Menoufia J. Soil Sci., Vol. 6 April (2021): 87 - 110 https://mjss.journals.ekb.eg/

CHARACTERIZING WATER DISTRIBUTION OF FURROW IRRIGATION TO IMPROVE SOIL PRODUCTIVITY IN NORTH NILE DELTA OF EGYPT

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Received: Mar, 6 , 2021 Accepted: Apr. 17 , 2021

ABSTRACT: Field trials were conducted at Sakha farm, Kafr EL-Sheikh Governorate, Egypt to find the best interaction between furrow design, cut-off irrigation, Alternative furrow irrigation, discharge and phosphorus fertilization to enhance faba bean productivity and profit (Net Return) of North Nile Delta soils. Design and evaluate the effect off cut off irrigation (100 % (I_1), 90 % (I_2) and 85 % (I_3) from furrow length) and alternative furrow irrigation (I_4) with 4 lps/m irrigation discharge and four fertilization treatments; F_1 (100% Rp, as control), F_2 (75 % Rp +Phosphorien), F_3 (65 % Rp+ Phosphorien) and F_4 (55 % Rp+ Phosphorien) on infiltration characteristics, intake family and chosen irrigation parameters with post irrigation of feba bean crop.

The results showed that, the infiltration rate decreased rapidly at elapsed time 4 hours in the two studied seasons and individual regression is considered representative of the soil intake conditions. The distribution uniformity for applied water is more than 0.9 under different cut-off irrigation and alternative furrow irrigation. Application efficiency increased as intake family decreased and is the best discharge management for furrow inflow rate at 2 lps/m.

The measured irrigation time, and advance time was higher than the designed. While the designed recession time, opportunity time and the ratio between irrigation time and advance time were higher than measured values. The ratio of inflow time to advance time for design parameters is more than 2 meanwhile, the design is valid in studied soil. The highest ratio was obtained with cut-off at 85% from furrow length. It can be concluded that the highest values of irrigation application efficiency were obtained with cut-off at 85% from furrow length for design and measured parameters. Concerning the economic evaluation, I_4 combined with F_3 achieved the highest values of net return and benefit cost ratio followed by combined treatments I_3F_3, while the lowest values of specific cost was detected with I_4F_3.

Key words: ***Irrigation Efficiency, Cut-off, Irrigation uniformity, Irrigation discharge, feba bean, furrow design, economic return.***

INTRODUCTION

Irrigation water management is very important in Egypt due to shortage in water resources which restricted the expansion of agriculture in newly reclaimed lands (Asseng et al., 2018). Water supply in Egypt is limited to the average annual share of the Nile water at Aswan (55.5×10^9 m^3) plus some minor quantities of groundwater and rainfall.

Water shortage that faces Egypt is in continuous increase, and it is prospected to reach the threshold level of less than 500 m^3 yr^{-1} $capita^{-1}$ (EL-Quosy, 1998). Surface irrigation is currently practiced on about 90% of the irrigated land in Egypt, generally at low levels of

performance (e.g., poor application efficiency).

Improper On-Farm irrigation practices lead to poor water distribution, non-uniform growth, excess leaching in some areas (leading to water logging), and insufficient leaching in others (leading to soil salinity buildup), all of which decrease the yield per unit of both land area and water applied (Mohamedin et al., 2010; Aragues et al., 2011; Periera et al., 2012).

Furrow irrigation is widely used because of its low cost and energy requirement (Holzapfel et al., 2010). The furrow irrigation system should be designed to ensure an adequate and uniform water distribution over one field and to minimize the potential water losses. Many researchers have engaged in optimizing the design of furrow irrigation system to improve irrigation performance which is depended on numerous factors including furrow inflow rate, application time, soil infiltration characteristics, furrow geometry, field slope, spacing, surface roughness, length and irrigation requirement (Periera and Trout, 1999).

Moreover, the irrigation performance also depends on farmer irrigation decision, mainly in relation to land leveling, maintenance, timeliness and time duration of every irrigation event, in addition to farmer's ability to overcome difficulties in water supply. Therefore, it is necessary to search for solutions that lead to achieve adequate compatibility among irrigation performance, water saving and economic for sustainable irrigation.

Improvements in irrigation practices such as level furrow irrigation, surface flow and alternative furrow irrigation are the main factors affecting directly the irrigation efficiencies (EL-Hadidi et al., 2008; Aiad, 2003; EL-Shahawy, 2004; Gillies et al., 2008).

Also, the cut-off irrigation event, the water front moves to irrigate more cultivated areas. This technique considered as a direct simple effective way in water saving (Amer, 2011; Kassab (2012); EL-Hadidi et al., (2016) and Khalifa (2016 and 2019).

Khalifa et al., (2018) evaluated the effect of level border irrigation system under different irrigation water discharge and cut-off irrigation on the infiltration characteristics, intake family and some irrigation parameters under post irrigation of wheat crop. They concluded that the design of border irrigation under different irrigation discharge and cut-off, is reasonably efficient limitation designs.

Aiad et al., (2019) concluded in cotton experiment that application efficiency is acceptable for inflow rate at 2 lps/m width along with land leveling of 0.1%, providing the importance of using soil conservation service (SCS) in design furrow irrigation system in the clayey soils at North Nile Delta (Egypt).

Numerous studies were carried out to enhance irrigation efficiency to achieve the proper economic use of the water. The good design of gated pipes with precision land leveling improved the water distribution uniformity and saved irrigation water by about 12% to 19% in cotton and wheat, respectively (Abo Soliman et al., 2008, Abdel Reheem, 2017 and Khalifa, 2019).

The objective of this study is to evaluate the implemented design of furrow irrigation system under condition of cut-off irrigation and alternative irrigation in case of post planting irrigation of faba bean crop and economic evaluation in clay soil at North Nile Delta region.

MATERIALS AND METHODS

1. Location and Soil characteristics of the studied area

Field trials were conducted in Sakha Agricultural Research Station, Kafr EL-Sheikh Governorate during two successive winter seasons of 2015/2016 and 2016/2017. The station is sited at 31º 07⁻ N latitude, 30º 57⁻ E longitude. It has an elevation of about 6 meters above the mean seav level. It represents the conditions of middle northern part of the Nile Delta region.

Soil samples were taken before sowing of faba bean from 4 depths namely: 0-15, 15-30, 30-45 and 45-60 cm, respectively. The soil samples were air dried, grounded, sieved and stored for physical and chemical analyses. Soil particle size distribution was carried out using the pipette method, to obtain soil texture. Soil bulk density and total porosity were measured using the core sampling technique as described by (Campbell, 1994). Infiltration rate (IR) cm hr^{-1}: was determined by using blocked furrow infiltrometer before planting, before post irrigation and after harvesting. Soil water constants, *i.e.,* field capacity (FC) and permanent wilting point (PWP) were determined using pressure cooker method at 0.33 and 15 atmosphere, respectively (Klute, 1986).

Soil reaction (pH) in soil suspension (1: 2.5) and EC in soil paste extract were measured as mentioned by Page *et al.*, (1982). Soil Physical and chemical properties of the experimental fields are shown in Table (1).

2. Agronomic practices and Field trails layout

Faba bean crop (*Vicia faba L*), Sakha 1 variety was chosen. The seeds were sown on Nov., 25th, 2015, Nov., 20th 2016. Date of harvesting take place in April, 9th, 2016 and April, 6th, 2017 in the 1st and 2nd seasons, respectively. In the two growing seasons, field preparation, land leveling (0.1% ground surface slope) and agronomic practices were performed as recommended in the area according to the usual agricultural practices.

Table (1): Some soil chemical and physical properties of the experimental field before planting faba bean crop (mean of the two seasons)

Soil depth cm	pH (1:2.5)*	EC dS m^{-1} **	SAR	Particle size distribution %			Textural class	Basic IR. $cmhr^{-1}$	Bulk density mg m^{-3}	Soil moisture constants***		
				Sand	Silt	Clay				FC %	PWP %	Aw %
0-15	8.1	3.76	8.51	16.5	27.2	56.3	Clay	0.88	1.28	45.12	24.1	21.02
15-30	8.19	3.78	7.62	16.72	28.41	54.87	Clay		1.36	44.2	23.38	20.82
30-45	8.32	4.10	8.64	17.53	29.12	53.35	Clay		1.38	39.55	21.24	18.31
45-60	8.14	4.23	8.27	19.1	29.6	51.3	Clay		1.4	37.46	21.12	16.34
Mean		3.97	8.26	17.46	28.58	53.96	Clay		1.36	41.58	22.46	19.12

IR: Infiltration rate FC: Field capacity PWP: Permanent wilting point AW: Available water
*** suspension ** soil paste extract *** as gravimetric method**

Faba bean was planted in strips, each strip contains 10 furrows. Each furrow was 100m long and 0.7m width (i.e., the area of each irrigation treatment was 700m^2,0.07 ha).

Strip block design, with three replicates, was used. The irrigation treatments (main plots) were as follows:

I_1: Full irrigation (i.e., 100% of furrow length)

I_2: cut-off irrigation at 90% of furrow length

I_3: cut-off irrigation at 85% of furrow length

I_4: Alternative irrigation, i.e., full irrigation of one furrow and leave next furrow dry (No-cutoff).

While, subplots were the fertilization treatments as follows:

F_1= adding the 100% of recommended dose of mineral-P (Rp) as (control treatment)

F_2= adding 75% of Rp+ phosphorien (as biofertilizer)

F_3= adding 65% of Rp+ phosphorien

F_4= adding 55% of Rp + phosphorien

3. Hydraulic relationships

The hydraulic relationships were basically developed by the soil conservation service (USDA, 1974 and 1979). These relationships rely on the infiltration concepts. Infiltration constants are required for the design of the surface irrigation systems. The soil was divided into different intake families, based on the final intake rate.

The equations of the design furrow irrigation system were presented, as described by EWUP (1983) as follows:

$SO=0.0875\ QF^{0.5419}/L$ ………………. (1)

where:

SO: slope (m/m)

QF: flow rate (l/sec)

L: furrow length (m)

$P=0.2647\ (QFn/SO^{0.5})^{0.4247}+0.2274$ …… (2)

where:

P: wetted perimeter of furrow (m)

QF: flow rate (l/sec)

SO: slope of furrow (m/m)

n: surface roughness, n (usually 0.04)

- $Tn=\left(\frac{\frac{W}{P+K}Du-c}{a}\right)^{\frac{1}{b}}$ …………………… **(3)**

where:

Tn= net infiltration time (min.)

W= Furrow spacing (m)

P= adjusted wetted perimeter (m)

a,b and c: are function parameters

C= 7.0747+1.7877 (intake family)

Du: the desired net depth of infiltrated (mm)

- $Ta=\frac{PL}{60QF}\left(aT^{b}oa+6.985\right)$ ………… **(4)**

where:

P: adjusted wetted perimeter (m)

L: furrow length (m)

QF: inflow rate (l/sec)

Ta: irrigation time (min.)

Toa: opportunity time (min.)

- **Toa= Tn +(** $\frac{1}{\frac{c}{L}\left(\frac{dL}{QS^{0.5}}\right)^{2}}\left(\left(\frac{dL}{QS^{0.5}}-1\right)e^{(dl/QS^{0.5})}+1\right))$ …… **(5)**

where:

Tn: net infiltration time (min.)

C: 7.0747+1.7877 (intake family)

d: $9.2493\times10^{-5}+3.263\times10^{-4}$ IF

L: furrow length (m)

S: furrow slope (m/m)

Tt= $\frac{L}{C}\ e^{\left(\frac{dl}{QS^{0.5}}\right)}$ ……………………………… **(6)**

Where:

Tt: advance time (min)

C: 7.0747 +1.7877 (IF)

d:$9.2493\times10^{-5}+3.263\times10^{-4}$ IF^{-}

Q: inflow rate (l/sec)

S: furrow slope (m/m)

L: furrow length (m)

- **Da=** $\frac{60\ QF\ Ta}{WL}$ …………………………… **(7)**

Where:

Da: depth applied in (mm)

QF: inflow rate (l/sec)

Ta: application time (min.)

W: furrow spacing (0.7m)

L: furrow length (m)

- **DP= Da – Du……………………………(8)**

Where:

DP: deep percolation (mm)

D_a: depth applied in (mm)

Du: net desired depth of infiltrated (mm)

- **Deep percolation ratio:** $\frac{DP}{Da}$……………(9)

Where:
DP: deep percolation (mm)
Da: depth applied (mm)

- **Ea=** $\frac{Dau}{Da}$………………………………(10)

Where:
Ea: application efficiency,(%)
Dau: desired depth of infiltration (mm)
Da: depth applied (mm)

- **Er=**$\frac{Dau}{Du}$…………………………………..(11)

Where:
Er: requirement efficiency (%)
Dau: desired depth of infiltration (mm)
Du: net desired depth of infiltrated (mm)

4. Amount of applied water

Irrigation water was delivered through a weir at the discharge rate of 4 l sec^{-1} m^{-1} at 10 cm as effective head over the crest and the amount of applied water was calculated using the following equation:
$Q=1.84\ LH^{1.5}$, where
Q= rate of discharge, m^3 min^{-1}, L= length edge of weir (0.5m)
H= height column of water above edge of weir, cm.

Each cultivated furrow (100 m long) was divided into with 10 m increment different stations (10). The advance time for reaching the water front during irrigation at each station, as well as at the end was recorded from the beginning of the watering event. Consequently, the corresponding time, to disappear (recession time) at each station was also recorded. The differences between advance time and recession time expressed as the opportunity time of irrigation at each station.

5. Water consumptive use (CU): **was calculated using the following equation of Israelsen and Hansen (1962)**

$$CU = \sum_{i=t}^{i=n} (\theta 2 - \theta 1)/100 * Dbi * Di \text{, where}$$

CU= water consumptive use (cm) in the effective root zone (60 cm).
ϴ2= soil moisture % 48 hours after irrigation
ϴ1= soil moisture % before the next irrigation
Dbi= Bulk density of the specific layer(Mg m^{-3})
Di= soil layer depth (15cm)

6. Water productivity (WP)

Water productivity (WP) was calculated by the following equation according to Ali et al. (2007).
WP= seed yield kg fed^{-1}/ water consumptive use (m^3 fed^{-1})

7. Productivity of irrigation water (PIW)

Productivity of irrigation water (PIW) was calculated in kg m^{-3} for different treatments to clarify how much kg seed yield is produced from one cubic meter of applied water (Ali et al., 2007).

PIW= seed yield (kg fed^{-1}) / applied water ($m^3 fed^{-1}$)

8. Evaluation of furrow irrigation:

All continuous furrows or alternative furrow irrigation with using cut-off irrigation technique was calculated according to equation described by James (1988) as follows:
R_Z= D (ϴfc-ϴ1)/100= Wa- Dp-Ro
Wa= Qt/A
where:
Rz= Amount of stored water in the effective root zone (m).
Wa= total water applied (cm)
ϴfc and ϴ1= volumetric water content in percent at field capacity and prior to irrigation respectively.
Q= average stream size during the irrigation (m^3/min.)
T= duration of irrigation (min.)
Dp= Deep percolation (cm)
R0= Run off (cm).
A= average irrigated area (m^2)
R0= Wa-D^-
where:
D^-= calculated infiltrated depth (cm)

DZ= Ɵfc-Ɵm

where:

DZ= depth to fill root zone (required depth, cm)

Ɵfc= soil moisture content at field capacity.

Ɵm= soil moisture content before irrigation

DP=D⁻ — Dz

Infiltrated depth (cm) was calculated through coefficient of linear regression between elapsed time (minutes) and cumulative infiltrated depth using the modified kostiakov's equation as (e.g. Gillies and Smith, 2005) as follows:

$Z= a\ T^b$

where, Z= calculated infiltrated depth, cm, T= opportunity intake time (min.), a= slope, and b= intercept.

Irrigation application efficiency (IAE, %) was calculated by dividing the volume of water stored in the effective root zone by the applied irrigation water (Downy, 1970) as follows: IAE= (Da-(Dp+R0)/Da× 100

Where:

Da= depth of water applied (cm), Dp= deep percolation (cm), Ro= Runoff (cm) and IAE= irrigation application efficiency.

Water distribution efficiency (EWD,%)

EWD was calculated according to James (1988) as follows: EWD= (1-y/d) ×100, where EWD= water distribution efficiency, d= average depth of soil water stored along furrow during irrigation and y= average numerical deviation from d.

9. Economic evaluation

Cash inflow and outflows for various treatments according to price of the local market were calculated, and some economic indicators were also estimated such as:

1- Total return and Net return (L.E fed^{-1})

2- Benefit – Cost ratio (BCR) , calculated by dividing the total seasonal return by total seasonal cost (Atiea, 1986)

3- Specific cost, is calculated by dividing the total cost (L.E fed^{-1}) by the faba bean seed yield (kg $fed.^{-1}$).

RESULTS AND DISCUSSION

1. Intake characteristics of the studied soils

Infiltration is generally defined as the process of water entry into the soil profile. The study and characterization of infiltration is of upmost important in irrigation. For design and evaluation purposes, it is necessary to know the rate at which water enters the soil and the amount which can be held in the profile before runoff and/or deep percolation begins. Soil infiltration capacity and rate are required data before irrigation designs or modifications can be formulated which will result in uniformity and efficiently applied water. This is especially true for surface irrigation methods. For border or basin irrigation, infiltration is generally assumed to occur vertically downward, cone dimensional, affected by the shape of the infiltration surface, which controls the rate of water entry. In furrow irrigation, this rate is more commonly termed intake rate. Most well drained soils will generally exhibit an initially high infiltration rate which decreases with time and eventually approaches a constant rate. This process of decreasing capillary pressure gradient resulted from a deepening wetting front.

Several tests have been conducted to determine the range of infiltration characteristics of Sakha soils in two growing seasons as shown in Table (2) and illustrated in Fig (1).

The rate at which a soil absorbs water usually decreases rather rapidly with time. After several hours however, it usually becomes nearly constant. At this point, the infiltration is reached to its basic rate (Garcia, 1978).

Table (2): Basic infiltration rate (cm hr^{-1}) and cumulative infiltrated depth for different treatments before post irrigation in the two growing seasons of faba bean crop

Elapsed time (min)	Infiltration rate (cm hr^{-1})		Cumulative infiltrated depth (cm)	
	1st season for all cut-off irrigation	2nd season for all cut-off irrigation	1st season	2nd season
5	9.72	9.96	0.81	0.83
10	6.24	6.24	1.33	1.35
20	4.02	4.08	2.0	2.03
30	1.92	1.98	2.32	2.36
45	1.92	1.96	2.8	2.85
60	1.8	1.76	3.25	3.29
90	1.02	1.04	3.76	3.81
120	1.02	1.04	4.28	4.35
180	0.89	0.88	5.17	5.23
240	0.89	0.88	6.06	6.12

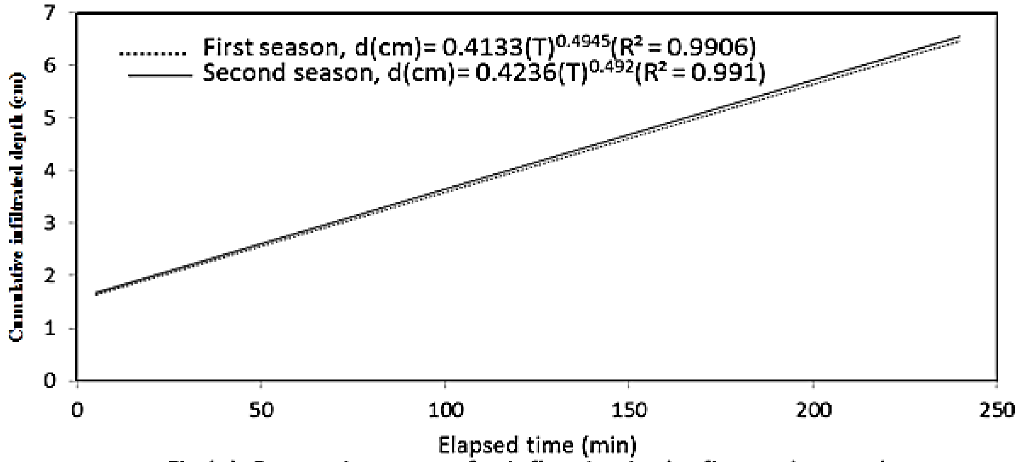

Fig (1): Regression curves for infltration in the first and second seasons of faba bean crop (post irrigation).

Table (2) shows the infiltration rate and cumulative infiltration values before post planting irrigation of faba bean crop in the two growing seasons. It was noticed that infiltration rates decreased rapidly from 9.72 to 0.89 cm hr^{-1} and from 9.96 to 0.88 cm hr^{-1} at 4 hours elapsed time in the first and second seasons, respectively, for all cut-off irrigation treatments. The cumulative infiltrated depth values were 6.06 and 6.12 cm at 4 hours elapsed time in the first and second seasons, respectively.

2. Infiltration function

Table (3) shows the infiltration functions of the data obtained, which were plotted between accumulated depth infiltrated in (cm) and elapsed time in (minutes). These data were then subjected to a curve fitting regression to determine the best fit regression coefficients, in a power function of the form of : $Z= a T^b$

Table (3): Intake functions for the different treatments for post irrigation during the first and second seasons

Crop	Infiltration function					
	First season			Second season		
	a	b	R^2	a	b	R^2
Faba bean	**0.553**	**0.5165**	**0.985**	**0.5531**	**0.5166**	**0.985**

This is the simple and well-known empirical infiltration function of the Kostiakov equation (e.g., Gillies and Smith, 2005) form, where Z is the accumulated depth infiltrated (cm), T is the elapsed time (minutes), and a (cm/min) and b are regression coefficients. Available test data for post irrigation of faba bean crop in the first and second seasons were analyzed using a curve fitting regression.

The results of individual regressions for all tests conducted with the post irrigation under cultivation of faba bean crop is considered representative of the soil intake conditions.

3. Soil intake families

The United States soil conservation service (SCS) has made a large number of field trails to measure and categorize infiltration rates. The SCS has used a slightly modified form of the kostiakov equation to represent infiltration. Application of this method has been aided by use of the intake family concept. The governing equation for infiltration using the SCS method is given by the following equation: $i= a(t)^b+c$.

Where, i and t are depth of infiltration, cm and time of infiltration, min, respectively. a and b are given as a function of intake family which varies depending on whether i is determined in inches or centimeters, and b are listed for different intake families in Table (4).

With reference to the SCS procedures for level furrow (USDA, 1979) irrigation designs and the SCS methods for classifying soils into intake families, the following comments are made concerning to the results in Table (4).

The results for the first and second seasons of faba bean as shallow rooted, the intake rates considered representative of the soil infiltration characteristics at post irrigation in the first and second seasons, which are equivalent to 0.35 and 0.35 intake families.

4. Uniformity coefficient of applied water

The uniformity of water applied is a convenient way to judge the performance of irrigation methods. High values of water distribution uniformity mean that different sections of the field received similar application depth.

As shown from Table (5) the results indicate similar uniformity. It is noted that calculated uniformity levels for the different cut-off irrigation and alternative furrow irrigation under irrigation discharge (4 L sec^{-1} m^{-1} width) with cultivation of faba bean as shallow rooted crop usually more than 0.9.

The uniformity coefficient values were found to be 0.94, 0.95, 0.93 and 0.95 for 100%, 90%, 85% cut-off irrigation and alternate furrow irrigation in both seasons, respectively. The highest values of distribution uniformity were obtained with alternative furrow irrigation followed by cut-off irrigation at 100% from furrow length.

Table (4): Calculated parameters of different intake families

Intake family	A	b	c	f	g
0.05	0.5334	0.618	7.0	7.16	1.088×10^{-4}
0.1	0.6198	0.661	7.0	7.25	1.251×10^{-4}
0.15	0.711	0.683	7.0	7.34	1.414×10^{-4}
0.2	0.7772	0.699	7.0	7.43	1.578×10^{-4}
0.25	0.8534	0.711	7.0	7.52	1.741×10^{-4}
0.3	0.9246	0.72	7.0	7.61	1.904×10^{-4}
0.35	0.9957	0.729	7.0	7.7	2.067×10^{-4}
0.4	1.064	0.736	7.0	7.79	2.23×10^{-4}
0.45	1.13	0.742	7.0	7.88	2.393×10^{-4}
0.5	1.196	0.748	7.0	7.97	2.556×10^{-4}
0.6	1.321	0.757	7.0	8.15	2.883×10^{-4}
0.7	1.443	0.766	7.0	8.33	3.209×10^{-4}
0.8	1.56	0.773	7.0	8.5	3.535×10^{-4}
0.9	1.674	0.779	7.0	8.68	3.862×10^{-4}
1.0	1.786	0.785	7.0	8.86	4.188×10^{-4}
1.5	2.284	0.799	7.0	9.76	5.819×10^{-4}
2.0	2.753	0.808	7.0	10.65	7.451×10^{-4}

$Z = a T^b + c$ where Z (mm) is intake depth, T (min) is intake opportunity time.

Table (5): Intake family and application uniformity (Uch) for the different treatments in post irrigation during two growing seasons of faba bean crop

Treatments	First season		Second season	
	SCS Intake family	Application uniformity	SCS Intake family	Application uniformity
Cut off at 100%	0.35	0.94	0.35	0.94
Cut off at 90%	0.35	0.95	0.35	0.94
Cut off at 85%	0.35	0.93	0.35	0.93
Alternative furrow irrig.	0.35	0.95	0.35	0.95

Generally, uniformity coefficient above 0.9 is considered suitable value, thus the designs formulated showed very good uniformity. The intake family and uniformity of different irrigation treatments for the two growing seasons of Faba bean crop are shown in table 5.

5. Level furrow design under different cut-off irrigation

In level furrow design, we seek to find the inflow rate for each furrow based on the input design conditions, acceptable irrigation time and application efficiency. Sometimes the irrigation time is also specified and some compromise between reduction in losses at the upper end of a field and at the lower end is necessary.

The SCS level furrow design model calls for the following input design parameters:

1) Furrow length, 2) furrow spacing, 3) SCS intake family and intake function

parameters, 4) design requirement depth, 5) manning's n-value (commonly n= 0.04 for furrow design).

A range of possible furrow inflow rates was tested. The very low flow rates will result in excessive water advance times and poor performance. The very high flow rates will cause erosion in the furrow and overtopping of the furrow ridge (i.e., run-off). Site specific conditions will generally constrain the range of possible trial flow rates. The larger the stream is, however, the better the performance will be. Also, for a given discharge, the uniformity of application varies inversely with intake rate; better uniformity with lower intake and vice versa. Thus, for level furrow irrigation the furrows must be large, deep and well-made. Therefore, good tillage and maintenance of furrow cross-section through the season is strongly recommended.

For each trial furrow stream, the model will determine the required application time, the estimated advance time, the furrow wetted perimeter, the depth applied, the deep percolation and the application efficiency. Thus, the goal is to minimize the deep percolation loss/or conversely maximize application efficiency. Choosing the best furrow inflow rate for the purpose of minimizing water losses and maximizing irrigation application efficiency and uniformity. With the total flow available at the field inlet known, the designer then determines the number of furrows which can be irrigated in one set.

6. Effects of design parameters variation

An irrigation system is usually designed to supply the crop water requirements during some peak use period. Typically, such design may be based on the design conditions (i.e., design parameter values) at the time of the peak use period. The variation over time of the design parameters is an important consideration which is often neglected. The designer must be aware of the effects of design parameters variation on system performance to formulate an effective design and to develop appropriate system management recommendations.

The effect of different furrow inflow rate, soil roughness, design depth and length for irrigating faba bean crop in the first and second seasons are shown in Tables (6-8). Consequently the best designs are formulated and the inflow time usually also varied with the other parameters changes. The general determined trends were: -

- **2 liter per second per meter, which result in acceptable application efficiency; however. inflow rates less than 2Lps, inflow times are excessive.**
- **Inflow rate at 2lps/m, which causes the lowest deep percolation.**
- **Cut-off irrigation at 85% combined with 2 lps/m achieved the highest values of application efficiency followed by cut-off at 90%. While the lowest value was recorded with cut-off irrigation at 100% from furrow length combined with lower value of inflow rate (0.5lps).**

In this concern, (Amer, 2011, EL-Hadidi et al., 2016 and Sahalou et al., 2018) reported that the method is the best suited for medium to low intake rate soils, which can be used for irrigating all crops. Proper design of level irrigation systems (basin dimensions, number of furrows which should be irrigated, etc.) depending on the water supply flow rate, soil infiltration characteristics and other factors.

Table (6): Effect of changes in intake rate, furrow inflow rate, roughness, design depth and length on irrigation parameters under cut-off irrigation at 100% for the post planting irrigation of Faba bean crop for the 1st and 2nd seasons and intake rate of 0.35

Irrigation parameters	Suggested tested inflow stream (l/sec.)																		
	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0
Design depth applied (mm)	75																		
Furrow slope, %	0.00060	0.00075	0.00088	0.00099	0.00109	0.00118	0.00127	0.00136	0.00144	0.00151	0.00159	0.00166	0.00173	0.00179	0.00185	0.00192	0.00198	0.0020	0.00209
Wetted perimeter (m)	0.47	0.5	0.53	0.55	0.57	0.585	0.6	0.614	0.627	0.639	0.65	0.66	0.67	0.68	0.69	0.7	0.707	0.717	0.72
Net infiltration time (min.)	593.62	542.13	497.56	471.05	447.01	429.85	413.94	399.94	387.6	376.75	367.22	358.9	350.86	343.12	335.64	328.42	323.51	316.69	314.7
Opportunity time (min.)	615.5	555.24	508.19	480.23	455.5	438.08	421.59	407.44	395.04	384.44	374.92	366.26	357.58	349.95	342.38	335.07	329.82	323.65	321.62
Advance time (min.)	72.14	36.02	26.36	22.15	19.84	18.41	17.44	16.68	16.18	15.86	15.48	15.24	14.94	14.79	14.64	14.5	14.35	14.34	14.24
Application time (min.)	179.38	118.56	88.76	70.9	59.1	50.64	44.29	39.38	35.45	32.25	29.58	27.29	25.32	23.64	22.17	20.86	19.69	18.69	17.75
Depth applied (mm)	76.88	76.22	76.08	75.98	75.96	75.96	75.93	75.94	75.96	76.02	76.06	76.02	75.96	75.99	76.01	75.99	75.94	76.1	76.07
Deep percolation (mm)	1.88	1.22	1.08	0.98	0.96	0.96	0.93	0.94	0.96	1.02	1.06	1.02	0.96	0.99	1.01	0.99	0.94	1.1	1.07
Deep percolation ratio	0.02	0.016	0.014	0.013	0.013	0.0126	0.012	0.0123	0.0126	0.013	0.014	0.013	0.0126	0.013	0.0132	0.013	0.0123	0.0144	0.0141
Application efficiency %	97.55	98.4	98.58	98.74	98.7	98.74	98.78	98.76	98.74	98.66	98.61	98.66	98.74	98.7	98.67	98.7	98.76	98.56	98.59

Table (7): Effect of changes in intake rate, furrow inflow rate, roughness, design depth and length on irrigation parameters under cut-off irrigation at 90% for the post planting irrigation of Faba bean crop for the 1st and 2nd seasons and intake rate of 0.35

Irrigation parameters	Suggested tested inflow stream (l/sec.)																		
	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0
Design depth applied (mm)	75																		
Furrow slope, %	0.00067	0.00083	0.00097	0.00110	0.00121	0.00132	0.00142	0.00151	0.0016	0.00168	0.00176	0.00184	0.00192	0.00199	0.002	0.0021	0.0022	0.00226	0.0023
Wetted perimeter (m)	0.46	0.5	0.52	0.54	0.56	0.58	0.59	0.61	0.62	0.63	0.64	0.65	0.66	0.67	0.68	0.69	0.7	0.704	0.71
Net infiltration time (min.)	612.6	542.13	512.73	484.01	458.64	435.4	424.4	403.8	394.2	384.84	375.9	367.2	358.9	350.9	343.11	335.6	328.4	325.6	321.44
Opportunity time (min.)	628.93	552.67	520.69	492.14	466	442.53	431.27	410.55	400.84	391.41	382.35	373.64	365.22	357.21	349.43	341.83	334.64	331.82	327.63
Advance time (min.)	50.33	27.9	21.51	18.52	16.75	15.73	15.01	14.51	14.12	13.83	13.58	13.39	13.22	13.09	13.0	12.88	12.78	12.71	12.65
Application time (min.)	160.37	106.38	79.68	63.71	53.07	45.5	39.8	35.39	31.86	28.96	26.55	24.51	22.76	19.93	18.76	18.12	17.72	16.79	15.95
Depth applied (mm)	76.37	75.99	75.89	75.85	75.81	75.83	75.81	75.84	75.86	75.85	75.86	75.86	75.87	75.92	75.93	75.92	75.95	75.95	75.95
Deep percolation (mm)	1.37	0.99	0.89	0.85	0.81	0.83	0.81	0.84	0.86	0.85	0.86	0.86	0.87	0.92	0.93	0.92	0.95	0.95	0.95
Deep percolation ratio	0.018	0.013	0.012	0.011	0.011	0.011	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.0125	0.0125	0.0125
Application efficiency%	98.21	98.7	98.83	98.84	98.93	98.91	98.93	98.89	98.87	98.84	98.87	98.87	98.85	98.79	98.78	98.79	98.75	98.75	98.75

Table (8): Effect of changes in intake rate, furrow inflow rate, roughness, design depth and length on irrigation parameters under cut-off irrigation at 85% for the post planting irrigation of Faba bean crop for the 1st and 2nd seasons and Intake rate of 0.35

Irrigation parameters	Suggested tested inflow stream (L/sec.)																		
	0.5	0.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5	2.75	3.0	3.25	3.5	3.75	4.0	4.25	4.5	4.75	5.0
Design depth applied (mm)	75																		
Furrow slope	0.00071	0.00088	0.001	0.0012	0.0013	0.0014	0.0015	0.0016	0.0017	0.0018	0.0019	0.00195	0.002	0.0021	0.0022	0.00225	0.0023	0.0024	0.0025
Wetted perimeter (m)	0.46	0.49	0.52	0.53	0.56	0.57	0.59	0.61	0.613	0.62	0.63	0.65	0.66	0.665	0.67	0.68	0.69	0.7	0.7
Net infiltration time (min.)	612.6	558.5	511.7	497.6	458.6	448.8	424.4	403..9	400.9	394.2	384.8	367.2	358.9	354.8	350.9	343.1	335.6	328.4	328.4
Opportunity time (min.)	626.7	568	519.7	504.9	465.5	453.3	430.9	410.1	407.1	400.3	390.9	373.2	364.9	360.8	356.7	349	341.5	334.2	334.2
Advance time (min.)	42.2	24.6	19.3	16.7	15.4	14.5	13.9	13.5	13.1	12.9	12.7	12.5	12.4	12.3	12.1	12.06	12	11.91	11.85
Application time (min.)	151.1	100.3	75.2	60.1	50.1	42.9	37.6	33.4	30.1	27.3	25.1	23.1	21.5	20.1	18.8	17.7	16.7	15.8	15.04
Depth applied (mm)	76.18	75.87	75.79	75.74	75.77	75.74	75.76	75.78	75.78	75.79	75.78	75.8	75.81	75.82	75.83	75.86	75.87	75.87	75.83
Deep percolation (mm)	1.18	0.87	0.79	0.74	0.77	0.74	0.76	0.78	0.78	0.79	0.78	0.8	0.81	0.82	0.83	0.86	0.87	0.87	0.83
Deep percolation ratio	0.015	0.0115	0.010	0.0098	0.01	0.0098	0.01	0.01	0.01	0.01	0.01	0.011	0.011	0.011	0.011	0.0113	0.0115	0.0115	0.011
Application efficiency %	98.45	98.85	98.96	99.02	98.98	99.02	99.0	98.97	98.97	98.96	98.96	98.94	98.93	98.92	98.91	98.87	98.85	98.85	98.91

7. Evaluation of the design

Tables (9 and 10) indicates the irrigation evaluation under different cut-off irrigation and alternative furrow irrigation to check the designs and to determine if the assumptions used in formulating the designs were correct. The evaluation was conducted with post planting irrigation for faba bean as shallow rooted. It is worthy to mention that the designs were determined under intake family of 0.35 with cultivation of faba bean crop in both seasons.

Tables (9 and 10) and Figs (2-5) present a comparison of the design and measured conditions for faba bean crop under different treatments.

The level furrow systems designed had furrow length of 100m, furrow spacing of 70cm and strip width of 7m. this means there was (10) long furrows in each strip

The results of evaluation for faba bean crop could be summarized as follows:

- **The measured irrigation inflow rate was equal two times of the desired design value (2lps/m).**
- **The measured irrigation time was more than the designed one except of alternative furrow irrigation since the measured irrigation time was lower than the designed one under cultivation.**
- **The measured advance time was higher than the design due to higher inflow rate.**

Table (9): Comparison of measured and design conditions of furrow irrigation at Sakha farm in post irrigation for faba bean crop in the first season

irrigation parameters \ Treatments		Cut-off irrigation at 100%	90%	85%	Alternative furrow
Furrow design	Length (m)	100			
	Furrow spacing (m)	0.7			
Furrow inflow rate Lps/m	Designed	2.0			
	measured	4.0			
Irrigation time (min.)	Designed	44.3	39.8	37.6	44.3
	Measured	51.0	55	65	40
Advance time (min.)	Designed	17.4	15.01	13.9	17.4
	Measured	48	48	42	37
Recession time(min.)	Designed	404.2	416.3	417	404.2
	Measured	260.7	256.6	257	242.4
Opportunity time (min.)	Designed	421.6	431.3	430.9	421.6
	Measured	212.7	208.6	215	205.4
Advance ratio	Designed	0.04	0.035	0.032	0.04
	Measured	0.226	0.23	0.195	0.18
Irrigation time /advance time	Designed	2.55	2.65	2.71	2.55
	Measured	1.06	1.15	1.55	1.18
Depth applied (mm)	Designed	75.93	75.81	75.76	75.93
	Measured	121.8	115.2	100.8	96
Deep percolation (mm)	Designed	0.93	0.81	0.76	0.93
	Measured	14.4	13.5	13.2	11.1
Deep percolation ratio	Designed	0.012	0.011	0.01	0.012
	Measured	0.118	0.117	0.131	0.116
Application efficiency (%)	Designed	98.78	98.93	99.0	98.78
	Measured	76.11	79.69	90.77	93.13
Depth required (mm)	Designed	75			
	Measured	78.3	78.3	78.3	78.3
Requirement efficiency (%)	Designed	100			
	Measured	64.29	67.97	77.68	81.56

Table (10): Comparison of measured and design conditions of furrow irrigation at Sakha farm in post irrigation for faba bean crop in the second season

irrigation parameters	treatments	Cut-off irrigation at 100%	90%	85%	Alternative furrow
Furrow design	Length (m)	100			
	Furrow spacing (m)	0.7			
Furrow inflow rate lps/m	Designed	2.0			
	Measured	4.0			
Irrigation time (min.)	Designed	44.3	39.8	37.6	44.3
	Measured	50.5	55	64	40
Advance time (min.)	Designed	17.4	15.01	13.9	17.4
	Measured	49.0	47.5	42.5	36
Recession time(min.)	Designed	404.2	416.3	417	404.2
	Measured	262.3	260.8	258.4	242.4
Opportunity time (min.)	Designed	421.6	431.3	430.9	421.6
	Measured	213.3	213.3	215.9	202.4
Advance ratio	Designed	0.04	0.035	0.032	0.04
	Measured	0.23	0.22	0.197	0.178
Irrigation time /advance time	Designed	2.55	2.65	2.71	2.55
	Measured	1.03	1.16	1.51	1.11
Depth applied (mm)	Designed	75.93	75.81	75.76	75.93
	Measured	121.3	114.4	102	95.0
Deep percolation (mm)	Designed	0.93	0.81	0.76	0.93
	Measured	14.4	13.5	13.2	11.1
Deep percolation ratio	Designed	0.012	0.011	0.01	0.012
	Measured	0.119	0.118	0.129	0.117
Application efficiency (%)	Designed	98.78	98.93	99.0	98.78
	Measured	76.67	80.94	90	94.32
Depth required (mm)	Designed	75			
	Measured	78.6			
Requirement efficiency (%)	Designed	100			
	Measured	64.8	68.7	77.06	82.3

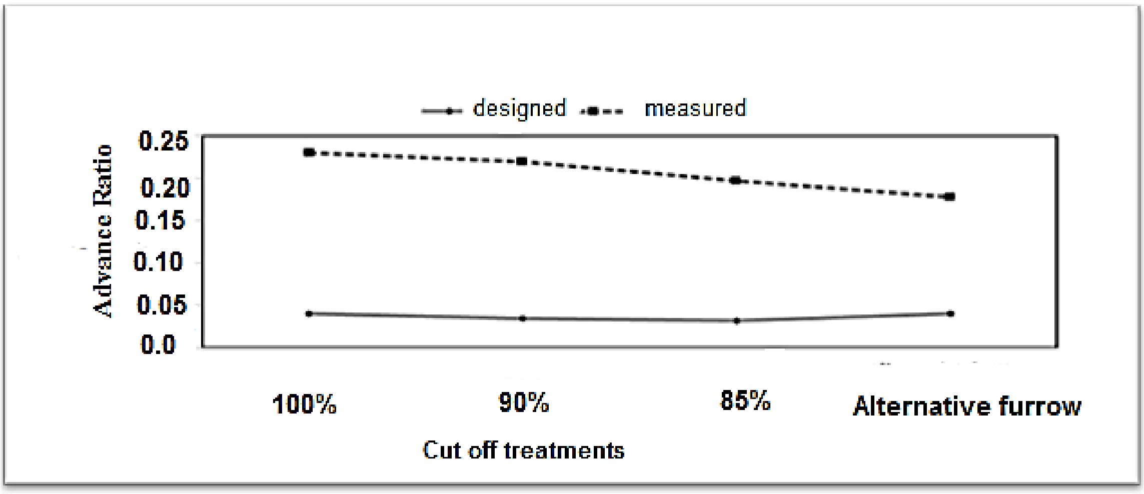

Fig (2): The relationship between advance ratio and different cut off and alternative furrow irrigation for designed and measured conditions under Feba bean crop in the first season (post irrigation)

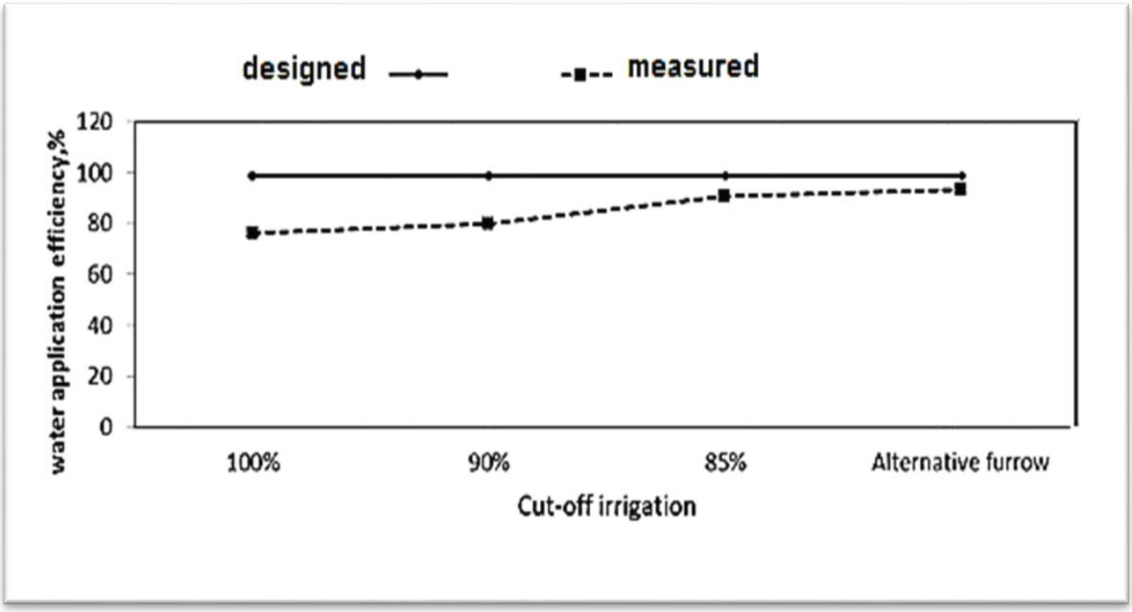

Fig (3): The relationship between application efficiency and different cut off and alternative furrow irrigation for designed and measured conditions under feba bean crop in the first season (post irrigation)

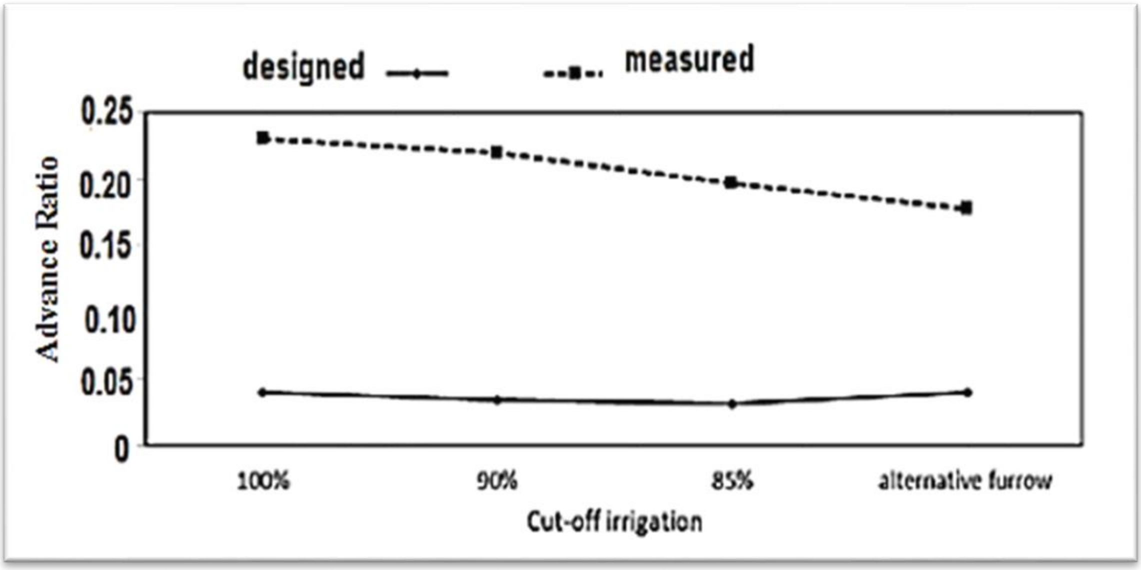

Fig (4): The relationship between advance ratio and different cut off and alternative furrow irrigation for designed and measured conditions under feba bean crop in the second season (post irrigation)

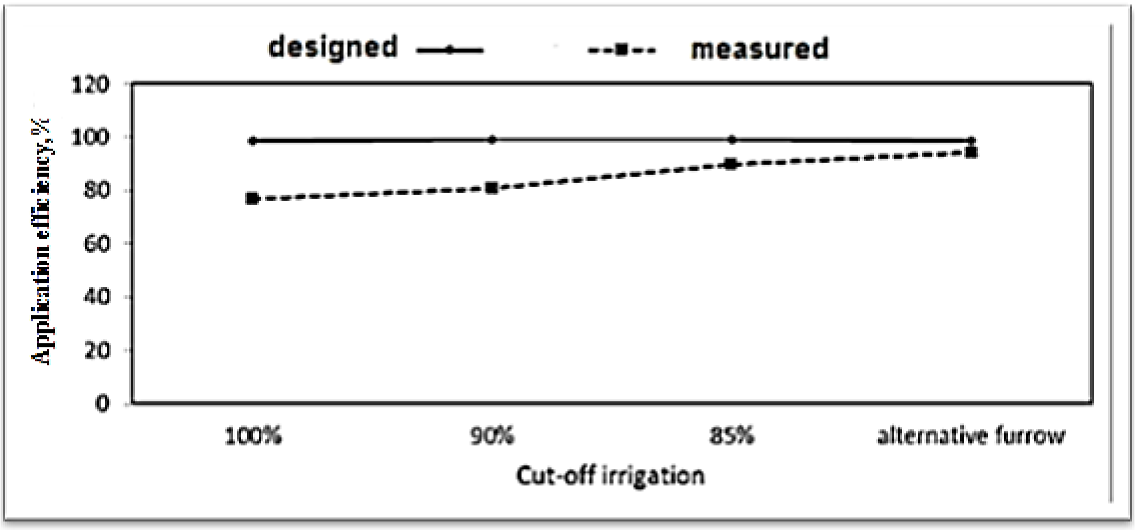

Fig (5): The relationship between application efficiency and different cut-off and alternative furrow irrigation for designed and measured conditions under feba bean crop in the second season (post irrigation).

- **The designed recession time, opportunity time, total irrigation time and advance time were higher than the measured ones.**
- **The highest values of advance ratio, irrigation depth applied, deep percolation and deep percolation ratio were recorded with measured parameters compared to design parameters.**
- **The ratio of inflow time to advance time as well as for designed parameters is more than 2 meanwhile, in this case the design is acceptable in clay soil. The highest ratio was obtained with cut-off at 85% from furrow length.**
- **The highest values of irrigation application efficiency were obtained with cut-off at 85% from furrow length for designed and measured parameters under cultivation.**

8. Economic evaluation

Economic evaluation requires special items through the evaluation process which can be implemented. The following aspects were suggested for the economic evaluation of the experimental treatments, economically are:

1. **Faba bean seed yield (kg fed.$^{-1}$)**
2. **Total return (L.E fed.$^{-1}$)**
3. **Total cost (L.E fed.$^{-1}$)**
4. **Net return = total return – total cost**
5. **Benefit- cost ratio (BCR)= Total return/ total cost**
6. **Specific cost, (L.E kg^{-1}) = Total cost/ faba been seed yield**

Faba bean seed yield:

Table (11) shows the effect of different cut-off irrigation treatments and alternate furrow irrigation combined with fertilizer treatments on faba bean seed yield and the economic evaluation parameters expressed as mean value of the two studied seasons 2015/2016 and 2016/2017. Obtained data cleared out that the interaction between alternate furrow irrigation (I_4) and F_3 treatment achieved the highest value of faba bean seed yield, followed by cut-off irrigation at 85% FL (I_3) and (F_3), while the lowest value of faba bean seed yield was recorded with interaction between (I_1) and (F) treatments.

Total seasonal return

Data in Table (11), revealed that the mean values of the total seasonal return were 9904.57, 10555, 11309.69 and 10548.06 L.E fed^{-1} for cut-off irrigation at 100%, 90%, 85% of furrow length and alternative furrow irrigation, respectively. Concerning the fertilization treatments, data indicated that the F_3 treatment resulted in increasing the total seasonal return compared to other treatments. This trend may be attributed to increasing the faba bean seed yield and growth parameters. It should be mentioned that the total seasonal return increased by 6.57, 14.19 and 6.50% under cut-off irrigation at 90%(I_2), 85%(I_3) from furrow length and alternative furrow irrigation (I_4) compared to I_1 treatment. While, the increase in total seasonal return under fertilization treatments of F_2, F_3 and F_4 were 20.10, 55.76 and 31.27% compared to F_1 treatment.

Table (11): The studied economic criteria (seed yield, Total return, Total cost, net return, benefit-cost ratio and specific cost) for faba bean production (average two seasons)

Treatments		Faba bean seed yield kg fed^{-1}. (a)	Total seasonal return L.E fed^{-1}. (b)	*Total seasonal cost L.E/fed. (c)	Net return L.E/fed. (b-c)	Benefit-cost ratio (b/c)	Specific cost L.E kg^{-1} (c/a)
Cut-off irrigation	Fertilizer treatments						
I_1	F_1	918.32	8252.75	3500	4752.75	2.36	3.81
	F_2	1139.43	10219.5	3438	6781.5	2.97	3.02
	F_3	1286.78	11641.75	3413	8228.75	3.41	2.65
	F_4	1060.51	9504.25	3376	6128.25	2.82	3.18
Mean		1101.26	9904.57	3431.75	6472.81	2.89	3.17
I_2	F_1	921.99	8301.25	3500	4801.25	2.37	3.80
	F_2	1058.93	9503.5	3438	6065.5	2.76	3.25
	F_3	1445.04	13046.25	3413	9633.25	3.82	2.35
	F_4	1267.01	11369	3376	7993	3.37	2.66
Mean		1175.74	10555	3431.75	7123.25	3.08	3.02
I_3	F_1	949.96	8514.75	3500	5014.75	2.43	3.68
	F_2	1128.14	10070.5	3438	6632.5	2.93	3.05
	F_3	1504.74	13521.75	3413	10108.75	3.96	2.27
	F_4	1463.27	13131.75	3376	9755.75	3.89	2.31
Mean		1261.53	11309.69	3431.75	7877.94	3.30	2.83
I_4	F_1	925.05	8309	3447.5	4816.5	2.41	3.73
	F_2	1155.54	10292.25	3438	6854.25	2.99	2.98
	F_3	1534.23	13781	3409.5	10371.5	4.04	2.22
	F_4	1096.21	9810	3376	6434	2.91	3.08
Mean		1177.76	10548.06	3417.75	7130.31	3.09	3.0

Marketable price for 1kg seed of faba bean (7.67 & 9.67 L.E) in the 1st and 2nd seasons, respectively with an average 8.67 L.E for the two seasons.
F_1= 100% Rp, F_2= 75% Rp+ phosohorien, F_3= 65% Rp+ phosphorien, F_4= 50% Rp+ phosphorien
I_1= cut-off at 100% FL, I_2= cut-off at 90% FL, I_3= cut-off at 85% FL and I_4= Alternative furrow irrigation
*Included all agricultural operations, mineral fertilizers and fixed costs (1537.51 L.E fed^{-1})

Net seasonal return

Data of Table (11) reveal that the net seasonal return showed the same trend as for the abovementioned discussion, (i.e the seasonal total return). This trend may be due to that the production cost for each treatment seemed to be the same, or that the differences between them are relatively small compared to the corresponding values of the differences between the return value for each treatment, which are relatively high. The highest value (10371.5 L.E fed^{-1}) was obtained with interaction between I_4 and F_3 followed by I_3 and F_3 (10108.75 L.E fed^{-1}), while the lowest value (4752.75 L.E fed^{-1}) was noticed under I_1 and F_1.

Benefit-cost ratio (BCR)

From the presented data in Table (11), the interaction between I_4 and F_3 achieved the highest value of BCR (4.04), while the I_1 treatment combined with F_1 recorded the lowest value of BCR (2.36).

Specific cost (L.E/kg)

As shown in Table (11) the specific cost decreased with (I_3) and (I_4) combined with F_3 treatment. The highest value (3.81 L.E kg^{-1}) was obtained with I_1 F_1. This finding is may be due to the lowest faba bean seed yield.

Choosing the best profit treatment for faba bean crop production:

Eight parameters were taken into account to select the best profit treatment for faba bean crop production under Egyptian conditions. These related parameters were: seed yield (kg fed^{-1}), straw yield (kg fed^{-1}), weight of 100seed (g), number of branches plant^{-1}, water productivity (WP), productivity of irrigation water (PIW), specific cost and Benefit cost ratio as shown in Table (12).

It is suggested to use a factor called (overall relative factor of evaluation, kt). Which is calculated using the following formula:

$$Kt = R_1K_1 \times R_2K_2 \times R_3K_3 \times R_4K_4 \times R_5K_5 \times R_6K_6 \times R_7K_7 \times R_8K_8$$

Where:

K_1= seed yield for the tested treatment / the same criterion for I_4F_3

K_2= straw yield for the tested treatment / the same criterion for I_4F_3

K_3=weight of 100 seed of the tested treatment/ the same criterion for I_4F_3

K_4= No. of branches plant^{-1} for the tested treatment/ the same criterion for I_4F_3

K_5= productivity of irrigation water for the tested treatment/ the same criterion for I_4F_3

K_6=water productivity for the tested treatment/ the same criterion for I_4F_3

K_7= specific cost for the tested treatment / the same criterion for I_4F_3

K_8= Benefit cost ratio for the tested treatment / the same criterion for I_4F_3

Different combinations between parameters may help in setting the overall relative factor of evaluation for each treatment and selecting the optimum treatment that meets the best irrigating management. The importance of each parameter differs according to marketing and environmental conditions, so the values of Ri,(i= 1-8) were taken throughout this work to be equal to the unity. Therefore, this procedure simplifies the abovementioned formula to be as follows:

$$Kt = K_1 \times K_2 \times K_3 \times K_4 \times K_5 \times K_6 \times K_7 \times K_8$$

It should be noted here that, I_4F_3 was used as basis to calculate the value of overall relative factor of evaluation (kt) for all treatments. So, the values of K_1 to K_8 for the treatment I_4F_3 was equal to the unity, and consequently, the value of kt for the base treatment must also be equal

to unity. Table (13) shows the values of K_1 through K_8 for the different investigated treatments and the corresponding values of overall factors of evaluation. Obviously it is clear that the value of overall factor (kt) of evaluation differs according to investigated treatments. So, the different tested treatments of faba bean production showed the following descending order: I_4F_3> I_3F_3> I_3F_4> I_2F_3> I_2F_4> I_4F_2> I_4F_4> I_1F_3> I_1F_4> I_3F_2> I_2F_2> I_1F_2> I_4F_1> I_2F_1> I_3F_1> I_1F_1.

Therefore, the study recommended the alternative furrow irrigation (I_4) combined with F_3 treatment followed by (I_3) cut-off irrigation at 85% of furrow length combined with F_3 are the best treatments which meet the desired results.

Table (12): Values of some features used for selection the best profit treatments for faba bean crop (two seasons average are presented).

Treatments		seed yield kg fed^{-1}	Straw yield kg fed^{-1}	Weight of 100 seed, (g)	No. of branches plant^{-1}	PIW, kg m^{-3} WA	WP, kg m^{-3} WC	Specific cost, L.E kg^{-1}	Benefit cost ratio
Cut-off irrigation	Fertilizer treatments								
I_1	F_1	918.32	735	86.74	2.61	0.52	0.72	3.81	2.36
	F_2	1139.43	678.13	87.81	2.67	0.64	0.89	3.02	2.97
	F_3	1286.78	875	85.69	2.86	0.73	0.99	2.65	3.41
	F_4	1060.51	833.96	91.69	3.25	0.6	0.82	3.18	2.82
I_2	F_1	921.99	525	86.71	2.81	0.55	0.73	3.8	2.37
	F_2	1058.93	695.63	88.38	2.83	0.63	0.84	3.25	2.76
	F_3	1455.04	774.36	89.58	3.25	0.86	1.15	2.35	3.82
	F_4	1267.01	831.25	83	3.75	0.76	0.99	2.66	3.37
I_3	F_1	949.96	590.63	86.22	2.75	0.6	0.78	3.68	2.43
	F_2	1128.14	621.25	87.12	3.14	0.72	0.91	3.05	2.93
	F_3	1504.74	857.5	90.03	3.36	0.96	1.21	2.27	3.96
	F_4	1463.27	866.26	87.47	3.34	0.93	1.17	2.31	3.89
I_4	F_1	925.05	595.0	90.73	3.67	0.68	0.84	3.73	2.41
	F_2	1155.54	695.63	86.25	3.17	0.85	1.04	2.98	2.99
	F_3	1534.23	905.63	92.61	3.09	1.13	1.37	2.22	4.04
	F_4	1096.21	743.75	88.63	3.25	0.82	0.98	3.02	2.91

F_1= 100% Rp, F_2= 75% Rp+ phosohorien, F_3= 65% Rp+ phosphorien, F_4= 50% Rp+ phosphorien
I_1= cut-off at 100% FL, I_2= cut-off at 90% FL, I_3= cut-off at 85% FL and I_4= Alternative furrow irrigation

Table (13): The economic parameters used for selecting the most profitable treatment for faba bean crop production.

Treatments		seed yield kg fed^{-1} (K_1)	Straw yield kg fed^{-1} (K_2)	Weight of 100 seed, (g) (K_3)	No. of branches plant^{-1} (K_4)	PIW, kg m^{-3} WA (K_5)	WP, kg m^{-3} WC (K_6)	Specific cost, L.E kg^{-1} (K_7)	Benefit cost ratio (K_8)	Overall factor (K_t)
Cut-off irrigation	Fertilizer treatments									
I_1	F_1	0.6	0.81	0.94	0.84	0.46	0.52	1.71	0.85	0.09
	F_2	0.74	0.75	0.95	0.86	0.57	0.65	1.36	0.73	0.17
	F_3	0.84	0.97	0.92	0.93	0.65	0.72	1.19	0.84	0.33
	F_4	0.69	0.92	0.99	1.05	0.53	0.6	1.43	0.7	0.21
I_2	F_1	0.6	0.58	0.94	0.91	0.49	0.53	1.71	0.59	0.12
	F_2	0.69	0.77	0.95	0.92	0.56	0.61	1.46	0.68	016
	F_3	0.95	0.86	0.97	1.05	0.76	0.84	1.06	0.94	0.53
	F_4	0.82	0.92	0.9	1.21	0.67	0.72	1.2	0.83	0.39
I_3	F_1	0.62	0.65	0.93	0.89	0.53	0.57	1.66	0.6	0.1
	F_2	0.73	0.68	0.94	1.02	0.64	0.66	1.37	0.72	0.2
	F_3	0.98	0.95	0.97	1.09	0.85	0.88	1.02	0.98	0.74
	F_4	0.95	0.96	0.94	1.08	0.82	0.85	1.04	0.96	0.61
I_4	F_1	0.6	0.66	0.98	0.86	0.6	0.61	1.68	0.6	0.13
	F_2	0.75	0.77	0.93	1.03	0.75	0.76	1.34	0.74	0.31
	F_3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	F_4	0.71	0.82	0.96	1.05	0.72	0.72	1.36	0.72	0.3

F_1= 100% Rp, F_2= 75% Rp+ phosohorien, F_3= 65% Rp+ phosphorien, F_4= 50% Rp+ phosphorien
I_1= cut-off at 100% FL, I_2= cut-off at 90% FL, I_3= cut-off at 85% FL and I_4= Alternative furrow irrigation

Conclusion:

For level furrow irrigation design, the analyses were furrow inflow rate, roughness, design depth under cultivation of faba bean crop. The results indicated that application efficiency increases according to intake family decrease. It is acceptable at inflow rate of 2 Lps/m. The cut-off irrigation at 85% combined with 2 Lps/m achieved the highest value of application efficiency. The measured irrigation time and advance time were higher than the design due to higher inflow rate. The highest values of advance ratio, irrigation depth applied, deep percolation and deep percolation ratio were recorded with measured parameters compared to designed parameters. It can be concluded that the design of furrow is acceptable under inflow rate of 2 Lps/m and cut-off irrigation at 85% in clay soil. Also, cut-off at 85% or alternative furrow irrigation combined with applying 65% RP+phosphorien gave the highest values of net return and benefit cost ratio.

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تحسين توزيع ماء الري لنظام ري الخطوط لزيادة انتاجية الاراضي في منطقة شمال دلتا النيل، مصر

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الملخص العربى

أجريت تجارب حقلية في مزرعة سخا بمحافظة كفرالشيخ في الموسمين الزراعيين ٢٠١٥/٢٠١٦، ٢٠١٦/٢٠١٧. وكان الهدف الرئيسي من هذا العمل هو إختبار تصميم الخطوط وتقييم تأثير إيقاف سريان المياه عند 85% (I_3), 90% (I_2), 100% (I_1) من طول الخط والري التبادلي في الخطوط (I_4) مع استخدام معدل تدفق المياه عند ٤ لتر/ ثانية/ متر من عرض شريحة الري و ٤ معاملات من التسميد كما يلي F_1 (إضافة ١٠٠٪ من الجرعة الموصي بها من RP)، F_2 (إضافة ٧٥٪ من RP+ الفوسفورين)، F_3 (إضافة ٦٥٪ من RP+ الفوسفورين)، F_4 (إضافة ٥٥٪ من RP+ الفوسفورين) على خواص تشرب المياه، عائلات التشرب وبعض مقاييس الري مع رية المحاياه لمحصول الفول البلدي بالإضافة الي ان التقييم الاقتصادي قد أخذ في الاعتبار وتضمنت اهم النتائج الأتي:-

تناقص معدل التشرب بسرعة بعد ٤ ساعات (زمن تجميعي) في الموسم الأول والثاني ويعتبر معامل الإرتباط ممثلا لظروف تشرب التربة. قيمة عائلة التشرب للأرض المنزرعة بالفول البلدي ٠.٣٥ في كلا الموسمين. زادت قيمة معامل تجانس المياه المضافة عن ٠.٩ مع معاملات إيقاف سريان المياه والري التبادلي في الخطوط. ازدادت قيمة كفاءة الري التطبيقية مع تناقص قيمة عائلات التشرب وتكون قيمتها مقبولة مع معدل تدفق مياه الري عند ٢ لتر/ثانية/متر. قيمة معدل سريان المياه المقاسة تساوي ضعف القيمة المصممة (٢لتر/ثانية/متر). كانت قيم زمن الري، زمن تقدم المياه أعلى من القيم المصممة، بينما القيم التصميمية لزمن انحسار المياه وزمن تشرب المياه والنسبة بين زمن الري وزمن تقدم المياه المصممة أعلى من القيم المقاسة. النسبة بين زمن اضافة المياه وزمن ٩تقدم المياه المصممة اعلى من ٢ وهذا يدل على أن تصميم الري بالخطوط مقبولاً في الأراصي الطينية، وأعلى نسبة تحصل عليها من إيقاف سريان المياه عند ٨٥٪ من طول الخط . وقد أعطي التفاعل بين (I_3 او I_4) و F_3 اعلي القيم من صافي الدخل ونسبة الفائدة الي التكلفة واقل القيم من التكلفة النوعية .

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