19 *Env. Biodiv. Soil Security*, **Vol. 7**, pp: 253 - 262 (2023)

Environment, Biodiversity & Soil Security

http://jenvbs.journals.ekb.eg/

Maximizing Water Use Efficiency for Faba Bean crop by using Leaky irrigation under El-Baharia Oasis Condition

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THE FABA BEAN crop is one of the most important strategic legume crops, in Egypt, so obtaining the highest productivity per feddan with least the amount of irrigation water added. It is one of the most important goals to seek modern applied research in the water requirements field of is based, an experiment was procedures through two winter consecutive seasons of 2020/2021 and 2021/2022, at a private plantation in El- Baharia Oasis area, Giza Governorate, Egypt, to compare the effect of leaky pipe (LBI) and sprinkler (SI) irrigation systems at different irrigation water levels (IR=100, 85, 70 and 55% calculated based on crop evapotranspiration) and three potassium humate fertilizer rates (PHR= 0, 4 and 8 kg fed^{-1}), on crop quality parameters, marketable seeds yield (MSY), seasonal actual evapotranspiration (ETa), water use efficacy (WUE) and irrigation water use efficiency (IWUE) for winter faba bean (*Vicia faba L.*) Giza 843. The results indicated that the marketable seeds yield and quality parameters except seed carbohydrate content (SCC) % and seed protein content (SPC) % of winter faba bean crop gave the highest values under LBI, IR=100%, and PHR = 6 kg fed^{-1} treatment for both seasons while, the seasonal ETa gave the lowest values: 176.37 and 172.79 mm for both seasons, respectively, under LBI, IR= 55% and PHR = 0 kg fed^{-1} treatment meanwhile, the maximum values of winter faba bean crop WUE and IWUE were 1.89 and 1.52 kg m^{-3}; 1.96 and 1.55 kg m^{-3} for both seasons, respectively, under LBI, IR=70% and HAR = 6 kg fed^{-1} treatment. This study indicated that the farming of winter faba bean crop under LBI, IR=70% and HAR = 6 kg fed^{-1} treatment could probably conserve about 30% of the applied irrigation water and raise marketable seeds yield of winter faba bean crop by about 36% as average for both seasons compared with that under control treatment (i.e. SI, IR=100% and PHR = 0 kg fed^{-1}).

Keywords: Leaky pipe; Faba bean; Iirrigation water levels; Actual evapotranspiration; Water use efficiency.

1. Introduction

In arid and semi-arid climates, water is the most constraining natural resource for agricultural productivity. The most cost-efficacious vibes to address water security issues are amended irrigation management and effective use of irrigation water strategies, which in turn affect crop quality and output. More susceptible to a lack of water than other seed legumes like common beans, peas, and chickpeas are faba bean crops (Ammar et al. 2014); (Montazar et al. 2020); (Brevik et al. 2022); (Fawzy et al. 2022). The faba bean (*Vicia faba L.*) is a legume that may be used to improve soil fertility and provide nourishment for human feed. It also acts as a N_2 fixer. Since faba beans make up a significant portion of the Egyptian diet, expanding faba bean production and enhancing its quality is a key goal in meeting the demands of the country's growing population. In the past 10 years, Egypt's faba bean cultivated area has shrunk from 71445 to 32532/ha (FAOSTAT 2017). Sandy soil has a problem with deep percolation and high levels of infiltration when conventional irrigation techniques are applied. On the other hand, small-scale irrigation techniques like drip and leaky pipes may yield better results because they minimize deep percolation by giving the root system just the right amount of water at the right rate. Along the leaky pipe, cross-sectional observations of the moisture patterns were made, and the wetting front's vertical and horizontal expansion was noted. The findings show that a leaky pipe system works well with light-textured soils because it gradually regulates deep percolation and needs little pressure to function (Golabi and Akhoonali 2008); (Rasheed 2021). In the current study, a cutting-edge drip irrigation system and an inventive leaky pipe were examined for their usefulness for underground

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Received: 24/11/2023; Accepted: 27/12/2023
DOI: 10.21608/JENVBS.2023.250968.1234

watering of lettuce. The findings indicate that, in comparison to drip irrigation, the porous pipe system required 35% less water and resulted in a 9% increase in total fresh biomass. As a result, the water consumption efficiency was much higher 58 kg/m^3 than it was with drip irrigation 34.4 kg/m^3 (Kunze et al. 2021). A few cultivars of lentils utilizing sprinkler and dripping irrigation methods on sandy soil were evaluated, two field tests were conducted, and the results indicated that drip irrigation produced higher values for the analyzed traits than spray irrigation (Khattb and El-Housini 2019). Potassium humate has both direct and indirect benefits for plant growth and development. Its impact on cell membranes results in better protein synthesis, increased mineral transport, plant hormone-like activity, enhanced photosynthesis, modified enzyme activities, solubility of micro- and macro-elements, decreased levels of active toxic minerals, and increased microbial populations (Hamideh et al. 2013). The agronomic performance of various crops, including plant height, plant spread, dry matter accumulation, crop growth rate, relative growth rate, nodule count, nodule dry weight, nutrient content, yield components, yield, and quality, can all be greatly impacted by the application of humic acid, as this review has demonstrated. The mentioned article also reviews the impact of humic acid on the following parameters related to soil quality: pH, electrical conductivity, microbial activity, bulk density, particle density, porosity, NPK content, organic matter content, and cation exchange capacity. Since The main component of humus and the organic material that it produces is humic acid. It has several characteristics that support the soil's fertility. Maintaining soil fertility requires enhancing the physical, chemical, and biological characteristics of the soil. Utilizing humic acid was found to have positive effects on fruit and vegetable production in addition to cereal and pulse production. Humic acid improves soil quality and increases crop yields when it is applied to different crops in different amounts and dosages. Whether it was applied to the soil or the plant directly, and through a range of application techniques, such as seed treatment, soil application, and foliar application, its use was found to be beneficial in agricultural output (Meganind et al. 2015); (Kumar 2018); (Ampong et al. 2022). The crop quality like Plant height, the number of branches, the number of pods, and the number of seed pods were among the growth and yield parameters that increased significantly with increasing rates of added P potassium humate, both separately and in combination. Their combined treatments, particularly at high application rates, produced the highest values (Awaad et al. 2020). One of the key strategies for conserving water in agricultural production is the use of deficit irrigation. A method to lower water demand, raise water use efficiency (WUE), and maximize crop yields such as faba beans, onions, tomatoes, and maize is deficit irrigation. It is clearly defined as applying water less than what the crop needs to thrive (Faghih et al. 2019); (Mohamed Abd El- Aziz 2020); (Basma and Reham 2022); (Tesfaye 2023). It is possible to conclude that the maximum irrigation regime of 100% ETc produced the highest values of faba bean crop growth, yield, and chemical composition, whereas the application of an irrigation regime of 60% ETc produced the highest values of plant height, N (%), protein (%), WUE, and WCP (kg m^{-3}). (Hegab et al. 2014); (Awadalla et al. 2018); (Fayed et al. 2018); (Hefzy et al. 2020).

This study aimed to discuss the effect of leaky pipe irrigation system on cultivation winter faba bean yield production, quality growth parameters, actual evapotranspiration, water use efficiency and irrigation water use efficiency compared to sprinkler irrigation system at different levels of applied irrigation water and potassium humate fertilizer rates.

2. Materials and Methods

Field experiments were carried out in El- Baharia Oasis, Giza Governorate, Egypt, at (28° 13` 21`` N: 28° 46` 34``E. 128 m above sea level) during the winter seasons 2020/2021 and 2021/2022. In a split-split plot design with three replicates, the experimental was divided into 60 m^2 plots; each bounded by 2 m wide barren to avoid horizontal infiltration. The obtained data were subjected to statistical analysis according to (Snedecor and Cochran 1989), using Co-state software program. The winter faba bean (*Vicia faba L.*) Giza 843 was irrigated by added four levels of applied irrigation water (IR=100, 85, 70 and 55% calculated based on crop evapotranspiration) and three potassium humate fertilizer rates (PHR= 0, 4 and 8 kg fed^{-1}), by using leaky pipe (LBI) and sprinkler (SI) irrigation systems (Fig.1). The Plant height (PH) cm, Leaf area index (LAI), total chlorophyll (TC) mg g^{-1}, number of branches plant^{-1} (NB), number of pods plant^{-1} (NP), number of seeds pod^{-1} (NS), seed carbohydrate content (SCC) %, seed protein content (SPC) % and marketable seeds yield (MSY) ton fed^{-1} were determined for winter faba bean crop.

While, the seasonal actual evapotranspiration (ETa) mm, water use efficiency (WUE) kg m^{-3} and irrigation water use efficiency (IWUE) kg m^{-3} were calculated for all applied irrigation water levels and potassium humate rates under different irrigation systems for all winter faba bean plots.

Soil characteristics

Soil samples were compiled to define the physical and chemical soil characteristics. The methodological steps pursued the methods depicted by (Page et al. 1982); (Klute 1986) as revealed in Tables (1 & 2).

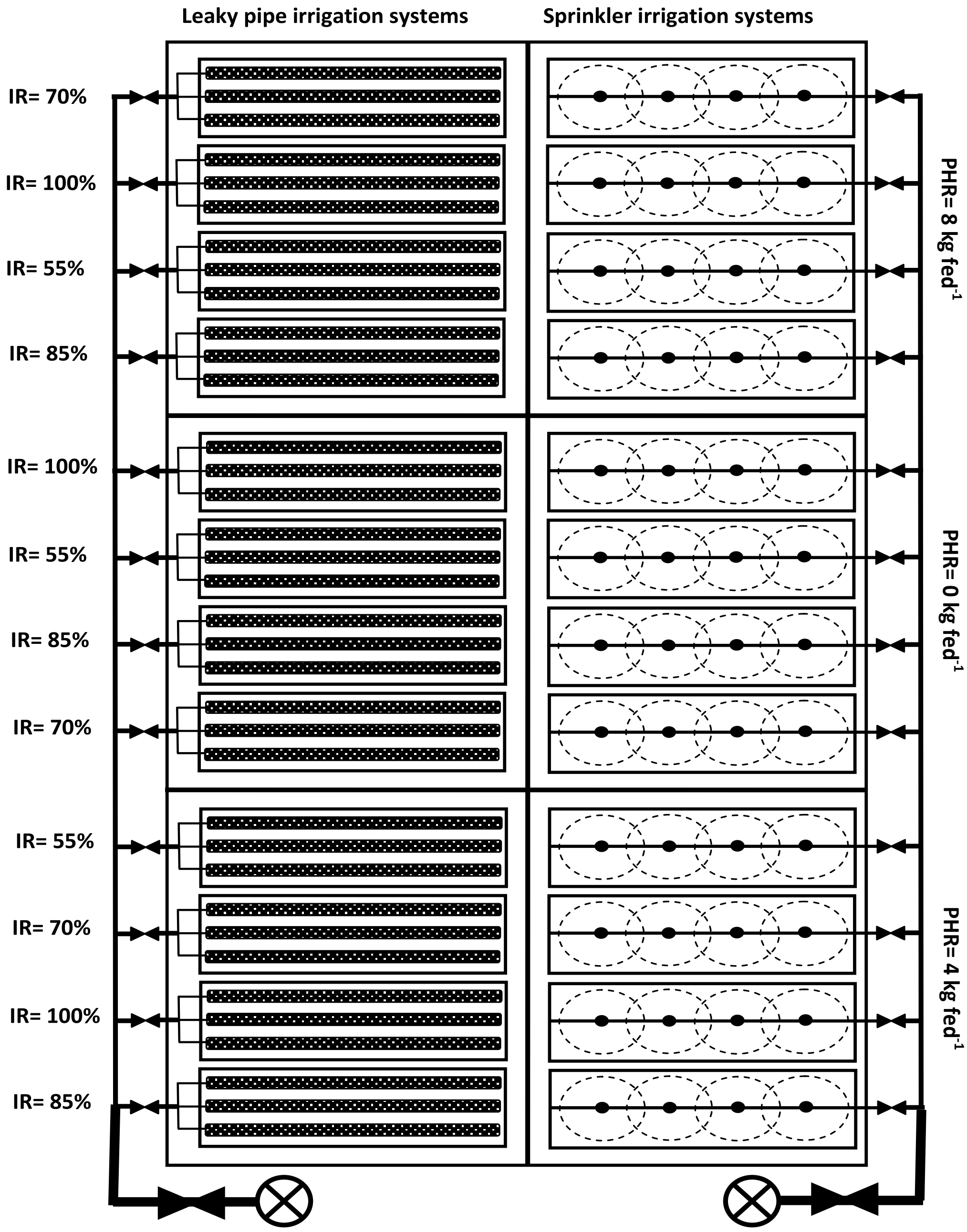

Fig. 1. Field experiment layout in El-Baharia Oasis.

Quality of irrigation water

Chemical analyses of the irrigation water were performed according to the methods depicted by (Ayers and Westcot 1994) and are shown in Table (3). calculated for all applied irrigation water levels and potassium humate rates under different irrigation systems for all winter faba bean plots.

Reference evapotranspiration ETo

The reference evapotranspiration (ETo) illustrated in Table (4) was calculated using the Penman-Monteith equation FAO 56 method (Allen et al. 1998).

Crop evapotranspiration ETc

The crop evapotranspiration ETc shown in Table (5) was calculated by using the equation:

ETc = Kc_{FAO} . ETo(mm period^{-1})(Allen et al. 1998)

Where: Kc_{FAO}: crop coefficient from FAO No.(56).

ETo: reference crop evapotranspiration, mm period^{-1}.

Table 1. Physical characteristics of the experimental soil.

Soil depth (cm)	Particle size distribution %					Textural class	OM %	ρ_b g/cm^3	Ks cm/h	FC %	WP %	AW %
	C. sand	M. sand	F. sand	Silt	Clay							
0-20	4.46	24.23	61.65	5.27	4.39	S	0.48	1.54	12.62	12.97	3.81	9.16
20-40	4.19	24.06	60.83	5.65	5.27	S	0.43	1.58	13.37	12.13	3.35	8.78
40-60	3.83	23.78	59.96	6.49	5.94	S	0.35	1.63	13.59	11.75	3.18	8.57

C=coarse; M=medium; F=fine.

Table 2. Chemical characteristics of the experimental soil.

Soil depth (cm)	EC (dS m^{-1})	pH	$CaCO_3$ %	CEC cmole kg^{-1}	Soluble ions (meq/l) in saturated soil paste extract							
					Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	CO_3^{--}	SO_4^{--}
0-20	4.47	7.23	4.65	7.51	20.34	1.98	12.23	10.15	18.31	2.63	-	23.76
20-40	4.29	7.35	3.87	7.63	19.59	1.89	11.85	9.57	17.83	2.16	-	22.91
40-60	3.74	7.47	2.39	7.85	17.07	1.34	10.58	8.41	15.47	1.79	-	20.14

Table 3. Chemical analysis of irrigation water.

Sample	pH	EC dS m^{-1}	SAR	Soluble cations, meq/l				Soluble anions, meq/l			
				Na^+	K^+	Ca^{++}	Mg^{++}	CL^-	HCO_3^-	$CO_3^=$	$SO_4^=$
Mean	7.12	0.45	1.64	1.72	0.59	0.81	1.38	2.26	1.73	-	0.51

Table 4. Calculated reference evapotranspiration (mm day^{-1}) through winter faba bean crop growth period.

Seasons	Month	Oct	Nov	Dec	Jan	Feb	Mar
2020/2021	**ETo mm day^{-1}**	5.12	3.53	2.76	2.84	3.89	5.17
2021/2022		5.05	3.47	2.69	2.76	3.82	5.11

Table 5. Calculated crop evapotranspiration (ETc), mm through winter faba bean crop growth period.

Stages	Initial	Develop.	Mid	Late	Seasonal
Planting date	**24/10 to 17/11**	**18/11 to 1/1**	**2/1 to 25/2**	**26/2 to 17/3**	**24/10 to 17/3**
Period length (day)	25	45	55	20	145
Kc_{FAO} (-)	0.50	0.83	1.15	0.30	--------
			Season 2020/2021		
ETo (mm)	100.97	134.29	182.45	99.56	517.27
$ETc_{100\%}$ (mm)	50.49	111.46	209.82	29.87	401.64
Eff. Rainfall (mm)	4	1	1	0	6
			Season 2021/2022		
ETo (mm)	99.39	131.26	178.30	98.33	507.28
$ETc_{100\%}$ (mm)	49.70	108.95	205.05	29.50	393.20
Eff. Rainfall (mm)	5	2	1	0	8

Applied irrigation water IR

The amounts of applied irrigation water (IR) for the winter faba bean crop shown in Table (6) were calculated by using the equation:

$$IR_{100,\,85,\,70,\,55\%} = (ETc - pe)Kr / Ea) + LR$$

(Keller and Karmeli 1974) **(mm period^{-1})**

Where:

ETc: crop evapotranspiration, mm period^{-1}, table (5).

Pe: effective rainfall, mm season^{-1}, Table (**5**).

Kr: correction factor for limited wetting at faba bean percent round coverage by canopy 80%, Kr = 0.90. (**Smith 1992).**

Ea: irrigation efficiency for sprinkler = 75% and leaky pipe = 90% (**Allen et al. 1998).**

LR: leaching requirements, (0.02 x ETc), mm**.**

Actual evapotranspiration

ETa = $(M_2\% - M_1\%) / 100 . db . D$ **(mm)**

(Doorenbos and Pruitt 1984)

Where:

M_2 : moisture content after irrigation %.

M_1 : moisture content before irrigation %.

d_b : specific density of soil .
D : mean depth, mm.
Water use efficiency
WUE = MY / ETa (kg m^{-3})
(Howell et al. 2001)
Where:
MY: marketable yield of faba bean crop, (kg fed^{-1}).
Irrigation Water use efficiency
IWUE = MY / IR (kg m^{-3})
(Michael 1978)
Where:
IR: seasonal applied irrigation water, (m^3), Table (6).

Table 6. Calculated applied irrigation water (IR), mm through winter faba bean crop growth period.

IS	DI (%)	Applied Irrigation water, mm Growth Stages				
		Initial	Development	Mid	Late	Seasonal
		Season 2020/2021				
SI	**100**	54.50	129.01	249.21	29.30	462.02
	85	46.33	109.66	211.83	24.91	392.73
	70	38.15	90.31	174.45	20.51	323.42
	55	29.98	70.96	137.07	16.12	254.13
LPI	**100**	45.60	107.92	208.45	24.53	386.50
	85	38.76	91.73	177.18	20.85	328.52
	70	31.92	75.54	145.92	17.17	270.55
	55	25.08	59.36	114.65	13.49	212.58
		Season 2021/2022				
SI	**100**	51.13	123.54	240.98	26.45	442.10
	85	43.46	105.01	204.83	22.48	375.78
	70	35.79	86.48	168.69	18.52	309.48
	55	28.12	67.95	132.54	14.55	243.16
LPI	**100**	42.79	103.35	201.57	22.15	369.86
	85	36.37	87.85	171.33	18.83	314.38
	70	29.95	72.35	141.10	15.51	258.91
	55	23.53	56.84	110.86	12.18	203.41

3. Results and discussion

3.1. Effect of IR and PHR on quality parameters for faba bean crop under SI and LPI irrigation systems

Data in Tables 7 & 8 show that the values of quality parameters for winter faba bean crop such as Plant height (PH) cm, Leaf area index (LAI), total chlorophyll (TC) mg g^{-1}, number of branches plant^{-1} (NB), number of pods plant^{-1} (NP) and number of seeds pod^{-1} (NS) increase with increasing applied irrigation water levels (IR) and potassium humate fertilizer rates (PHR) for all treatments except seed carbohydrate content (SCC) % and seed protein content (SPC) % decreased with increasing IR and PHR. In addition, using leaky pipe (LBI) irrigation system had a clear effect on all treatments compared to sprinkler (SI) irrigation system. The results indicate the same trend for both seasons 2020/2021 and 2021/2022. The highest values of winter faba bean crop PH, LAI, TC, NB, NP and NS were (132.43 cm, 5.37, 58.74 mg g-1, 5.58 branches plant^{-1}, 23.46 pods plant^{-1} and 12.79 seeds pod^{-1}) for the 1st season; (134.19 cm, 5.51, 59.35 mg g^{-1}, 5.64 branches plant^{-1}, 23.98 pods plant^{-1} and 12.97 seeds pod^{-1}) for the 2nd season respectively, except SCC and SPC were (42.43 % and 23.94 %) for the 1st season; (42.85 % and 24.37 %) for the 2nd season, respectively, under LBI, IR=100% and PHR = 8 kg fed^{-1} treatment. While, the lowest values of winter faba bean crop PH, LAI, TC, NB, NP and NS were (34.52 cm, 2.96, 28.65 mg g^{-1}, 1.37 branches plant^{-1}, 15.04 pods plant^{-1} and 6.07 seeds pod^{-1}) for the 1st season; (37.65 cm, 3.11, 29.28 mg g^{-1}, 1.43 branches plant^{-1}, 15.57 pods plant^{-1} and 6.15 seeds pod^{-1}) for the 2nd season respectively, except SCC and SPC were (53.78 % and 32.95 %) for the 1st season; (54.19 % and 33.61 %) for the 2nd season, respectively, under SI, IR=55% and PHR = 0 kg fed^{-1} treatment, these results are in accordance with (FAOSTAT 2017); (Golabi and Akhoonali 2008); (Rasheed 2021); (Awaad et al. 2020); (Awadalla et al. 2018); (Fayed et al. 2018).

3.2. Effect of IR and PHR on MSY for faba bean crop under SI and LPI irrigation systems

Data in Figure 2 illustrate that the values of marketable seeds yield (MSY) ton fed^{-1} for winter faba bean crop increase with increasing IR and HAR for all treatments. In addition, using leaky pipe (LBI) irrigation system had a clear effect on all treatments compared to sprinkler (SI) irrigation system. The results record the same trend for both seasons 2020/2021 and 2021/2022. The highest values of MSY for winter faba bean crop were (1.73 and 1.76 ton fed^{-1}) for both seasons respectively, under LBI, IR=100% and PHR = 8 kg fed^{-1} treatment. While, the lowest values were (0.47 and 0.50 ton fed^{-1}) for both seasons respectively, under SI, IR=55% and PHR = 0 kg fed^{-1} treatment, these results may be attributed to be applied leaky pipe irrigation system in sandy soil decreased deep percolation amount irrigation water and mineral fertilizers added compared to sprinkler irrigation system and then make the most of which at effective root zone which reflects positively on increase productivity of faba bean crop also, added different Potassium humate rates impact on cell membranes results in better protein synthesis, increased mineral transport, plant hormone-like activity, enhanced photosynthesis, modified enzyme activities, solubility of micro- and macro-elements, decreased levels of active toxic mineral, and increased microbial populations which lead to an increase in faba bean crop productivity too. Moreover that, using deficit irrigation technique depends on saving irrigation water by obtaining the highest productivity of faba bean crop in the least amount of irrigation water added, these results were similar to those indicate by (Kunze et al. 2021); (Golabi and Akhoonali 2008); (Rasheed 2021); (Hamideh et al. 2013); (Meganind et al. 2015); (Kumar 2018); (Ampong et al. 2022); (Tesfaye 2023), (Awadalla et al. 2018); (Hegab et al. 2014).

3.3. Effect of IR and PHR on ETa for faba bean crop under SI and LPI irrigation systems

Data in Table 9 report that the values of seasonal actual evapotranspiration (ETa) mm for winter faba bean crop decreased with decreasing IR and HAR for all treatments. In addition, using leaky pipe (LBI) irrigation system had a clear effect on all treatments compared to sprinkler (SI) irrigation system. The results record the same trend for both seasons 2020/2021 and 2021/2022. The lowest values of seasonal ETa were (176.37 and 172.79 mm) for both seasons respectively, under LBI, IR= 55% and PHR = 0 kg fed-1 treatment. While, the highest values were (423.17 and 416.34 mm) for both seasons respectively, under SI, IR=100% and PHR = 0 kg fed-1 treatment. These results may be attributed to using the leaky pipe system works well with light-textured soils because it gradually regulates deep percolation and needs little pressure to function compared to sprinkler irrigation system thus, reduces evaporation of irrigation water added form soil surface significantly moreover that, add potassium humate rates were improve physical and chemical sandy soil properties, the most important increase values both of free swell index and readily available water thus, increase the storage capacity of sandy soils which reduces seasonal ETa. Also, using levels of irrigation water added reduces evaporation rate from the surface of sandy soil and then it decreases the actual irrigation water consumption; These results are in agreement with that found by (Golabi and Akhoonali 2008); (Rasheed 2021); (Meganind et al. 2015); (Kumar 2018); (Ampong et al. 2022).

3.4. Effect of IR and PHR on WUE and IWUE for faba bean crop under SI and LBI irrigation systems

Data in Table 9 indicate that the highest values of water use efficiency (WUE) and irrigation water use efficiency (IWUE) for winter faba bean crop were (1.89 and 1.45 kg m^{-3}); (1.96 and 1.55 kg m^{-3}) for both seasons respectively, under LBI, IR=70% and HAR = 8 kg fed^{-1} treatment. While, the lowest values were (0.50 and 0.44 kg m^{-3}); (0.54 and 0.49 kg m^{-3}) for both seasons respectively, under SI, IR= 55% and HAR = 0 kg fed^{-1} treatment. Meanwhile, the values of WUE and IWUE under LBI, IR=70% and HAR = 8 kg fed^{-1} treatment were increased significantly by about (178 and 134 %); (176 and 131 %) for both seasons, respectively, compared to that under the control treatment (SI, IR=100% and HAR = 0 kg fed^{-1}). These results may be attributed to applied leaky pipe irrigation system and deficit irrigation water technique led to decrease irrigation water evaporation added from sandy soil surface Also add potassium humate rates from increasing storage capacity for sandy soil which leads to increase marketable seeds yield of faba bean crop versus decrease in water consumption and irrigation water added, these results are in accordance with (Awadalla et al. 2018); (Hegab et al. 2014); Fayed et al. 2018); (Faghih et al. 2019); (Hefzy et al. 2020); (Basma and Reham 2022).

Table 7. Effect of IR and PHR on PH, LAI, TC and NB of faba bean crop under SI and LPI irrigation systems at seasons 2020/2021 and 2021/2022.

IS	PHR (kg fed^{-1})	IR (%)	PH (cm)		LAI (-)		TC (mg g^{-1})		NB (branches plant^{-1})	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
SI	0	**100**	98.86h	102.03g	4.21j	4.39l	48.27g	48.91h	3.34l	3.42m
		85	91.09i	94.87h	4.14k	4.32m	45.03h	45.65i	2.91m	2.98n
		70	59.34m	63.59l	4.07l	4.24n	39.82j	40.43k	2.83n	2.91o
		55	34.52o	37.65o	2.96q	3.11t	28.65m	29.28p	1.37t	1.43u
	4	**100**	111.48f	114.21e	4.69g	4.87g	51.69d	52.34e	4.29g	4.37g
		85	105.15g	107.12f	4.61h	4.79i	49.31f	49.92h	3.68i	3.75k
		70	89.39i	92.91i	4.53i	4.71k	43.68i	44.32j	3.59k	3.67l
		55	58.21m	60.74m	3.47p	3.64r	34.45k	35.07n	1.97r	2.03s
	8	**100**	112.64f	115.07e	4.75f	4.90f	51.76d	52.41e	4.38f	4.46f
		85	107.72g	109.29f	4.68g	4.82h	49.64f	50.25g	3.73h	3.81j
		70	91.28i	94.13h	4.59h	4.74j	43.93i	44.60j	3.65j	3.73k
		55	61.89l	63.31l	3.52o	3.68q	34.89k	35.54n	2.09q	2.16r
LPI	0	**100**	107.57g	111.21f	4.74f	4.91f	54.09c	54.73d	4.27g	4.34h
		85	101.13g	104.45g	4.67g	4.85g	50.82e	51.47f	3.65j	3.71k
		70	71.95j	74.17j	4.61h	4.78i	45.41h	46.05i	3.59k	3.65l
		55	39.39n	42.73n	3.29p	3.43s	31.67l	32.28o	1.72s	1.78t
	4	**100**	129.84b	131.57b	5.29c	5.45b	58.21a	58.86b	5.51b	5.58b
		85	125.46d	127.12c	5.24d	5.41c	56.05b	56.69c	4.65d	4.72d
		70	118.62e	123.91d	5.18e	5.34e	50.30e	50.92g	4.58e	4.64e
		55	67.28k	69.34k	3.86n	4.02p	38.51j	39.14m	2.53p	2.59q
	8	**100**	132.43a	134.19a	5.37a	5.51a	58.74a	59.35a	5.58a	5.64a
		85	128.29c	129.97b	5.31b	5.46b	56.89b	57.53b	4.72c	4.79c
		70	125.87d	127.25c	5.24d	5.39d	50.53e	51.18f	4.65d	4.72d
		55	69.91j	72.02j	3.92m	4.07o	39.29j	39.91l	2.61o	2.67p

Table 8. Effect of IR and PHR on NP, NS, SCC and SPC of faba bean crop under SI and LPI irrigation systems at seasons 2020/2021 and 2021/2022.

IS	PHR (kg fed^{-1})	IR (%)	NP (pods plant^{-1})		NS (seeds pod^{-1})		SCC (%)		SPC (%)	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
SI	0	**100**	18.41o	18.95o	9.31i	9.53j	48.11f	48.53g	27.39m	27.75k
		85	17.56q	18.07q	8.75k	8.97l	48.87e	49.31f	28.17k	28.53h
		70	16.18t	16.73t	7.13o	7.29o	51.32c	51.75d	29.83f	30.47d
		55	15.04u	15.57u	6.07p	6.15p	53.78a	54.19a	32.95a	33.61a
	4	**100**	20.06i	20.59i	10.45e	10.67f	46.42i	46.86l	26.96o	27.47l
		85	19.21k	19.76k	9.87g	10.09h	47.01h	47.42k	27.68l	28.13i
		70	18.28p	18.82p	8.29l	8.51m	48.86e	49.28f	29.31h	29.95e
		55	16.27t	16.83t	7.11o	7.34o	52.09b	52.54b	32.42b	32.89b
	8	**100**	20.22h	20.75h	11.62c	11.85c	43.25m	43.71r	24.61s	25.03p
		85	19.35j	19.91j	10.95d	11.17e	44.19l	44.63q	25.14r	25.51o
		70	18.52n	19.07n	9.37h	9.59i	46.03j	46.49n	27.36m	27.89j
		55	16.65s	17.19s	8.24m	8.46n	48.81e	49.27f	30.23e	30.65d
LPI	0	**100**	20.97g	21.49g	10.43e	10.69f	47.28g	47.72j	26.75p	27.17m
		85	20.21h	20.75h	9.91g	10.14h	48.06f	48.45h	27.53l	27.85j
		70	18.82m	19.37m	8.25m	8.43n	50.49d	50.91e	29.17i	29.79f
		55	16.95r	17.51r	7.19n	7.37o	52.94b	53.37c	32.29c	32.93b
	4	**100**	23.07b	23.62b	11.57c	11.79d	45.59k	46.04o	26.31q	26.84n
		85	22.35d	22.87d	10.95d	11.17e	46.17i	46.59m	27.05n	27.46l
		70	21.41f	21.94f	9.31i	9.53j	48.04f	48.46h	28.63j	29.29g
		55	18.52n	19.06n	8.23m	8.45n	51.26c	51.71d	31.78d	32.23c
	8	**100**	23.46a	23.98a	12.79a	12.97a	42.43n	42.85s	23.94t	24.37r
		85	22.61c	23.15c	11.97b	12.21b	43.36m	43.79r	24.47s	24.83q
		70	21.85e	22.41e	10.34f	10.53g	45.21k	45.63p	26.72p	27.25m
		55	19.09l	19.63l	9.26j	9.49k	47.98f	48.41h	29.56g	29.98e

Table 9. Effect of IR and PHR on ETa, WUE and IWUE for faba bean under SI and LPI at seasons 2020/2021 and 2021/2022.

IS	PHR (kg fed^{-1})	IR (%)	Eta (mm season^{-1})		WUE (kg m^{-3})		IWUE (kg m^{-3})	
			1st	2nd	1st	2nd	1st	2nd
SI	0	100	423.17a	416.34a	0.68q	0.71q	0.62o	0.67o
		85	361.84d	352.25d	0.76o	0.80o	0.70l	0.75k
		70	285.21g	278.97j	0.63r	0.67s	0.55p	0.60p
		55	227.93k	221.19o	0.50t	0.54u	0.44r	0.49r
	4	100	411.06b	404.69b	0.76o	0.79o	0.68m	0.73l
		85	349.89e	341.45e	0.85m	0.89m	0.76k	0.81j
		70	276.21h	273.92k	0.72p	0.76p	0.61o	0.67o
		55	223.19l	217.15o	0.58s	0.62t	0.51q	0.56q
	8	100	399.23c	392.14c	0.81n	0.84n	0.70l	0.75k
		85	346.11e	336.57f	0.89l	0.93l	0.78j	0.84i
		70	275.07h	270.82k	0.75o	0.79o	0.64n	0.69n
		55	219.62l	211.28o	0.63r	0.69r	0.54p	0.60p
LPI	0	100	354.75e	349.81d	1.01j	1.05j	0.93h	1.00g
		85	299.07g	295.36i	1.19h	1.23h	1.08f	1.16e
		70	235.01j	232.78n	1.38e	1.42e	1.20e	1.28d
		55	192.82o	190.24q	0.72p	0.76p	0.65n	0.71m
	4	100	328.28f	325.31g	1.22g	1.25g	1.03g	1.10g
		85	271.35h	267.83l	1.45d	1.49d	1.20d	1.27d
		70	210.43m	208.47p	1.73b	1.78b	1.35b	1.43b
		55	184.06p	182.18r	0.87l	0.91k	0.75k	0.82j
	8	100	315.31g	312.54h	1.31f	1.34f	1.07f	1.13f
		85	258.54i	255.26m	1.57c	1.62c	1.24c	1.32c
		70	208.13n	205.82p	1.89a	1.96a	1.45a	1.55a
		55	176.37q	172.79s	0.98k	1.05j	0.81i	0.89h

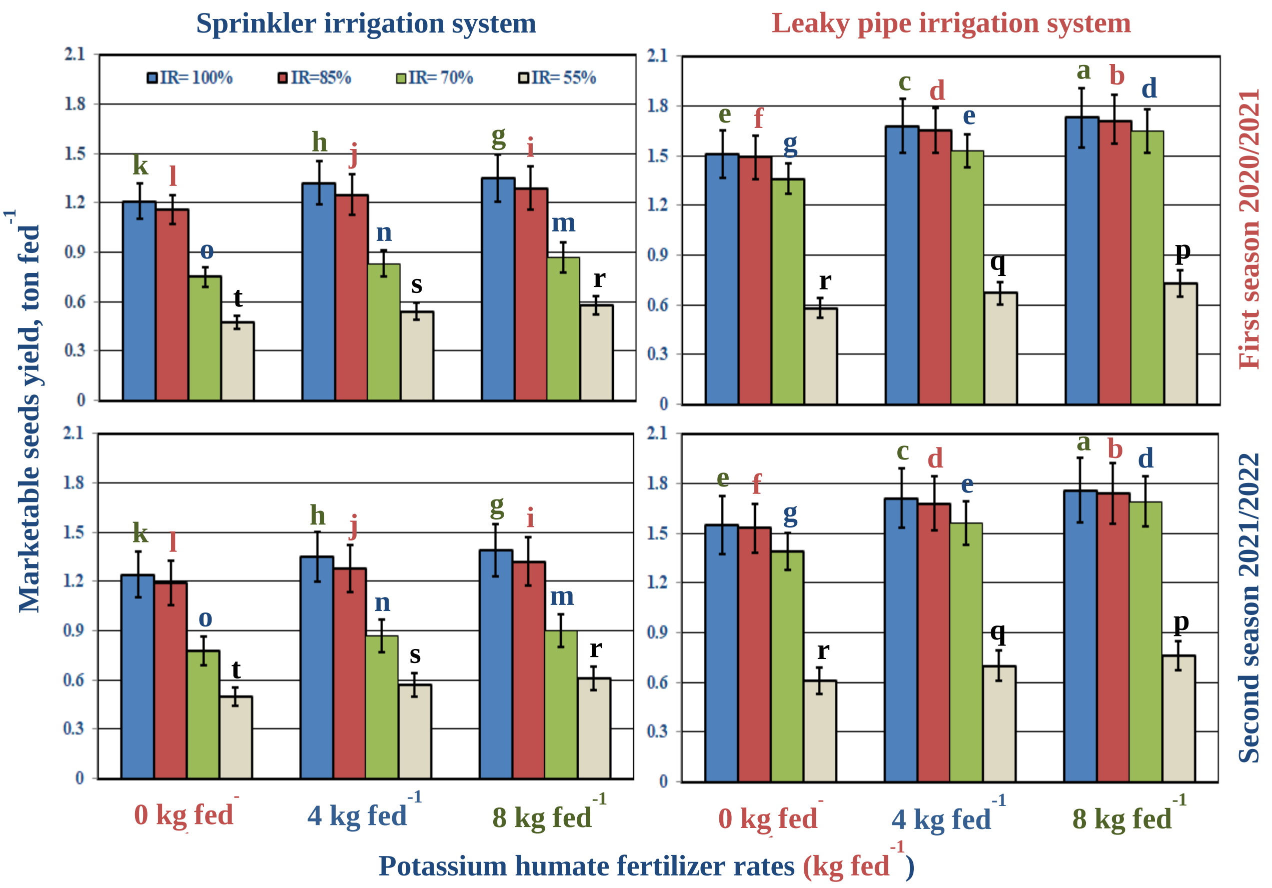

Fig. 2. Effect of IR and PHR on marketable seeds yield for faba bean under SI and LPI at seasons 2020/2021 and 2021/2022.

Conclusions

This applied study goals to saving in the amounts of irrigation water add and increasing productivity of feddan through comparing effect of leaky pipe irrigation system (LPI) under different irrigation water levels (IR) and add potassium humate rates (PHR) on quality parameters yield, marketable seeds yield, seasonal ETa, WUE and IWUE for winter faba bean crop comparing to sprinkler irrigation system (SI) treatment, under sandy soil conditions of El- Baharia Oasis area. The results of this study indicated that the marketable seeds yield and quality parameters yield except seed carbohydrate content and seed protein content for winter faba bean crop gave the highest values under LBI, IR=100% and PHR = 8 kg fed^{-1} treatment. On the other side, the seasonal ETa for faba bean crop gave the lowest values under LBI, IR= 55% and PHR = 0 kg fed^{-1} treatment. Finally, the values of winter faba bean crop WUE and IWUE under LBI, IR=70% and PHR = 8 kg fed^{-1} treatment increased significantly by about (178 and 134 %); (176 and 131 %) for both seasons, respectively, compared to that under the control treatment (SI, IR=100% and PHR = 0 kg fed^{-1}).

So, it is recommended to apply treatment (LBI, IR=70% and PHR = 8 kg fed^{-1}) to cultivate winter faba bean crop under El-Baharia oasis condition because this treatment can provide about 30% of amount irrigation water added. also, increases marketable seeds yield of faba bean crop by about 36% as average for both seasons compared to that under control treatment (i.e. SI, IR=100% and PHR = 0 kg fed^{-1}).

Ethics approval and consent to participate:

This article does not contain any studies with human participants or animals performed by the author.

Consent for publication:

The author declares their consent for publication.

Conflicts of Interest:

The author declares no conflicts of interest.

Contribution of Authors:

The author writing, editing, revising, and approving the manuscript for publication.

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