recommendations of Field Crop Institute, ARC, Egypt, Ministry of Agriculture and Land Reclamation for garlic.

Measurements and calculations:

Total grain yield (Mg/ha.)(ton/ha.).

Water productivity, (WP).

It was calculated according to Talha and Aziz 1979 as follows.

WP = Grain yield (kg/ha)/ water applied (m^3/ha).

Pumping energy requirements:

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

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

$$Bp = \frac{Q * TDH}{Ei * 75}$$

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

Irrigation was operated at total dynamic head (1.0m) for all of planted season.

Pumping energy requirements (Er) (Hp.h) were calculated as follows:

Er = Bp * It

Where:

It = Irrigation time per season (h).

Pumping energy applied efficiency (EAE) was calculated as follows:

$$\text{EAE (kg/Hp.h)} = \frac{\text{Total fresh yield}}{\text{Energy requirements}}$$

Cost analysis:

Cost analysis to evaluate the drip irrigation systems was computed according to Worth and Xin (1983) .

Fixed cost is calculated according to market price level of 2020 for equipment and operating irrigation process. Cost analysis is based on one hectare, (48m× 200m).

1– Initial cost (IC) :

(IC)(LE/ha.)=Drip irigation system price (LE)*Item quantity per ha

2– Annual fixed cost (F):

Annual fixed cost (LE/year) invested in the irrigation systems was calculated according to the following equation:

$$F = D + I + T$$

Where:

F	=	Annual fixed cost (LE/year),
D	=	Depreciation rate (LE/year),
I	=	The interested (LE/year).
T	=	Taxes and overhead ratios (LE/year) taken 1.5% from initial cost..

Depreciation rate cost was calculated using the following equation :

$$D = (I.C – D.C) / E.L$$

$$I = (I.C + D.C) \times 0.5\ IR$$

Interest on initial was calculated as follows:

Where :

I.C	=	Initial cost (LE/ha)
D.C	=	Price after depreciation (LE)
E.L	=	Expected life (year)
IR	=	Interest rate per year (taken 14%).

Taxes and overhead ratios were taken as 1.5 % of initial cost.

3– Operating cost (O):

Annual operating cost (LE/year) of the capital investment in the irrigation system was calculated as follows:

$$O = L + E + (R \& M) + IS$$

Where:

O	=	Operating cost
L	=	labor cost (LE/year).
E	=	Energy cost (LE / year).
R & M	=	Repair and maintenance cost (LE / year).R & M cost taken as 3 % of initial cost .
IS	=	Lateral installation cost (LE / year).

Energy cost was calculated as follows:

$$Bp = (Q * TDH) / k * E$$

Where:

Bp	=	Break horse power (Hp)
Q	=	Discharge rate (L/s)
TDH	=	Total dynamic head (m).
K	=	Coefficient to convert to energy unit, 1.2
E	=	The overall efficiency, 55% for pump driven by internal combustion engine.

The power cost of diesel type source was calculated using the following formula:

$$E.C = 1.2\ Bp\ H * S * F.C$$

Where:

E.C	=	Energy cost of diesel (LE/Hp)
H	=	Annual operating hours (h).
S	=	Specific fuel consumption (L/Hp.h).
F.C	=	Fuel price (LE).
1.2	=	Factor accounting for lubrication.

4–Total annual cost (LE/year) = F + O

5- Irrigation cost of water unite (LE/m^3).

6– Unit production irrigation cost (LE/kg) =

7- Economic efficiency of irrigation systems (EEIS, %).

$$\left[\frac{\text{Annual irrigation cost (LE/m}^3\text{)}}{\text{FWUE (kg/m}^3\text{)}}\right]$$

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

EEIS = (Actual yield ÷ typical yield)

Results

Applied amounts of water

Results show that the highest applied water is BD, IPD_3, IPD_2 and IPD_1 respectively, where the highest saving water is 58 and 50% IPD_1, IPD_2 and IPD_3 respectively, the significant saved water is due to the desired appllied treatment experiments, on the other hand it necessary to save the yields and quality according to economic criteria, according to (Houda et al. 2018). There are a water loss by deep percolation under drip irrigation system may be reached to 45% of supply water according to the sandy soil texture which has a low water hold capacity, and the mismatch of irrigation requirements and water consumptions, moreover, the water losses by soil surface evaporation which reach to 43% in some conditions in semi arid area, according to (Bonachela, et al. 2001& Nassah *et al.*, 2018), IPD systems reduce a water losses by both of deep-percolation and surface evaporation which increase the saving water and water productivity. Figure.1.

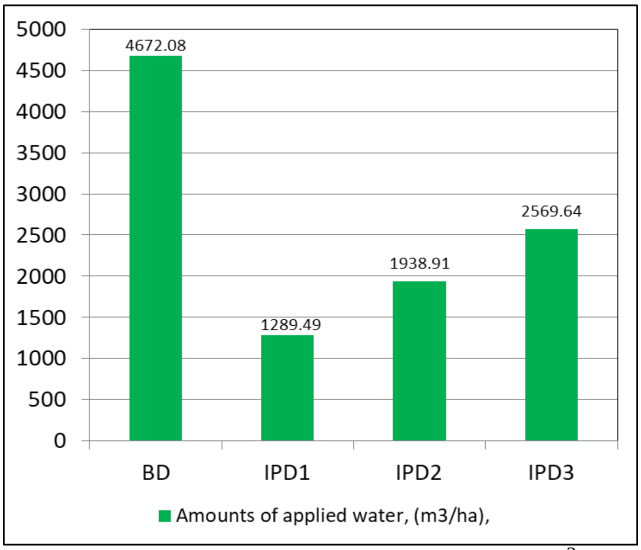

Fig. 1: The applied amounts of irrigation water, m^3/ha.

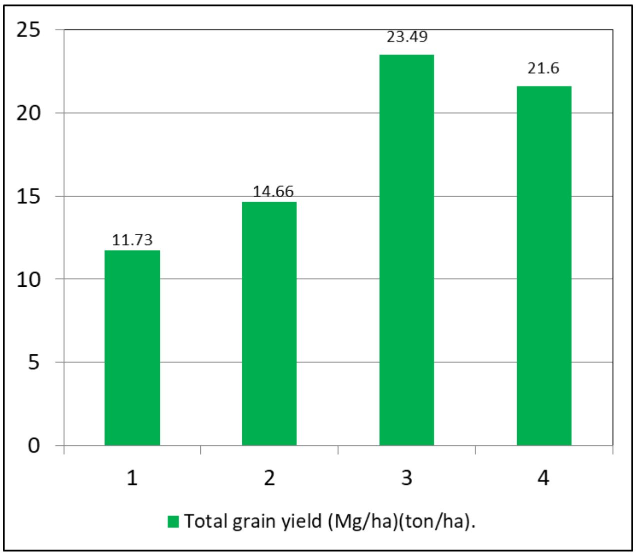

Fig. 2: Total grainyield of garilc under irrigation systems, (Ton/ ha).

Total grain yield (Ton/ha.)

The total grain yield of garlic is estimated for every treatment. The highest significant grain yield is 23.2, 21, 14.3 and 14.4 ton/ha for IPD_2, IPD_3, IPD_1 and BD respectively. The significant increasing of grain yield for both of IPD_2 and IPD_3 is due to the water appliying approach which realized using IPD irrigation systems. In addition to IPD2 is higher than IPD_1 because the garlic is sensitive to the increasing of moisture contents and need to a lot of air for growth and expanded where the garlic crop is under soil surface, especially the soil is calcareous soil. IPD depends on the ultra-low flow of IPD which give the water a chance to move slowly and not under head pressure on soil layers, as a result of the low applied amounts in a long time, by the same token give the plant a high plenty of time to have their requirements of water, As a consequence give a high plenty of time to nutrients to have a fully soluble environment. As a result of this a lot of nutrient92159215s are becoming facilitated for plant and this new approach is returned by the high best benefits of the plant. The results of BD are agreement with (Abd El-Hady, M., Ebtisam I. Eldardiry, 2016 - Abd El-Latif Kh. M. and A. A. Abdelshafy, 2017). In addition to the minimum or less fluctuation in the soil moisture in the effective garlic root zone support the increment of yield. Figure.2.

Water productivity, (WP)

The water crop productivity values clear that the highest significant is 12, 11.4 and 8.5 kg/m3 for both of IPD_2, IPD_1 and IPD_3 respectively, correspondingly, the crop productivity value for BD is 2.4 kg/m3. According to Martínez J. and J. Reca, 2014 .As we have seen, there is a big gap of both of crop productivity values of both of traditional drip irrigation systems and innovative porous drip systems according to the new technique of water application, where the IPD irrigation systems is working based on soil moisture constants, by other means, the water potential of soil can contribute to suck water from the dripper porous. Moreover this potential increasing whenever the soil moisture contents is low and close to the welting point, so that the suction increasing, hence the flow of IPD increase as a result for the last soil case. In comparison, when the soil moisture contents is close to field capacity and then saturation point the soil water potential will decrease, by the same token, the flow of IPD is responsible to soil water potential and decrease automatically. The investigation of IPD is considered a nuclear of automatic irrigation system without any external applied energy. Which support ecosystems and climate act which are realized to UN-SDGS. Figure.3.

Energy analysis

Pumping energy requirements

The pumping energy requirments is an idicator for the operating pressure head. The operation pressure head of traditional drip irrigation systems is 1 bar (10 meters head), and dripper flow is 4 l/h. On the other hand, the operating pressure of IPD is 0.2 bar (2 meters head). Accordingly, the lowest pumping energy requiremnets is IPD including the three types of hoses nomber allround the plant row. But, there are any significant difference between them. In comparison, the highest significate pumping energy requirements is both of tradtional drip irrigation. And also there are any significant difference between them. By the sam token, the pumping power for two systems, It is quite predictable that the carbon emissions (GHG) will reduce for IPD according to reduction of pumping energy requirments. These results are compeletly agreed with the UN SDGs, specialy with the goal No. 13 (climate action) and the goal No. 15 (life on land), Figure.4.

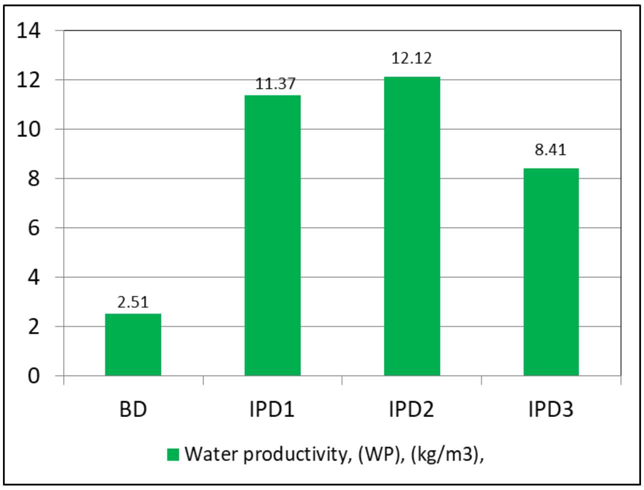

Fig. 3: Water productivity of garilc under irrigation systems, (kg/m^3).

Pumping energy applied efficiency (EAE)

The pumping energy applied efficiency equlas the ratio between total fresh crop yield and energy requirments. To estimate the feasbility of applied energy. Data clear the the highest signifcate value of EAE is 257,236.7, 167 and 160 kg/hp.h for IPD$_2$, IPD$_3$, BD and IPD$_1$ respectivly. Having considered the pressure reduction, it is also reasonable to look at the increasing of operating hours of IPD which may be reduce pumping energy applied efficiency (EAE) especially for 50% of supplied water for IPD$_1$, but it's still the highest for both of IPD$_2$ And IPD$_3$, respectively. Fig.4.

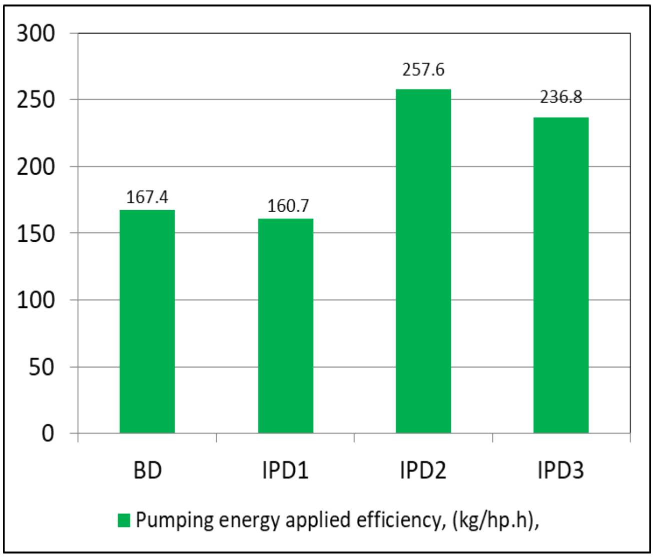

Fig. 4: Pumping energy applied efficiency of irrigation systems, (kg/hp.h).

Cost analysis:

Initial cost (IC) :

The significant highest initial cost is 23165 LE/ha for and BD 16690 and 16435 LE/ha for IPD$_3$, IPD$_2$ and DFD, respectively.The initial cost of two irrigation systems are calculated according to the market price in 2019, Per one hectare. The values of IC clear that the IC of hoses is cut to half according to use a small hoses in IPD system (8 mm), In comparison, the diameter of traditional drip irrigation hoses is (16mm), so that the initial cost of hoses for IPD system is lower than GR irrigation systems. Accordingly, the IPD systems is more economical than traditional drip systems.

Annual fixed cost (F):

The significant highest value of annual fixed cost is 1502, 1102, 1082 and 1063 for BD, IPD$_3$, IPD$_2$ and IPD$_1$ respectively. The annual fixed costs of two irrigation systems are calculated according to the market price in 2019. The initial costs include capital costs, depercation, interest, taxes and insurance

The value of annual fixed costs clear that the highest significat value is BD and then the IPD$_3$, IPD$_2$ and IPD$_1$, the significant deffrence between IPD ans (BD) is due to the hoses diameter. The significant difference of IPD$_3$, IPD$_2$ and IPD$_1$ is due to the number of hoses allround the plant row where IPD$_3$ means there are four hoses allround the plant row where, IPD$_2$ and IPD$_1$ means there are three and two hoses, respectively allround the plant row. Figure.5.

Operating cost (O)

Operating costs is the summation of labor costs, energy costs, repair, maintenance and installation costs.

Energy cost

The significant highest value of energy cost is 58, 57.6, 57.3 and 45 LE/ha for IPD_1, IPD_2, IPD_3 and BD respectively. As we have seen the energy cost of IPD systems is higher than traditional drip irrigation systems But we should also consider, the factors of energt cost equation, it's so important to note that the annual operating hours which multiplied to the other factor and increasing the value of energy cost, Although, IPD system is still economic according to other factors covering this increasing of operating cost. It's crystal clear in operating costs and total annual costs. The end of economic feasibility, the IPD systems is more feasibility more than traditional drip systems.

Total annual cost (LE/year)

The total annual cost is the summation of both of total fixed annual costs and total operating annual costs, the highest significant value of total annual cost 2328.3, 1755.7, 1727 and 1700 LE/ha for BD, IPD_3, IPD_2 and IPD_1, respectivly. The total annual cost of IPD system is lower than traditional drip irrigation systems by 27% which means the modern IPD system saved about 27 of annual costs of irrigation process. So IPD is more economic. Figure.6.

Irrigation cost of water unite (LE/m^3)

The unite Irrigation cost of water expresses the cost of puming a unite of irrigation water (qubic meter), during irrigation proces and through irrigation net or throu any irrigation system, the significante lowest value of Irrigation cost of water unite is 0.5, 0.68, 0.88 and 1.32 LE/m^3. for BD, IPD_3, IPD_2 and IPD_1, as we have seen, the mean of unite Irrigation cost of water of IPD system is higher than mean of BD, further point to be considered.that the cause of last results is the ammount of applied water, in IPD the amount applied water is lower than it in traditional drip irrigation. Where the unite Irrigation cost of water is the ratio between annual costs and annual applied water amount. Accordingly, the mean value unite Irrigation cost of water under IPD is higher than it in traditional drip irrigation systems.

Unit production irrigation cost (LE/kg)

The unite production unite costs express the ratio between annual irrigation costs and crop yield in the same area unite. The siginficante highest value of UPIC is 0.15, 0.12, 0.07, 0.04 LE/kg. for BD, IPD_1, IPD_2 and IPD_3 respectivly.

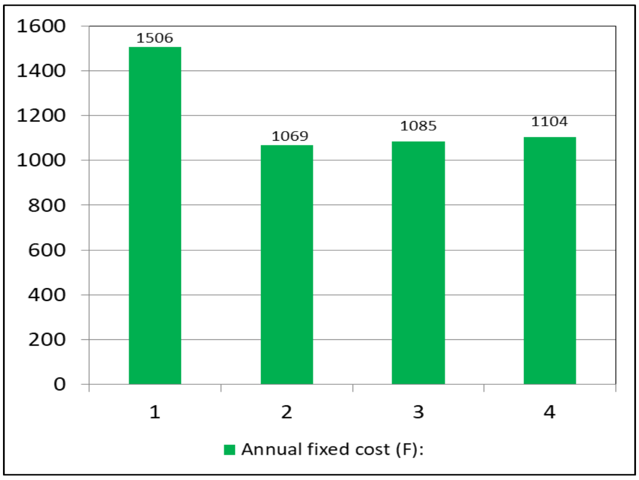

Fig. 5: Annual fixed costs of irrigation systems, (LE/ha).

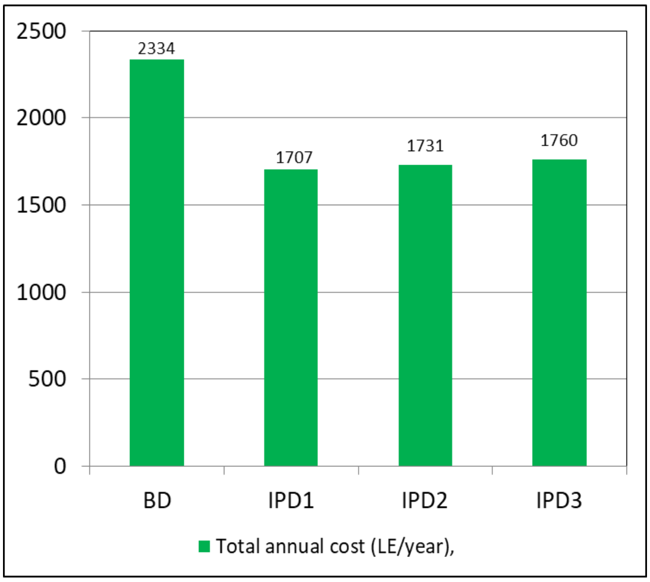

Fig. 6: Total annual costs of irrigation systems, (LE/ha).

Economic efficiency of irrigation systems (EEIS, %)

The Economic efficiency of irrigation systems (EEIS, %) is the ratio between actiual yield and typical yiled for the same area unit under the same conditions, as it possible. It's important to mention that the economic yield of garlic in Egypt is 12.6 ton/ha accroding to (Economic Affairs Sector, 2015). The claculations of EEIS considered the typical yield is 12.6 ton/ha.

Conclusion

For garlic crop, Irrigation water is saved by the Innovative porous rippers, (IPD) under the field evaluation and comparing with the traditional system in the same field Buried soil belt-in dripper (Gr) irrigation system, the innovative porous drippers (IPD) systems introduce a new semi-automatic generation from micro-drip irrigation system which works based on soil moisture contents and under arid and semi-arid area. The IPD is best economic, ecosystemic, controlling, saving water and self-compensating of both flow and pressure, finally IPD saved more than of 72% of supplied water for garlic under desert conditions, By reduction of soil surface evaporation and deep-percolation losses. So the higehst significant value of EEIS is IPD_2, IPD_3, IPD_3 and BD respectivly, so the best irrigation system which garlic yield resopnse to it is IPD_2. . IPD_2 systems succseses to save 58% from supplied water and products a highest significat yield 23.2 Ton/ha. In addtition to saved 72 and 45% for both of IPD_1 and IPD_3, respectivly, It's important to mention that both of IPD_2 and IPD_3 increasing crop yiled productivity by 32.5% of economic yield.

Table 1: The significant influence of irrigation of garlic crop

	W_A	W_s	TGY	WP
BD	4671.3A	5.0433D	11.627E	2.4367E
IPD_1	1288.0D	72.183A	14.390D	11.357B
IPD_2	1937.2C	58.083B	23.220A	12.023A
IPD_3	2568.1B	44.917C	21.033B	8.4633C
	PP	**Er**	**EAE**	**IC**
BD	2.3000A	69.880B	167.20D	23165A
IPD_1	1.1300B	91.233A	160.37E	16435 D\
IPD_2	1.1300B	91.167A	257.30A	16690C
IPD_3	1.1367B	91.383A	236.73B	16977B
	F	**O**	**EC**	**TAC**
BD	1502.3A	826.00A	45.000B	2328.3A
IPD_1	1063.0D	637.00D	58.333A	1700.0D
IPD_2	1082.3C	644.67C	57.333A	1727.0C
IPD_3	1102.0B	653.67B	57.667A	1755.7B
	ICWU	**IPIC**		
BD	0.5000D	0.1473A		
IPD_1	1.3167A	0.1150B		
IPD_2	0.8833B	0.0743C		
IPD_3	0.6800C	0.0390D		

BD =	Buried traditional drip irrigation system (Gr),
IPD =	Innovative porous drippers,
IPD_1	= Two of hoses all-round the plant row, 50% of desired applied water,
IPD_2	= Three of hoses all-round the plant row, 75% of desired applied water,
IPD_3	= Four of hoses all-round the plant row, 100% of desired applied water,
W_A	= Amounts of applied water, (m^3/ha),
W_s	= Irrigation water saving percentage, (%),
TGY	= Total grain yield (Mg/ha)(ton/ha).
WP	= Water productivity, (WP), (kg/m^3),
PP	= Pumping power, (hp),
Er	= Pumping energy requirements, (hp.h)
EAE	= Pumping energy applied efficiency, (kg/hp.h),
IC	= Initial cost,
F	= Annual fixed cost (F):
O	= Operating cost,
EC	= Energy cost,
TAC	= Total annual cost (LE/year),
ICWU	= Irrigation Cost of water unite (LE.m^3), and
IPIC	= Unit production irrigation cost (LE/kg).

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