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Response of Faba Bean to Alternate Irrigation and Cut-off Irrigation Combined with Mineral Phosphorus Levels and Biofertilizer at North Nile Delta Soils

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A FIELD trails were conducted during the two growing winter seasons of 2015/2016 and 2016/2017 at Sakha Research station , Kafr El-sheikh Governorate to study the effect of four irrigation regimes; cut-off irrigation at 100% (I_1), 90%(I_2), 85%(I_3) of the furrow length and alternative furrow irrigation (I_4), and four fertilization treatments; F_1 (100% of recommended phosphorus (RP)) as control, F_2 (75% RP+ phosphorien), F_3 (65%RP+ phosphorien) and F_4 (50%RP+ phosphorien) on Faba bean yield, some water relations, ground water table contribution and economic returns. The obtained results showed that water applied and water consumptive use could be arranged in descending order as; $I_1 > I_2 > I_3 > I_4$ in both seasons. Water saving by I_2, I_3 and I_4 treatments were 4.64, 10.92 and 22.55%, respectively, comparing to I_1-Treatment. Both of (I_3) and (F_3) treatments gave the highest increasing percent of the seed yield of faba bean and most its components, in both seasons. The highest values of water consumptive use, water application and water distribution efficiencies and ground water contribution were recorded under (I_4) in both seasons. The combination of I_4 and F_3 treatments surpassed the other treatments in increasing water productivity and productivity of irrigation water for seed and straw yields, net return, net return from water unit and economic efficiency of faba bean seed and biological yields in both seasons. It can be concluded that I_4 or I_3 in combination with F_3 is the proper treatments to obtain higher production of faba bean, water saving and economic returns.

Keywords: P-fertilizer, Phosphorien, Irrigation regimes, Ground water contribution, Economic return, Water efficiencies, Seed yield

Introduction

Faba bean (*Vicia faba* L.) is an important pulse in the term of popularity and seed protein content. In addition, it's the most important food legume crop for human nutritive in Egypt. Also, it's considered as one of the basic source of protein in the Egyptian diet with relatively low price. According to (MAE, (2017/2018) the cultivated area occupied by Faba bean was 90,000 fed. The total world cultivated area occupied with Faba bean was approximately 4-7 M ha^{-1} (FAO, 2012). The nutritional value of Faba bean was attributed to its high protein content with a range of 27-34%. Hossain and Mortuza (2006) noticed that, depending on the genotypes, the protein comprised of globulins (79%), albumins (7%) and glutelins (6%). Due et al. (1999) stated that under the water deficit condition, protein content of Faba bean tended to increase, and these results compensated with data obtained by Alghamdi (2009) and Ibrahim & Kandil (2007). Alireza and Farshad (2013) showed that relationships between total dry weight, water use efficiency, water loss rate were significant and they belong to the variation among cultivars. EL-Dakroury (2008) showed that increasing of the irrigation treatments from 60 to 100% of ET, significantly increased the growth criteria, *i.e.,* plant height, number of branches and pods/plant, leaves area and dry weight of both stem and total plant.

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In the traditional agricultural irrigation, yield increase was mainly attained from the amounts of water used in irrigation satisfying the biological characteristics of water demand (Deng et al., 2002). Enhancing water use efficiency, both under rain-fed and irrigated agriculture is a high priority for agricultural improvement in developing countries (Canone et al., 2015, Melkonyan, 2015, Ronaldo et al., 2015). Thus, new irrigation strategies must be established to use the limited water resource more efficiently. In recent years, the concept of alternate partial root-zone irrigation (APRI) or partial root-zone drying (PRD) has been raised and attracted considerable interest (Kang and Zhang, 2004).

Water management under PRD irrigation focuses on efficient use of limited soil water and increasing crop water use efficiency. The effect of this irrigation mode on increasing WUE and maintaining yield has been extensively verified (Davis and Hartung 2004). The development of water saving strategy is important to find the most representative combination between acceptable yield and water use (Pereira et al. 2002). Alderfasi and Alghamdi (2010) irrigated Faba bean using 75% of the field capacity (Fc) resulted in elevated plant height, large number of plant branches, number of seeds and seed yield/ha. Nevertheless, Hirich et al. (2012) applied 50% of FC to Faba bean and obtained high WUE that enhanced crop productivity.

Because of the water limitation faced Egypt, we should do our best towards effective rationalization of irrigation at farm level. Furrow irrigation is a common type of surface irrigation and it is suitable for Faba bean watering especially in the clayey soils. Under traditional irrigation practiced by local farmers, the wetting front is allowed to reach the tail end of the strip. In other words, a long time is allowed for water to stay in the upper portion of the irrigation strip which results in more losses by deep percolation. Then to generate the increase of the advancements of water movement in such clayey soils, irrigation front should be stopped before the end of cultivation border. Following cut-off irrigation event, water front move to irrigate more cultivated area. This technique considered as a direct simple effective way in water saving. In addition, less water will percolate downward to the drainage system at the area (Kassab and Ibrahim, 2007, Ibrahim and Emara, 2009, Kassab, 2012, Abdel-Fatah, 2011, Abu-Hashim and Shaban, 2016 and EL-Hadidi et al. 2016).

Under Egyptian conditions beside limitation of water resources there is a big problem faces Egyptian agriculture that is increasing prices of mineral fertilizers, in addition to their bad effects on soil and water properties by making pollution for them and will be hard to reuse drainage water again. This problem can be solved by using biofertilizers instead of mineral ones. So, nowadays, on the way of clean agriculture through applying products with minimum pollution effects, the use of biofertilizers is recommended by several investigators to substitute the chemical fertilizers (EL-Aggory et al., 2001 and Abd EL-Magid, 2002). Bacillus megaterium PDB (Phosphorine) was the most important group in the solubilization process of insoluble phosphorus in soils (EL-Kathat, 1992). The application of the prepared biofertilizers of various bacterial in mixture have become recently a new technique which is having a define role in plant growth, yield and transformation of nutrient (N,P and K) in plants (Zahana and Abo-Kaied, 2007 and Irina Kravchenko et al., 2013).

The objective of the current study is to investigate the influence of water supply regimes and partial replacement of P-mineral levels by biofertilizer application (phosphorien) on Faba bean productivity, some water relations, as well as economic returns.

Materials And Methods

Two field experiments were conducted during the two growing winter seasons of 2015/2016 and 2016/2017 at Sakha Agricultural Research station, Kafr EL-Sheikh Governorate, to study the effect of irrigation regimes and partial substitute of P-Mineral fertilizer levels by Biofertilizer application, (phosphorien) as a phosphate dissolving bacteria, PDB (Bacillus-megaterium var. phosphaticum) on productivity of Faba bean crop (C.V. Sakha1) and some water relations. The soil chemical and physical properties of the experimental site is presented in Table (1) and Agro-meteorological data of Sakha station, during the two seasons of study are presented in Table (2).

The determination of soil properties was carried out according to the methods reported by Page et al. (1982) and Klute (1986). The experiment was laid out in a strip-block design with three replicates. The main plots was occupied by the irrigation regimes as follows:

I_1= cut-off irrigation at 100% of furrow length (control)

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

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

I_4= Alternative furrow irrigation.

While the sub plots were devoted to four combinations of partial replacement of P-Mineral fertilizer levels by Bio-fertilizers (phosphorien) application as follows:

F_1= Applying 100% of recommended dose of mineral-p (as control)

$F_{2=}$ Applying 75% of recommended dose of mineral-P+ phosphorien

$F_{3=}$ Applying 65% of recommended dose of mineral-P+ phosphorien

F_4= Applying 50% of recommended dose of mineral-P+ phosphorien

All the experimental plots received recommended of N at the rate of 15kg N fed^{-1}., as a starter dose in the form of urea 46.5%N) just before the first irrigation in both growing seasons. Also, recommended dose of potassium (24 kg K_2O fed^{-1}.) in the form of potassium sulphate (48%K_2O) was added to all fertilizer treatments in both seasons. Phosphorus fertilizer in the form of calcium superphosphate (15.5%P_2O_5) at rate of 30kg P_2O_5 fed^{-1} as recommended dose was added during land preparation before sowing. Agronomic practices were performed according to the usual cultural practices as a recommended for Faba bean production, except the studied treatments.

Each sub-plot area was 58.1 m^2 (10 ridges×8.3m length×70cm apart). The used inoculating bacteria, phosphorien (Bacillus megatherium var phosphaticum) was adsorbed on peatmoss power as carrier and registered to Biofertilizers unit, Ministry of Agriculture and land Reclamation, Egypt, from which it was obtained. The inoculation was done by mixing Faba bean seeds immediately before sowing. Inoculated seeds of each treatment was mixed with Rhizobia strain of rhizobial namely (Okadein) was obtained from soil microbiology department of Sakha Agric. Research Station and manual planting in hills on both sides of the ridge with 20 cm between hills. The irrigation was done directly in both seasons. Two plants per hill was maintained by thinning the seedlings after completely emergence. The preceding crop was rice in both seasons.

TABLE 1. Some soil chemical and physical properties of the experimental site before sowing of Faba bean plant (mean of the two seasons)

a- Chemical properties

Soil depth cm	*PH (1:2.5)	**EC dsm^{-1}	SAR	Soluble cations meq/L				Soluble anions meq/L			
				Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	CL^{-}	SO_4^{--}
0-15	8.10	3.76	8.51	6.64	7.84	22.9	0.22	-	5.11	13.62	18.87
15-30	8.19	3.78	7.63	7.45	8.53	21.56	0.26	-	5.51	13.71	18.58
30-45	8.32	4.10	8.56	7.60	8.56	24.33	0.31	-	6.12	14.10	20.58
45-60	8.14	4.23	8.28	8.54	8.94	24.47	0.35	-	5.62	15.22	21.46
Mean	-	3.97	8.26	7.56	8.47	23.32	0.29	-	5.59	14.16	19.87

*= soil water suspension **= soil paste extract

b- Physical properties

Soil depth (cm)	Particle size distribution,%			Textural class	Basic IR, cm/hr	Bulk density, Mg m^{-3}	Total porosity,%	Soil water constant,%		
	Clay	Silt	sand					FC	PWP	AW
0-15	56.30	27.20	16.50	clayey		1.28	51.70	45.12	24.10	21.02
15-30	54.87	28.41	16.72	Clayey		1.36	48.68	44.20	23.38	20.82
30-45	53.35	29.12	17.53	Clayey	0.85	1.38	47.93	39.55	21.24	18.31
45-60	51.30	29.60	19.10	Clayey		1.40	47.17	37.46	21.12	16.34
Mean	53.96	28.58	17.46	Clayey		1.36	48.87	41.58	22.46	19.12

FC=field capacity PWP= permanent wilting point AW= available water.

TABLE 2. Mean of some meteorological data for Kafr El-sheikh area during the two growing seasons of Faba bean crop**

Month	Air temperature, (^{0}c)			Relative humidity,%			Wind velocity Km/24hr	Pan evaporation mm/month	*Rain fall mm/month
	Max.	Min.	Mean	Max.	Min.	mean			
				1st season					
Nov.2015	24.40	14.42	19.41	87.0	64.2	75.6	57.2	244.6	-
Dec.2015	19.70	8.36	14.03	88.6	67.2	77.9	57.9	250.4	25.0
Jan.2016	18.40	6.35	12.38	85.6	62.5	74.1	69.2	252.4	43.22
Feb.2016	22.58	9.35	15.97	85.0	53.1	69.1	58.8	251.9	-
Mars.2016	24.50	11.60	18.05	81.5	58.3	69.9	63.2	359.2	13.2
Apri.2016	30.03	18.62	24.33	81.6	41.8	61.7	87.1	593.8	-
				2nd season					
Nov.2016	24.9	17.9	21.4	77.9	56.8	67.4	56.0	198.1	-
Dec.2016	19.3	10.8	15.1	85.4	65.1	75.3	64.7	156.4	21.34
Jan.2017	18.2	5.70	12.0	87.3	62.9	74.7	51.9	136.2	16.66
Feb.2017	19.7	10.2	15.0	85.8	60.1	73.0	59.3	214.4	16.26
Mars.2017	21.7	17.9	19.8	84.9	60.4	72.7	83.8	295.4	-
Apri.2017	26.5	21.6	24.1	79.4	50.8	65.1	89.3	263.4	10.6

*Effective rainfall(ER) = incident rainfall×0.7 (Novica 1970)

**Source: Meteorological station at Sakha Agriculture Research station 31^0 07^- N latitude and 30^0 57^- E longitude with an elevation of about 6meters above mean sea level.

Date of sowing was on Nov. 25th, 2015 and Nov. 20th, 2016 and date of harvesting took place on April, 9th ,2016 and April, 6th ,2017 in both seasons, respectively. The length and width of each furrow were 100m and 7 m (10 row× 0.7width), respectively. Irrigation discharge rate of 4Lsec^{-1} m^{-1} width was used, and therefore water was cut-off when the water front reached 100%, 90% and 85% of furrow length and alternative irrigation. Each irrigation treatment was isolated by ditches of 1.5m width to avoid lateral movement of irrigation water to adjacent plots. Along each cultivated furrow irrigation, different stations 10m apart were stalked all the way till the end of the proposed irrigation run. The time consumed for reaching the water front during the 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 water at each station was also recorded from the beginning irrigation. The difference between water advance time and recession time expressed as the opportunity time of irrigation water at each station.

At maturing in both seasons, Faba bean plants were harvested. Random samples of ten guarded plants from each plot were taken to stimulate yield components: plant height (cm), weight of seeds/ plant(g), 100-seeds weight (g), No. of branches/ plant, No. of pods/plant and No. of seed /plant. Seed yield, Straw yield and Biological yield were obtained from central area of each plot (two rows) and calculated as kg/fed. Crude protein (%) in seeds were determined according to A.O.A.C (1990). Also, the uptake of N&P by seeds of Faba bean was calculated as (kg/fed.). Data collected were subjected to statistical analysis according to Snedecor and Cochran (1982). The differences between the means were compared by Duncan's multiple range test.

Data collected

Amount of irrigation water applied (WA)

The amount of water applied for Faba bean as a winter crop at each irrigation was determined on the basis of raising the soil moisture content to its field capacity plus 10% as leaching requirement. For irrigation timing, soil samples were taken periodically from consecutive depths of 15cm down to 60 cm. until it reached the desired level of allowable moisture (50% of available soil moisture).

Irrigation water was applied through a weir at the water discharge rate of 4L sec^{-1} m^{-1} width at 10cm as effective head over the crest and the amount of water was calculated by using equation as follows: $Q= 1.84\ L\ H^{1.5}$ where, Q= rate of discharge, m^3/min., L= Length edge of weir, cm and H= height column of water above edge of weir crest, cm.

During the whole growing seasons of faba bean crop only three irrigations were applied in each season for all treatment, as shown in Table a.

TABLE (a). Date of irrigation and irrigation interval for different treatments

Irrigation number	1st season		2nd season	
	Date of irrigation	Irrigation intervals, days	Date of irrigation	Irrigation intervals, days
1st irrigation	25/11/2015-7/1/2016	44	20/11-31/12/2016	40
2nd irrigation	8/1-25/2/2016	48	1/1-20/2/2017	51
3rd irrigation	26/2-9/4/2016	44	21/2-6/4/2017	45

Seasonal water applied was calculated as described by (Giriappa 1983) as follows: WA= Iw +ER + GWC, where WA= water applied, Iw= Irrigation water applied by multiplying discharge rate by required time for furrow irrigation, ER= effective rainfall and GWC= amount of soil moisture contribution to consumptive use from the shallow ground water table.

Water consumptive use (CU)

Soil moisture percentage was determined (on weight basis) before and 48 hours after each irrigation as well as at harvest. Soil samples were taken from successive layer in the effective root zone (0-15, 15-30, 30-45 and 45-60 cm). This method of consumed water is depending upon soil moisture depletion (SMD) or so-called actual crop-water consumed (ETc) as reported by Hansen et al (1979).

$$CU = \sum_{i=i}^{i=N} \frac{\theta 2-\theta 1}{100} * Dbi * Di$$, where

CU= water consumptive use (cm) in the effective root zone (60 cm)

$\theta_{2=}$ soil moisture percentage 48 hours after irrigation

$\theta_{1=}$ soil moisture percentage before the next irrigation,

Dbi=soil Bulk density of the specific layer (Mg m^{-3})

Di = soil layer depth (15cm).

Water consumed per fed was calculated

Water productivity (water consumed)

Water productivity (WP), is generally defined as crop yield

Per cubic meter of water consumption. It was calculated according to (Ali et al., 2007) as follow

WP= Y/ETc≈ cu, where

WP= Water productivity (kg m-3 water consumed)

Y= the seed or straw yield of Faba bean (kg fed-1) and

ETc= Total water consumption of the growing season (m3 fed-1).

Productivity of irrigation water (PIW,kg m-3)

It was calculated according to (Ali et al, 2007) as follows:

PIW = Y/WA, where

PIW= productivity of irrigation water = water applied use efficiency (kg m-3 WA)

Y= the seed and straw yields kg fed-1, and

WA= seasonal water applied (m3 fed-1)

Consumptive use efficiency (Ecu, %)

It was calculated according to Doorenbos and Pruitt (1975) as follows:

Ecu = CU/WA *100, where

Ecu= consumptive use efficiency (%)

Cu= seasonal water consumptive use (m3 fed-1).

WA= Irrigation water applied (m3 fed-1).

Ground water table Contribution to Faba bean water need (GWC, %)

It was calculated as follows: GWC, %= ETc-SMD/ETc *100, where

ETc= crop evapotranspiration = ET0*Kc

SMD= soil moisture depletion ≈ CU

ETo= was calculated using three methods:

Blaney&criddle, Pan evaporation (Doorrenbos and Pruitt, 1975) and Penman Montieth, average values was calculated and considered in calculation (Allen et al., 1998).

Irrigation application efficiency (EWA, %) It was obtained by dividing the volume of water stored in the effective root zone to the applied irrigation water (Downy,1970) as follows:

EI= (Da – (Dp+ R0)/Da *100, where

Da= applied water (cm), Dp= deep percolation (cm) and R0= Runoff (cm) and EWA= irrigation application efficiency.

Water distribution efficiency (Ewd, %): It 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 the furrow length during the irrigation and y= average numerical deviation from-d

- Nutritional analysis: seed samples were collected from each plot at the end of the two growing seasons and prepared to the following different analysis
- N-content, %: was determined using micro-Kjeldahl method according to Jackson,1967
- Crude protein content, %: was calculated by multiplying the N percentage by 6.25 (A.O.A.C. 1990).
- Phosphorus content, %: was determined by using hydroquinine method (Snell and Snell,1967)
- The uptake of N and P of Faba bean seeds (kg fed-1) was calculated as follows:
- N or P uptake = seed yield (kg fed-1) × (N or P), %/100.

Economical evaluation (profitability): it was calculated according to the equation outlined by FAO, 2000, Such as,

net return, (L.E fed-1) = total return – total cost

net return from water unit (L.E m-3)= net return (L.E fed-1)/ applied water (m3 fed-1)

economical efficiency = net return (L.E fed-1)/ total cost (L.E fed-1)

Results and Discussion

Seasonal water applied and water saving

The amount of seasonal water applied (WA) for Faba bean crop consists of three components; irrigation water (IW), amount of effective rainfall (ER) and ground water contribution to crop water-need (GWC). Presented data in Table 3 clearly show that the highest seasonal values of water applied 1758.12 m^3 fed^{-1} (41.86cm) and 1777.02 m^3 fed^{-1} (42.31cm) were recorded under cut-off irrigation treatment at 100%FL (I_1) in comparison with other irrigation treatments in the two growing seasons, respectively. This amount of water applied is the result of the sum of 35.20 cm as irrigation water, 5.7 cm as effective rainfall and 0.96 cm as contribution of groundwater table in the 1st season, while the corresponding values in the 2nd season were 38.0 cm as irrigation water, 3.54 cm as effective rainfall and 0.77 cm as groundwater contribution. On the other hand, alternate furrow irrigation treatment (I_4) received the lowest values of water applied; 1355.76 m^3 fed^{-1} (32.28 cm) and 1371.72 m^3 fed^{-1} (32.66cm) for both seasons, respectively, which consists of (25.10 cm and 27.92 cm) as irrigation water, (5.7cm and 3.54 cm) as effective rainfall and (1.48 cm& 1.20cm) as ground water contribution for the 1st and 2nd seasons, respectively. Thus, average of water applied of the two seasons was in the descending order as follows: I_1 (1767.57) > I_2 (1685.88)> I_3 (1574.58> I_4 (1363.74) m^3 fed^{-1}.

In comparison with the control treatment (I_1) cut-off irrigation at 100% FL, average water saving in the two growing seasons were 81.69, 192.99 and 403.83 m^3 fed^{-1} or 4.64, 10.92 and 22.55% for cut-off at 90% FL(I_2), 85% FL (I_3) and alternate furrow irrigation (I_4), respectively. Based on the highest crop yield, saved water could be used for irrigation more crops and for horizontal expansion in agriculture. Data in the same table also illustrated that fertilization treatments didn't have any effect on seasonal amount of water applied in the two growing seasons. These findings agree with those obtained by Emara and Ibrahim (2004), Kassab (2012) and Moursi et al. (2015). Also, Liang et al. (2013), Mei et al. (2012) and Yang et al. (2015) reported that alternative furrow irrigation maintain a reasonable crop yield and save irrigation water.

Water consumptive use of Faba bean (CU)

Crop water consumptive use (CU) has the same trend as that of seasonal water applied. Water consumptive use is a direct function of the soil water status which already affected by the amount of applied water. Data in table (4) show that the overall mean values of seasonal water consumptive use for Faba bean, in the two growing seasons, were I_1 (30.69)> I_2 (30.11) > I_3 (29.64) > I_4 (26.65) cm. It is obvious that CU was the highest 30.69 cm for cut-off 100%FL (I_1), which resulted from irrigation till the end of cultivated furrow. This due to the highest water applied to treatment

(I_1). On the other hand, the lowest value (26.65cm) was recorded with alternate Furrow irrigation (I_4). Also, data in the same table indicate that, with decreasing P-Mineral rates addition and using biofertilizer (phosphorien) led to slight increases of CU of Faba bean in both seasons compared to recommended of P-Mineral (F_1). Therefore, the highest overall mean values of CU were recorded under irrigation treatment (I_1) and applying 50% of Recommended-P+ phosphorien application (F_4) and the value is 30.89 cm (1297.38 m^3 fed^{-1}). Meanwhile, the lowest overall mean values of cu were recorded under irrigation treatment I_4 (alternate, irrigation) and applying 100% of Recommended-P (F_1) and the value is 26.38 cm (1107.96 m^3 fed^{-1}).

Increasing the seasonal values of water consumptive use under F_2, F_3, and F_4 treatments comparing with F_1-treat., might be due to application of biofertilizers (phosphorien) to seeds which contain bacteria for dissolving phosphorus, this helping to form plants with a conclensed vegetative cover and consequently increasing the values of water consumptive use. These results greatly agree with those reported by Abdel-Aziz (2005), EL-Habbasha et al. (2007), Khalifa et al. (2013) and Soltan & Marzoka (2015).

Water efficiencies

The studied water efficiencies such as water productivity (WP, kg m-3), productivity of irrigation water (PIW, kg m-3) and consumptive use efficiency (Ecu, %). Presented data in tables (5&6) show that, the overall mean values for the abovementioned water efficiencies were clearly affected by both irrigation regimes treatments and phosphorien (Bio-fertilizer) with different levels of P-fertilization. Regarding, the effect of irrigation treatments on Ecu, WP and PIW, the highest overall mean values through the two growing seasons were recorded under irrigation treatment (I4) in comparison with other irrigation treatments (I1, I2 and I3).

TABLE 3. The amount of seasonal applied water for Faba bean crop as affected by irrigation treatments in the two growing seasons

Irrigation treatments	Water components: IW		ER		GWC		Total applied water (TAW)		Water saving	
	cm	m^3 fed^{-1}	cm	m^3 fed^{-1}	cm	m^3 fed^{-1}	cm	m^3 fed^{-1}	m^3 fed^{-1}	%
					1st season					
I_1= cut-off at 100%FL	35.20	1478.4	5.70	239.4	0.96	40.32	41.86	1758.12	-	-
I_2= cut-off at 90% FL	33.27	1397.34	5.70	239.4	1.14	47.88	40.11	1684.62	73.50	4.18
I_3= cut-off at 85% FL	30.21	1268.82	5.70	239.4	1.32	55.44	37.23	1563.16	194.46	11.06
I_4= Alternate irrigation	25.10	1054.20	5.70	239.4	1.48	62.16	32.28	1355.76	402.36	22.29
					2nd season					
I_1= cut-off at 100%FL	38.0	1596	3.54	148.68	0.77	32.34	42.31	1777.02	-	-
I_2= cut-off at 90% FL	35.69	1498.98	3.54	148.68	0.94	39.48	40.17	1687.14	89.88	5.10
I_3= cut-off at 85% FL	33.10	1390.2	3.54	148.68	1.11	46.62	37.75	1585.50	191.52	10.78
I_4= Alternate irrigation	27.92	1172.64	3.54	148.68	1.20	50.40	32.66	1371.72	405.30	22.81
					The over mean values of the two seasons					
I_1= cut-off at 100%FL	36.60	1537.2	4.62	194.04	0.87	36.33	42.09	1767.57	-	-
I_2= cut-off at 90% FL	34.48	1448.16	4.62	194.04	1.04	43.68	40.14	1685.88	81.69	4.64
I_3= cut-off at 85% FL	31.66	1329.51	4.62	194.04	1.21	51.03	37.49	1574.58	192.99	10.92
I_4= Alternate irrigation	26.51	1113.42	4.62	194.04	1.34	56.28	32.47	1363.74	403.83	22.55

IW= irrigation water ER= effective rainfall GWC= Ground water contribution.

TABLE 4. Effect of irrigation regimes, P-Mineral rates and Biofertilizer (phosphorien) on seasonal water consumptive use for Faba bean crop in the two growing seasons

Treatments		1st season		2nd season		The over mean values of water consumptive use for the 2 seasons	
Irrigation (I)	Fertilization(F)	Seasonal water consumptive use		Seasonal water consumptive use			
		cm	m^3fed^{-1}	cm	m^3fed^{-1}	cm	m^3fed^{-1}
Cut-off irrigation at 100%FL (I_1)	F_1	30.42	1277.64	30.52	1281.84	30.47	1279.74
	F_2	30.54	1282.68	30.73	1290.66	30.64	1286.88
	F_3	30.57	1283.94	30.85	1295.70	30.71	1289.82
	F_4	30.80	1293.60	30.98	1301.16	30.89	1297.38
Mean		30.58	1284.47	30.77	1292.34	30.68	1288.46
Cut-off irrigation at 90%FL (I_2)	F_1	29.88	1254.96	29.94	1257.48	29.91	1256.22
	F_2	29.94	1257.27	30.14	1265.88	30.04	1261.68
	F_3	30.02	1260.84	30.30	1272.60	30.16	1266.72
	F_4	30.14	1265.88	30.52	1281.84	30.33	1273.86
Mean		29.99	1259.58	30.23	1269.66	30.11	1264.62
Cut-off irrigation at 85%FL (I_3)	F_1	29.22	1227.24	29.56	1241.52	29.39	1234.38
	F_2	29.33	1231.86	29.84	1253.28	29.59	1242.78
	F_3	29.45	1237.11	29.98	1259.16	29.72	1248.24
	F_4	29.56	1241.73	30.13	1265.46	29.85	1253.7
Mean		29.39	1234.49	29.88	1254.96	29.64	1244.78
Alternative Furrow irrigation (I_4)	F_1	25.87	1086.54	26.88	1128.96	26.38	1107.96
	F_2	26.06	1094.52	27.04	1135.68	26.55	1115.10
	F_3	26.21	1100.82	27.25	1144.50	26.73	1122.66
	F_4	26.34	1106.28	27.43	1152.06	26.89	1129.38
Mean		26.12	1097.04	27.15	1140.3	26.64	1118.78

FL= Furrow irrigation length, F_1= recommended dose of P(100%RP), F_2= 75%RP+ phosphorien , F_3= 65% RP+ phosphorien, F_4= 50%RP+ phosphorien.

Generally, the values of Ecu, WP and PIW can be descended in order $I_4 > I_3 > I_2 > I_1$ in the two growing seasons. For Ecu, the values are 82.46, 79.05, 75.01 and 72.90% (Table 5), while WP of seeds, the values are 1.06, 1.02, 0.93 and 0.86 kg m^{-3}, meanwhile PIW, the values are 0.87, 0.80, 0.70 and 0.62 kg m^{-3} for I_4, I_3, I_2 and I_1, respectively (table 6). The WP and PIW values of Faba bean straw are lower than those for seeds, the values for WP are 0.66, 0.58, 0.56 and 0.61 kg m^{-3}, while PIW, values are 0.55, 0.47, 0.42 and 0.45 kg m-3 for I_4, I_3, I_2 and I_1, respectively. Increasing the over mean values of Ecu, Wp and PIW under irrigation treatment I_4 might due to decreasing amount of seasonal water consumptive use comparing to other irrigation treatments. These results are in the same line with those reported by Moursi et al. (2015), Alderfasi and Alghamdi (2010) and Sallam et al. (2014).

Concerning the effect of fertilization treatments on Ecu, WP and PIW, data in Tables 5 and 6 clearly illustrated that, the overall mean values for the previous studied parameters were affected by P-Mineral levels and phosphorien applications, where the highest overall mean values through the two growing seasons were recorded under F_4-treatment (applying 50% of RP+ phosphorien) for Ecu and under F_3-treatment (applying 65% Rp+ phosphorien) for WP and PIW in comparison with F_1 and F_2 treatments in both seasons. Generally, the overall mean values for Ecu can be descended in order $F_4 > F_3 > F_2 > F_1$, while for WP and PIW descended in order $F_3 > F_4 > F_2 > F_1$. On the other hand, the highest values of PW and PIW for both seeds and straw of Faba bean were achieved from the combination of I_4 (alternate irrigation) and F_3 (65% RP+ phosphorien) in both seasons. The findings are in the same line with those obtained by Hirich et al. (2012) and Irina Kravehenko et al. (2013).

TABLE 5. Effect of irrigation regimes and partial replacement of P-levels by Bio-fertilizer (phosphorien) on water consumptive use efficiency (Ecu, %) for Faba bean in the two growing seasons

Fertilization / irrigation treatments	1st season				Seasonal average of irrigation	2nd season				Seasonal average of irrigation	The over mean values for the two seasons
	F_1	F_2	F_3	F_4		F_1	F_2	F_3	F_4		
Cut-off irrigation at 100%FL (I_1)	72.62	72.94	73.05	73.63	73.06	72.08	72.63	72.95	73.27	72.73	72.90
Cut-off irrigation at 90%FL (I_2)	74.38	74.58	74.88	75.26	74.78	74.29	75.03	75.50	76.13	75.24	75.01
Cut-off irrigation at 85%FL (I_3)	78.40	78.72	79.14	79.52	78.95	78.18	79.05	79.16	79.88	79.07	79.01
Alternative Furrow irrigation (I_4)	79.85	80.56	81.40	84.53	81.59	82.66	82.72	83.61	84.42	83.33	82.46
Seasonal average of fertilization	76.31	76.70	77.12	78.24		76.80	77.36	77.81	78.43		

FL= Furrow irrigation length, F_1= recommended dose of P(100%RP), F_2= 75%RP+ phosphorien , F_3= 65% RP+ phosphorien, F_4= 50%RP+ phosphorien.

TABLE 6. Water productivity (WP, kg m-3), and irrigation water productivity (PIW, kg m-3) for seeds & straw of Faba bean as affected by irrigation treatments and P-Levels application and Biofertilizer (phosphorien) in the two growing seasons

Treatments		1st season				2nd season				Average values of the two seasons			
Irrigation (I)	Fertilization(F)	WP, kgm^{-3} WC		IWP, kgm^{-3} WA		WP, kgm^{-3} WC		IWP, kgm^{-3} WA		WP, kgm^{-3} WC		IWP, kgm^{-3} WA	
		seed	straw	seed	Straw	seed	straw	seed	straw	seed	straw	seed	straw
Cut-off irrigation at 100%FL (I_1)	F_1	0.71	0.60	0.51	0.44	0.73	0.55	0.53	0.40	0.72	0.58	0.52	0.42
	F_2	0.89	0.56	0.65	0.41	0.88	0.49	0.64	0.36	0.89	0.53	0.64	0.39
	F_3	0.92	0.70	0.67	0.51	1.07	0.66	0.78	0.48	0.99	0.68	0.73	0.50
	F_4	0.82	0.70	0.61	0.51	0.81	0.59	0.59	0.43	0.82	0.65	0.60	0.47
Mean		0.84	0.64	0.61	0.47	0.87	0.64	0.64	0.41	0.86	0.61	0.62	0.45
Cut-off irrigation at 90%FL (I_2)	F_1	0.70	0.42	0.52	0.31	0.76	0.42	0.57	0.31	0.73	0.42	0.55	0.31
	F_2	0.83	0.63	0.62	0.47	0.85	0.47	0.64	0.35	0.84	0.55	0.63	0.41
	F_3	1.15	0.67	0.86	0.50	1.14	0.55	0.86	0.42	1.15	0.61	0.86	0.46
	F_4	0.99	0.64	0.75	0.48	0.99	0.67	0.76	0.51	0.99	0.66	0.76	0.50
Mean		0.92	0.59	0.69	0.44	0.93	0.53	0.71	0.40	0.93	0.56	0.70	0.42
Cut-off irrigation at 85%FL (I_3)	F_1	0.80	0.42	0.60	0.33	0.76	0.46	0.59	0.36	0.78	0.43	0.60	0.35
	F_2	0.95	0.53	0.75	0.42	0.87	0.47	0.69	0.37	0.91	0.50	0.72	0.40
	F_3	1.21	0.75	0.96	0.59	1.20	0.63	0.96	0.50	1.21	0.69	0.96	0.55
	F_4	1.17	0.75	0.93	0.60	1.16	0.63	0.93	0.51	1.17	0.69	0.93	0.56
Mean		1.03	0.61	0.81	0.49	1.00	0.55	0.79	0.44	1.02	0.58	0.80	0.47
Alternative Furrow irrigation (I_4)	F_1	0.84	0.61	0.67	0.49	0.83	0.47	0.68	0.38	0.84	0.54	0.68	0.44
	F_2	1.11	0.63	0.89	0.51	0.96	0.62	0.80	0.51	1.04	0.63	0.85	0.51
	F_3	1.37	0.77	1.12	0.63	1.36	0.84	1.14	0.70	1.37	0.81	1.13	0.67
	F_4	1.01	0.79	0.85	0.67	0.94	0.53	0.79	0.45	0.98	0.66	0.82	0.56
Mean		1.08	0.70	0.88	0.558	1.02	0.62	0.85	0.51	1.06	0.66	0.87	0.55

FL= Furrow irrigation length, F_1= recommended dose of P(100%RP), F_2= 75%RP+ phosphorien , F_3= 65% RP+ phosphorien, F_4= 50%RP+ phosphorien.

Water application efficiency and water distribution efficiency

Data in Fig. 1 show that both of the water application efficiency (EWA, %) and water distribution efficiency (EWD, %) are clearly affected by all irrigation treatments in both seasons. The highest values of EWA (81.55 and 82.30%) was recorded under alternate furrow irrigation (I_4) in the 1st and 2nd seasons, respectively, with an average of 81.93% for the two seasons. Meanwhile, the lowest ones (64.29 and 64.80%) were detected with I_1-Treat. (cut-off irrigation at 100% of FL in both seasons, respectively, with an average of (64.55%) for the two seasons. Also, the highest values of water distribution efficiency (76.17 and 76.79%) were achieved with I_4-treatment (alternate furrow irrigation) for the 1st and 2nd seasons, respectively, with an average of 76.48% for the two seasons. Meanwhile, the lowest ones (70.77 and 72.47%) were recorded under I_1-treatment (cut-off irrigation at 100%FL) for both seasons, respectively, with an average of 71.62% for the two seasons.

Generally, the over mean values of EWA, % can be descended in order $I_4 > I_3 > I_2 > I_1$, meanwhile, for EWD, % was descended in order: $I_4 > I_2 > I_1 > I_3$. This finding is in a good agreement with those obtained by Meleha (2000), EL-Shehawy (2004) and EL-Hadidi et al. (2008).

Yield and yield components of Faba bean

Data illustrated in Table 7, clearly indicated that most yield characters of Faba bean were significantly affected by irrigation regimes in both seasons. The highest values of number of pods/plant (14.08&13.54); No. of branches/plant (3.21 & 3.08); seed weight/plant (39.37 &39.81 g), No. of seeds/plant (44.35& 43.36); seed yield (1293.16 and 1254.10 kg fed^{-1}) and biological yield (2077.10&1938.79 kg fed^{-1}) were resulted from irrigation treatment I_3 (cut-off irrigation at 85% FL) in both seasons, respectively. On the other hand, the lowest values of the abovementioned parameters were obtained under I_1 treat. (Cut-off at 100% FL) in both seasons.

In comparison with I_1 treat. (Cut-off irrigation at 100% FL), the increase of Faba bean seeds were (7.31, 14.75 and 9.40 %) for I_2, I_3 and I_4, respectively as a mean values of the two seasons. Also, data show that irrigation till the end of Faba bean cultivated furrow (treat. I_1) resulted in excess water more than the actual needs of the growing plants. Either excess or less water leads to reduction in most yield characters of Faba bean. Similar results were obtained by Kassab (2012), Link et al. (2010), Alirezal & Farshad (2013) and Sallam et al. (2014).

Regarding, the effect of fertilization treatments on yield and its components of faba bean plant, data in Table 7 also show that the treatments caused a high significant differences in the most yield characters of faba bean; plant height (cm), No.of pods/plant, No. of branches/plant, seed weight/ plant, straw yield/plant (g), No. of seeds/plant,

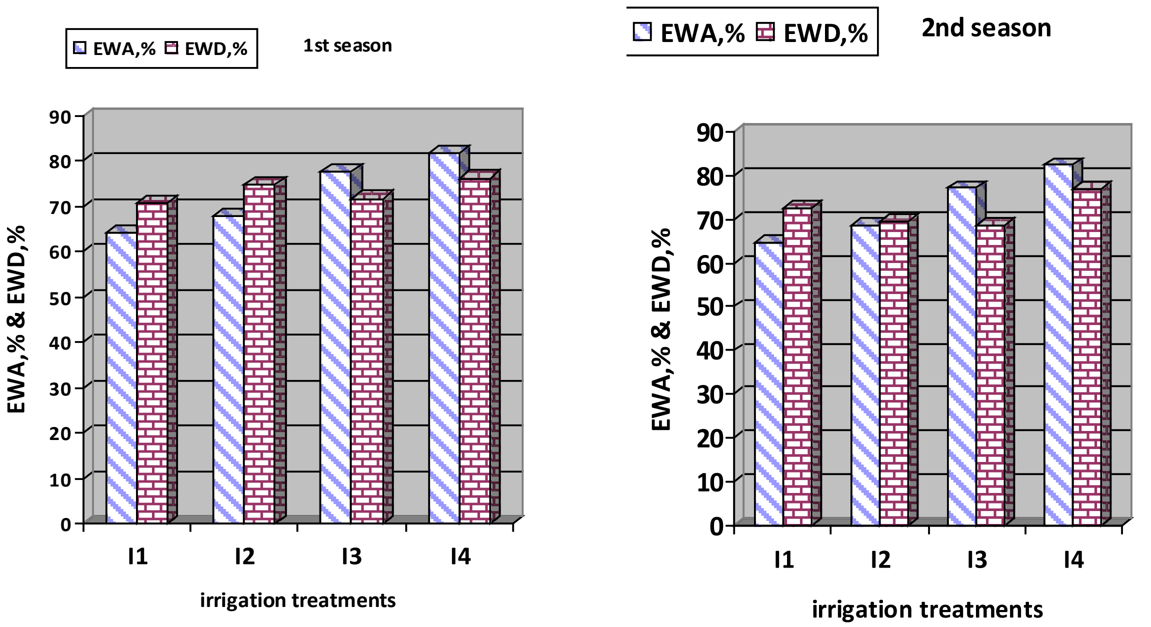

Fig. 1. Water application efficiency (EWA, %) and water distribution efficiency (EWD, %) as affected by irrigation treatments in the two growing seasons

seed yield (kg fed^{-1}), straw yield (kg fed^{-1}) and biological yield (kg fed^{-1}). The highest values of the aforementioned parameters were resulted from F_{3}-teatment (65% RP+ biofertilizers (phosphorien)), followed by F_4-treat. (50% RP + phosphorien) in both seasons. These results revealed the importance of number of pods/plant, No. of branches/plant and seed yield/plant on effective yield components which markedly influenced seed yield.

Adding 65% of recommended –P + biofertilizer (phosphorien) exerted the highest number of pods /plant (15.53& 15.11), seed weight/plant (44.79 & 46.97 g), No. of seeds/plant (50.43 &52.92), seed yield (1410.94 and 1479.46 kg fed^{-1}) and biological yield (2290.32 & 2306.33 kg/fed). Furthermore, from the above-mentioned results, the highest seed yield was obtained with saving from 35-50% of mineral-P with the application of biofertilizers and avoiding its undesirable effects (Fernands et al., 2007 and Janagard et al., (2013)., who suggested that the importance of the superiority of the applied P-bio dissolving was not only taken as a criterion for increasing the income for crop or rationalize of costly mineral P-fertilizers, but also for minimizing the possibly adverse dearsa both human health and environmental risks resulted from mineral- P fertilizers.

TABLE 7. Yield and its components of Faba bean crop as affected by Irrigation regimes and P-Mineral levels and bio- fertilizer application (phosphorien) during the two growing seasons

Treatments	Plant height, cm	No. of pods/ plant	No. of branches/ plant	Seed weight/ plant (g)	100-seed weight, g	straw yield/plant (g)	No. of seeds/plant	Seed yield, kg fed^{-1}	Straw yield , kg fed^{-1}	Biological yield kg fed^{-1}
					1^{st} season					
Irrigation (I)										
I_1=cut-off 100%FL	83.64^{a}	13.45	3.00	34.05^{b}	88.02	27.22^{a}	38.12^{b}	1108.96^{b}	820.30	1929.26^{c}
I_2=cut-off 90%FL	77.33^{c}	13.67	3.29	36.85^{ab}	87.45	23.61^{b}	42.65^{ab}	1193.28^{ab}	768.75	1962.03^{c}
I_3=cut-off 85% FL	77.26^{c}	14.08	3.21	39.37^{a}	88.64	24.86^{b}	44.35^{a}	1293.16^{a}	783.13	2077.10^{a}
I_4=alternate irrigation	81.05^{b}	13.76	3.15	37.16^{ab}	88.80	24.45^{b}	42.15^{ab}	1232.16^{ab}	770.00	2002.16^{b}
F-Test	**	NS	NS	*	Ns	**	**	**	Ns	**
Fertilization (F)										
F_1=100%of RP	74.66^{c}	10.86^{C}	2.75^{C}	27.53^{c}	90.35	22.70^{c}	30.50^{c}	1051.61^{d}	693.13^{c}	1744.74^{c}
F_2=75% of RP+phosp.	79.53^{b}	13.66^{b}	3.04^{b}	36.26^{b}	86.88	23.40^{b}	41.88^{b}	1142.23^{c}	715.31^{b}	1857.54^{b}
F_3=65%of RP+phosp.	82.84^{a}	15.53^{a}	3.22^{b}	44.79^{a}	89.65	27.85^{a}	50.43^{a}	1410.94^{a}	879.38^{a}	2290.32^{a}
F_4=50% of RP+ phosp.	82.26^{a}	14.91^{a}	3.64^{a}	38.85^{b}	86.04	28.19^{a}	44.46^{b}	1223.56^{b}	879.37^{a}	2102.93^{b}
F-Test	**	**	**	**	Ns	**	**	**	**	**
Interaction (I×F)	NS	NS	NS	*	Ns	Ns	*	*	Ns	*
					2^{nd} season					
Irrigation (I)										
I_1=cut-off 100%FL	83.23^{a}	12.45	2.69^{b}	35.82^{b}	87.95	24.10	41.01	1112.63^{b}	740.74	1853.37^{b}
I_2=cut-off 90%FL	78.64^{b}	13.23	3.03^{a}	37.80^{ab}	86.38	21.32	43.53	1190.7^{ab}	669.38	1860.08^{ab}
I_3=cut-off 85% FL	77.93^{b}	13.54	3.08^{a}	39.81^{a}	86.77	21.74	43.36	1254.10^{a}	684.69	1938.79^{a}
I_4=alternate irrigation	83.31^{a}	13.21	2.93^{a}	36.83^{b}	90.30	22.22	41.04	1197.7^{ab}	700.10	1897.8^{ab}
F-Test	**	Ns	**	*	Ns	Ns	Ns	*	Ns	*
Fertilization (F)										
F_1=100%of RP	76.22^{c}	11.24^{c}	2.67^{c}	29.99^{d}	84.85	19.47^{c}	35.37^{c}	1045.45^{c}	589.69^{b}	1635.14^{d}
F_2=75% of RP+phosp.	78.78^{b}	12.37^{b}	2.86^{bc}	34.62^{c}	87.90	21.10^{b}	39.88^{b}	1098.76^{c}	630.10^{b}	1728.76^{c}
F_3=65%of RP+phosp.	84.01^{a}	15.11^{a}	3.06^{ab}	46.97^{a}	89.30	26.67^{a}	52.92^{a}	1479.46^{a}	826.88^{a}	2306.33^{a}
F_4=50% of RP+ phosp.	84.10^{a}	13.70^{b}	3.15^{a}	38.69^{b}	89.35	24.24^{a}	40.78^{b}	1219.93^{b}	758.24^{ab}	1978.17^{b}
F-Test	**	**	**	**	Ns	**	**	**	**	**
Interaction (I×F)	**	**	Ns	**	Ns	**	*	**	**	**

NS, *, ** insignificant, significant at 0.05 and 0.01 level of probability, respectively. Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test.

The interaction effect between irrigation and fertilization treatments had high significant effect on the most yield characters of faba bean. These findings are consistent with those obtained by Alghamdi (2009), Manochehr et al. (2013) and Sallam et al. (2014).

Effect of different treatments on protein content and uptake of N and P by seeds of Faba bean

Data listed in Table 8 revealed that both irrigation and fertilization treatments were significantly affected the protein content of seeds. Increasing trend in seed protein was in parallel with less water applied. Therefore, the highest values of the protein content of seeds (20.58&21.63%) in both seasons, respectively were recorded under I_4-treat. (Alternate furrow irrigation). Regarding the effect of fertilization treatments, the highest values of the protein content in seeds (20.72 &22.00%) were resulted from F_4-treat. (50% RP+phosphorien) in both seasons, respectively. Also, it was noticed that there no significant differences in the protein content, % in seeds as affected by both (I_3 and I_4) and (F_3 & F_4) treatments in both seasons. Also, data in the same Table (9) showed that both of irrigation and fertilization treatments had high significant effect on the uptake of N and P by seeds of faba bean in both seasons. The highest values of N-uptake (45.507 and 43.524 kg fed^{-1}) and P-uptake (6.973 and 5.677 kg fed^{-1}) were resulted from I_3-treatment (cut-off irrigation at 85% FL) in the 1st and 2nd seasons, respectively, followed by I_4 (alternate furrow irrigation) in both seasons. With respect to the effect of fertilization treatments, data in the same table revealed that the highest values of N-uptake (46.696 and 51.869 kg fed^{-1}) and P- uptake (7.894 and 6.807 kg fed^{-1}) were achieved from F_3-teatment (applying 65%rp+ phosphorien) in the 1st and 2nd seasons, respectively, followed by F_4-Treatment (applying 50%RP+ phosphorien) in both seasons. The interaction between irrigation and fertilization treatments had highly and high significant effects for N and P- uptakes, respectively in both seasons. These findings are in harmony with those obtained by Abdel-Aziz (2005), EL-Habbasha et al. (2007) and Janagrad et al. (2015).

TABLE. 8. Effect of irrigation regimes and P-mineral levels, Bio- fertilizer (phosphorien) on NP-conc., %, uptake (kg fed-1) and crude protein content, % in seeds of Faba bean plant in the two growing seasons

Factors	N-conc.,%	Crude protein,%	N-uptake, kg fed^{-1}	P-conc.,%	P-uptake, kg fed^{-1}
Irrigation (I)			1st season		
I_1=cut-off 100%FL	3.256	20.35^{c}	36.108^{c}	0.543	6.027^{c}
I_2=cut-off 90%FL	3.271	20.44^{ba}	39.032^{b}	0.544	6.491^{b}
I_3=cut-off 85% FL	3.285	20.55^{a}	42.507^{a}	0.547	6.973^{a}
I_4=alternate irrigation	3.293	20.58^{a}	40.574^{a}	0.549	6.530^{a}
F-Test	Ns	*	**	Ns	**
Fertilization (F)					
F_1=100%of RP	3.186^{c}	19.91^{c}	33.504^{d}	0.520	5.541^{c}
F_2=75% of RP+phosphorien.	3.298^{b}	20.61^{b}	37.670^{c}	0.546	6.238^{ba}
F_3=65%of RP+ phosphorien	3.308^{a}	20.68^{a}	46.696^{a}	0.559	7.894^{a}
F_4=50% of RP+ phosphorien	3.316^{a}	20.72^{a}	40.581^{b}	0.558	6.829^{b}
F-Test	*	*	**	Ns	**
Interaction (I×F)	Ns	*	**	Ns	*
Irrigation (I)			2nd season		
I_1=cut-off 100%FL	3.398	21.24^{b}	37.807^{c}	0.444	5.028^{c}
I_2=cut-off 90%FL	3.428	21.42^{b}	40.955^{b}	0.443	5.349^{b}
I_3=cut-off 85% FL	3.455	21.60^{a}	43.524^{a}	0.450	5.677^{a}
I_4=alternate irrigation	3.460	21.63^{a}	41.440^{b}	0.450	5.390^{b}
F-Test	Ns	*	**	Ns	*
Fertilization (F)					
F_1=100%of RP	3.343^{c}	20.89^{c}	34.949^{d}	0.433	4.526^{c}
F_2=75% of RP+ phosphorien	3.368^{b}	21.05^{b}	36.996^{c}	0.436	4.788^{c}
F_3=65%of RP+ phosphorien	3.505^{a}	21.91^{a}	51.869^{a}	0.460	6.807^{a}
F_4=50% of RP+ phosphorien	3.525^{a}	22.00^{a}	43.027^{b}	0.462	5.644^{b}
F-Test	*	*	**	Ns	**
Interaction (I×F)	Ns	*	**	Ns	*

NS, *, ** insignificant, significant at 0.5 and 0.01 level of probability, respectively. Mean values designed by the same letter in each column are not significant according to Duncan's Multiple Range Test.

Data presented in Table 9 and Fig. 2 show that, the seasonal average values of ground water table contribution (GWC) as affected by different irrigation regimes were 0.96cm (33.63%), 1.14 cm (40.46%), 1.32 (46.86%) and 1.46 (51.45%) for cut-off irrigation at 100%, 90% and 85% FL and alternative furrow irrigation, respectively. in the 1st season. The corresponding values in the 2nd season were 0.77 cm (27.59%), 0.99cm (33.25%), 1.11 cm (39.96%) and 1.20 cm (41.76%) for the aforementioned irrigation regimes, respectively.

Also, data in the same table clearly indicate that GWC to Faba bean –ET was increased with increasing cut-off irrigation from Furrow length and alternate furrow irrigation in both seasons under different fertilization treatments. So, irrigation Faba bean plant with alternate furrow irrigation (I_4) which received the lowest applied water as mentioned previously and therefore recorded the highest percentage of ground water table contribution percent, followed by cut-off at 85% FL in both seasons. These results somewhat agree with those obtained by Kahlown et al. (2005), Khalifa (2013) and EL-Hadidi et al. (2016).

TABLE 9. Ground water contribution to ETc of faba bean as influenced by different irrigation treatments and partial replacement of P-mineral by bio- fertilizers (phosphorien) in the two growing seasons

Fertilization (F) / Irrigation treatments (I)	F_1		F_2		F_3		F_4	
	GWC, cm	GWC, %	GWC, cm	GWC, %	GWC, cm	GWC, %	GWC, cm	GWC, %
Cut-off irrigation at 100%FL(I_1)	0.99	34.87	0.97	33.83	0.95	32.29	0.93	32.51
Cut-off irrigation at 90%FL(I_2)	1.20	42.38	1.17	41.42	1.12	39.77	1.08	38.28
Cut-off irrigation at 85%FL(I_3)	1.36	48.50	1.35	47.75	1.31	46.26	1.27	44.92
Alternate furrow irrigation (I_4)	1.60	56.96	1.46	53.25	1.41	48.83	1.36	46.76
Seasonal mean of fertilization	1.29	45.68	1.24	44.10	1.20	42.01	1.16	40.62
Cut-off irrigation at 100%FL(I_1)	0.80	28.45	0.77	27.47	0.75	26.74	0.74	26.39
Cut-off irrigation at 90%FL(I_2)	1.07	38.40	0.94	33.55	0.90	31.83	0.86	31.26
Cut-off irrigation at 85%FL(I_3)	1.17	41.93	1.11	40.04	1.09	38.90	1.08	38.97
Alternate furrow irrigation (I_4)	1.26	44.58	1.23	43.26	1.17	40.67	1.12	38.54
Seasonal mean of fertilization	1.08	38.34	1.01	36.03	0.98	34.54	0.95	33.79

F_1= applying 100%RP , F_2= 75% RP+ phosphorien , F_3= 65% RP + phosphorien. , F_4 = 50% RP + phosphorien

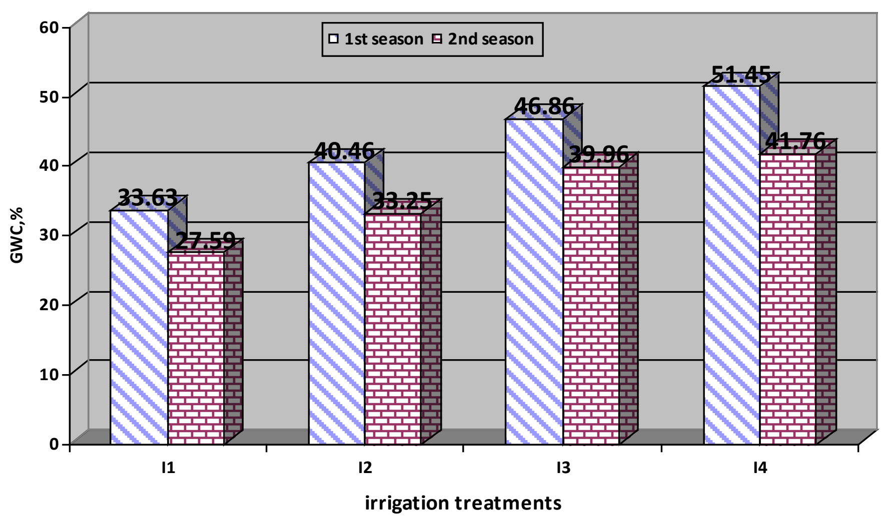

Fig. 2. Seasonal mean of ground water contribution, % to faba bean crop as affected by irrigation treatments in the two growing seasons

Economic evaluation

The total cost of faba bean production (including fixed and variable costs) according to local market price (L.E) in the two growing seasons were calculated. Economic assessment requires some items which the evaluation process can be conducted in table 10, obtained data show that the combination of I_3-Treatment (cut-off irrigation at 85%FL) and F_3 treatment (applying 65% Recommended-P +Phosphorien) recorded the highest values of total return (12818.5 and 16136.88 LE fed^{-1}) and net return (9687.8 and 12441.88 LE fed^{-1}) for the 1st and 2nd season, respectively, followed by the combination of $I_{4\ and}$ F_3 treatments. Meanwhile, the highest values of net return from water unit for seed yield (6.53 and 8.69 LE m^{-3}) and net return from water unit for biological yield (7.16 and 9.57 LE m^{-3}) were achieved from the combination of I_4-treat. (Alternate furrow irrigation) and F_3-treat. (Cut-off irrigation at 85% of furrow length) in both seasons, respectively.

While, the lowest values for the previous parameters were recorded with the combination of I_1-treat. (Cut-off irrigation at 100% FL) and F_1-treat. (100% Recommended-P) in both seasons and found to be (7923 &10227.5 LE/fed) for total return, (4723 and 6427.5 LE/fed) for net return, (2.45 & 3.12 LE/ m^{-3}) for net return from water unit of seed yield and (2.68 and 3.61 LE/m^3) for net return from water unit of biological yield.

TABLE 10. Total return, net return, net return from water unit and economical efficiency of faba bean crop as affected by irrigation and fertilization treatments, in the two growing seasons.

Treatments		return, LE.fed^{-1}		Total return	Total cost	Net return	Applied water	Net return from water unit, LE. m^{-3}		Economical efficiency	
Irrigation (I)	Fertiliz-ation (F)	seed	Straw	LE.fed^{-1}	LE.fed^{-1}	LE.fed^{-1}	m^{3}fed^{-1}	seed yield	Biological yield	Seed yield	Biological yield
					1st season						
Cut-off at 100%FL(I_1)	F1	7153	770	7923	3200	4723	1759.38	2.45	2.68	1.24	1.48
	F2	9027.5	717.5	9745	3151	6594	1758.35	3.34	3.75	1.86	2.09
	F_3	9407	892.5	10299.5	3131	7168.5	1757.7	3.57	4.08	2.00	2.29
	F_4	8452.5	901.22	9353.72	3102	6251.72	1756.86	3.05	3.56	1.72	2.02
Cut-off at 90%FL(I2)	F_1	7003.5	525	7528.5	3200	4328.5	1687.14	2.25	2.57	1.19	1.35
	F_2	8291.5	796.25	9087.75	3151	5936.75	1685.88	3.05	3.52	1.63	1.88
	F_3	11534.5	848.75	12383.25	3131	9252.25	1683.78	4.99	5.49	2.68	2.96
	F_4	9993.5	805	10798.5	3102	7696.5	1682.1	4.10	4.58	2.22	2.48
Cut-off at 85%FL(I_3)	F_1	7590	521.5	8111.5	3200	4911.5	1565.34	2.80	3.14	1.37	1.53
	F_2	9280.5	656.25	9936.75	3151	6785.75	1564.92	3.92	4.34	1.95	2.15
	F_3	11891	927.5	12818.5	3131	9687.5	1563.24	5.60	6.20	2.80	3.09
	F_4	11546	936.27	12482.27	3102	9380.27	1561.56	5.41	6.01	2.72	3.02
Alternative irrigation (No-cut-off)(I_4)	F_1	7222	665	7887	3200	4687	1360.8	2.96	3.44	1.26	1.46
	F_2	9637	691.25	10328.25	3151	7177.25	1358.2	4.78	5.28	2.06	2.28
	F_3	11960	848.75	12808.75	3131	9677.75	1352.4	6.53	7.16	2.82	3.09
	F_4	8832	875	9707	3102	6605	1308.72	4.38	5.05	1.85	2.13
					2nd season						
Cut-off at 100%FL(I_1)	F_1	9352.5	875	10227.5	3800	6427.5	1778.28	3.12	3.61	1.46	1.69
	F_2	11411.5	798.44	12209.94	3725	8484.94	1777.02	4.33	4.77	2.06	2.28
	F_3	13876.5	1071.88	14948.38	3695	11253.38	1776.18	5.73	6.34	2.76	3.05
	F_4	10556	958.38	11514.38	3650	7864.38	1775.76	3.89	4.43	1.89	2.15
Cut-off at 90%FL(I_2)	F_1	9599	656.25	10255.25	3800	6455.25	1692.6	3.43	3.81	1.53	1.70
	F_2	10715.5	743.75	11459.25	3725	7734.25	1987.14	3.52	3.89	1.88	2.08
	F_3	14558	875	15433	3695	11738	1685.46	6.45	6.96	2.94	3.18
	F_4	12745.5	1071.88	13817.38	3650	10167.38	1683.78	5.40	6.04	2.49	2.79
Cut-off at 85%FL(I_3)	F_1	9439.5	710.94	10150.44	3800	6350.44	1588.02	3.55	4.00	1.48	1.67
	F_2	10860.5	732.81	11593.31	3725	7868.31	1585.5	4.50	4.96	1.92	2.11
	F_3	15152.5	984.38	16136.88	3695	12441.88	1584.66	7.23	7.85	3.10	3.37
	F_4	14717.5	995.31	15712.81	3650	12062.81	1584.24	6.99	7.61	3.03	3.30
Alternative irrigation (No-cut-off)(I_4)	F_1	9396	656.25	10052.25	3695	6252.25	1365.52	4.10	4.58	1.47	1.65
	F_2	10947.5	875	11822.5	3725	8097.5	1372.98	5.26	5.90	1.94	2.17
	F_3	15602	1203.13	16805.13	3688	13110.13	1370.46	8.69	9.57	3.22	3.55
	F_4	10788	765.63	11553.63	3650	7903.63	1368.38	5.22	5.78	1.96	2.17

Marketable price for 1kg seed of faba bean (7.67&9.67 L.E) and marketable price for 1kg of faba bean straw (1&1.25 L.E) in the 1st and 2nd seasons, respectively.

Net income from water unit= Net income L.E fed^{-1} / WA (m^3 fed^{-1}.) Economical efficiency = Net income / total cost (LE/ fed)

F_1= applying 100%RP , F_2= 75% RP+ phosphorien , F_3= 65% RP + phosphorien. , F_4 = 50% RP + phosphorien

fixed costs were (1500 L.E and 1575 L.E) for 1st and 2nd seasons respectively.

Concerning economical efficiency, data in the same table show that alternate furrow irrigation (I_4) + 65% of RP + phosphorien (F_3) gave the highest values of economical efficiency (2.82 and 3.22) for seed yield and (3.09 and 3.55) for biological yield in the 1st and 2nd seasons, respectively. Meanwhile, the lowest values of economical efficiency (1.24 &1.46) for seed yield and (1.48 &1.69) for biological yield in both seasons, respectively. So, the effect of irrigation regimes under applying 65% of mineral-P recommended+ phosphorien on the faba bean crop can be arranged from the economical evaluation in the descending orders: cut-off at 85%FL > alternate furrow irrigation > cut-off irrigation at 90% FL> cut-off irrigation at 100%FL.

Conclusion

The results of this study showed that alternate irrigation or cut-off irrigation at 85% FL in combination with 65% of recommended mineral-p in the presence of phosphorien (biofertilizer) was more efficient according to the concept of water saving, water productivity and seed yield and productivity of irrigation water, as well as, the use of phosphorien can be minimize the mineral phosphorus fertilizer, and then reduce the cost production and pollution, which could occurred by the excessive use of chemical fertilizers.

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استجابة الفول البلدي للري التبادلي وايقاف سريان مياه الري بالتداخل مع مستويات من الفوسفور المعدني والتسميد الحيوي في أراضي شمال الدلتا

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أجريت تجربة حقلية خلال الموسم الشتوي لموسمي ٢٠١٦/٢٠١٥ & ٢٠١٧/٢٠١٦ بمحطة البحوث الزراعية بسخا محافظة كفر الشيخ لدراسة وتقييم أربع نظم للري وهي المعاملة الأولي ($I_{١}$) وقف جبهة سريان مياه الري عند ١٠٠٪ من طول الخط , المعاملة الثانية ($I_{٢}$) وقف جبهة سريان مياه الري عند ٩٠٪ من طول الخط ، المعاملة الثالثة($I_{٣}$) وقف جبهة سريان مياه الري عند ٨٥٪ من طول الخط ، المعاملة الرابعة ($I_{٤}$) الري التبادلي (كمعاملات رئيسية) ، أربع معاملات للتسميد وهي : المعاملة الأولي ($F_{١}$) إضافة ١٠٠٪ من الجرعة الموصي بها من الفوسفور المعدني كمقارنة ، المعاملة الثانية($F_{٢}$) إضافة ٧٥٪ من الجرعة الموصي بها من الفوسفور المعدني + الفوسفورين ،المعاملة الثالثة ($F_{٣}$) إضافة ٦٥٪ من الجرعة الموصي من الفوسفور المعدني +الفوسفورين، المعاملة الرابعة ($I_{٤}$) إضافة ٥٠٪ من الجرعة الموصي بها من الفوسفور المعدني + الفوسفورين) علي الإنتاج ومكوناته لنبات الفول البلدي ، بعض العلاقات المائية ، توفير مياه الري وكذلك مساهمة الماء الأرضي للاحتياجات المائية لنبات الفول ، العائد الاقتصادي. أوضحت النتائج المتحصل عليها ما يلي. يمكن ترتيب معاملات الري طبقا لكمية مياه الري المضافة، الاستهلاك المائي الموسمي في الترتيب التالي: المعاملة الأولي > المعاملة الثانية> المعاملة الثالثة >المعاملة الرابعة. كمية مياه الموفرة بواسطة المعاملة الثانية، المعاملة الثالثة، المعاملة الرابعة لري نبات الفول كانت ٤,٦٤، ١٠,٩٢، ٢٢,٥٥٪ على الترتيب مقارنة بمعاملة الري الأولي. الاحلال الجزئي من السماد الفوسفوري بواسطة السماد الحيوي (الفوسفورين) أدي الي زيادة طفيفة في الاستهلاك المائي الموسمي تحت جميع معاملات الري. تحصل علي فروق معنوية في انتاج الفول البلدي من البذور ومكوناته، نسبة محتوي البروتين في البذور وامتصاص النتروجين والفوسفور بواسطة البذور في كلا الموسمين. كلا من معاملة الري الثالثة $I_{٣=}$ و معاملة التسميد ($F_{٣}$) تفوقا في زيادة انتاج البذور للفول البلدي ومعظم مكوناته في كلا الموسمين. اتضح من النتائج أن اعلي القيم لكلا من كفاءة الاستهلاك المائي، كفاءة إضافة مياه الري، كفاءة التوزيع لمياه الري، مساهمة الماء الأرضي للاحتياجات المائية لنبات الفول تحصل عليها بواسطة المعاملة الرابعة (الري التبادلي) في كلا الموسمين. الخليط من (معاملة الري الرابعة& معاملة التسميد الثالثة) تفوقت على باقي المعاملات الأخرى في زيادة الإنتاجية المائية من الماء المستهلك (WP)، الإنتاجية المائية من ماء الري المضاف (PIW) لكلا من انتاج البذور والقش لنبات الفول، العائد الموسمي الكلي، صافي العائد، صافي العائد من الوحدة المائية والكفاءة الاقتصادية في كلا الموسمين. تحت ظروف الدراسة الحالية يمكن التوصية بالري بالمعاملة الرابعة (الري التبادلي) أو بالمعاملة الثالثة (وايقاف جبهة سريان مياه الري عند ٨٥٪ من طول الخط مع إضافة التسميد بالمعاملة الثالثة (إضافة ٦٥٪ من الجرعة الموصي بها من الفوسفور المعدني+ الفوسفورين كسماد حيوي) للحصول علي أعلي إنتاجية للفول البلدي، توفير مياه الري، واعلي عائد اقتصادي.