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Effect of Drip Irrigation Water Regime and Calcium Humate on the Growth Performance, Yield of Faba Bean (*Vicia faba* L.) Grown in Sandy Soil

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Abstract: Field experiments were conducted during two successive winter seasons of (2016/2017 and 2017/2018) in Ali Mubark experimental farm, El-Bostan area, Southern EL-Tahrir Region El-Beheira Governorate, Egypt. The experiments aimed to study the effect of different irrigation water requirements (100 (I_{100}), 75 (I_{75}) and 50 (I_{50})% of ET_o) and calcium- humate at rates of 0 , 10, 20 liter acre^{-1} sprayed on soil surface on growth, yield of beans (*Vicia faba* L.) and soil fertility in sandy soils under drip irrigation system. The results indicated that increasing irrigation water significantly increased soil available macronutrients, soil respiration and soil organic matter, as well as, leaf and seed NPK contents, protein contents and total yield. There were relative increases in total yield due to irrigation treatments I_{75} and I_{100}, as mean values of the two growing seasons (4.69 and 12.52 %) compared with I_{50}. Increasing irrigation water above I_{50} led to a reduction in water use efficiency (WUE) since WUE mean values of the two growing seasons were 2.21, 1.54 and 1.24 kgm^{-3} for I_{50}, I_{75} and I_{100}, respectively. Calcium-humate application showed significant increase in soil available NPK, organic matter and respiration compared with non-treated soil. In addition, significant increases in leaf and grain of NPK, proteincontents and total yield were reported with increasing calcium-humate application rate while proline was less at Ca-H20. Results showed that increasing Calcium-humate application has had a pronounced effect on WUE values compared with other water irrigation treatments. Mean values of WUE were 1.25, 1.59 and 1.83 kg m^{-3} for Ca-H0, Ca-H10 and Ca-H20, respectively. The highest values of WUE were obtained from the treatment 50% ET_o with calcium-humate at a rate of 20 liters acre^{-1}, the highest rate of yield of Faba bean was reported under 100 % of the ET_o and with the use of calcium-humate at a rate of 20 liter acre^{-1}.

Key words: Calcium-humate · Faba bean · Sandy soil · Irrigation water regime · Water use efficiency

INTRODUCTION

The beneficial role of legume plants in order to sustain and maintainagriculturalsoils, environment and economic due to their important ability to fix atmospheric nitrogen in root nodules by rhizobia ina symbiotic relationship [1]. In Egypt, faba bean (*Vicia faba* L.) is one of the most important legume winter crops, for human consumption as a major source of vegetarian protein [2], as well as in animal production, seeds are also used asa feed with a high protein content [3]. However, due to decreasing the cultivated area from 271, 000 acre 2000 to 81, 000 acre in 2018, with increasing the demand of faba bean crop [2], it is important to increase the productivity of unit area in order to meet this increasing.There was an urge to reclaim new lands and cultivate them with beans to increase the horizontal expansion [4]. In sandy soils growing faba bean need integration between inoculation with bacteria and mineral fertilizer for high quality and quantity yield production [2]. The nutritious value of faba bean has always been attributed to its high protein content (27-34%) depend on genotypes [5, 6]. Seeds contain several slight proteins including trypsin inhibitors, lectins, lipoxygenase and urease, which are appropriate to the nutritional quality [7]. In addition, the seeds contain many biologically active compounds such as polyphenols [8].

The poor status of soil fertility of newly reclaimed lands is not the main production constraint [9]. However, the production of faba bean in Egypt is limited and affected by different factors such as soil fertility and water supply [10].

Humic acidis a substance that contains many of the functional groups present in the carbon chain. It contains carboxyl and phenol groups, amine, alcohol, aldehyde, ketone, ether, ester and amide, which are effective groups

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that work by chelating elements, which improves plant growth [11]. Humic acid promotes the conversion of nutrients into forms available to plants and stimulates seed germination and viability [12], which influences several ways on plant growth and soil characters [13]. Humic acid is manufactured commercially and widely used as organic fertilizer. The major role of humic acid components is to enhance soil fertility and rise nutrients availability, improve plant growth, yield and reduce the harmful influence of biotic and/or abiotic stresses through several mechanisms inside plants and soil [14].

Calcium humate is used as an organic fertilizer and an ameliorating agent, which promotes low humus structure of soils and sediments with unfavorable structure and physical properties [15]. The application of calcium as an inorganic nutrient has important effects on soil aggregation.

Mean values of water consumptive use for faba bean were 1348 with farmer practice, 1316 at 100% of water requirement and 1081 m^3acre^{-1} with 75% of water requirement, respectively [16]. Application of 75% N+Ca-H has recorded nearly the maximum seasonal water consumptive use with 25% of saved nitrogen dose. The highest water use efficiency was 1.00 kg seeds m^{-3} water consumption was obtained by irrigation at 75% WR combined with 75% N+Ca-H. The lowest water use efficiency 0.30 kg seeds m^{-3} water consumption was obtained by farmer practice [17]. Improving the irrigation system to cope with the shortage of fresh water is achieved by increasing the efficiency of water use under drought conditions. The highest value of protein in the bean seeds takes place, when less water is used [18]. So, the objective of this study is to investigate the effect of different amounts of applied irrigation water and application rates of calcium humate additions on growth and yield of faba bean (*Vicia faba* L.) grown under drip irrigation systems in sandy soils.

MATERIALS AND METHODS

Experimental Layout: Two field experiments were carried out during the winter growing seasons of 2016/2017 and 2017/2018 at Ali Mubark Farm, El-Bostan area, El-Beheira Governorate, Egypt, (Longitude 30°42'36.00" E, Latitude 30°34'12.00" N) to investigate the interactive effects of different amounts of applied irrigation water and application rates of Ca-humate on the growth and yield of beans (*Vicia faba* L.) grown in sandy soil under a drip irrigation system. Faba bean seeds (*Vicia faba* L. var. Nubaria 1), were inoculated with rhizobium bacteria (*Rhizobium Leguminosarum*), on 15th November of each growing season. The drip irrigation system used in the present work consisted of the main delivery pipeline (PE, 32 mm) and a sub-main line (PE, 25 mm). The drip laterals were made from polyethylene material (16 mm diameter) with inline emitters spaced at 25 cm apart with an actual discharge rate of 3.7 liters h^{-1}. The calcium-humate application was sprayed on the soil surface, added three times every 15 days after sowing.

The irrigation requirements were calculated using CROPWAT 8.0 using the climatic data of El-Bostan area. The average values of standard evapotranspiration are shown in Table (2).

Experimental Design: A split-plot design in complete randomized blocks arrangement with three replications was used to layout all trials (three levels of irrigation water regime and three treatments of Calcium-humate). The total numbers of experimental plots were 27 plots. The main treatments were: 100% ET_o of Faba bean based on ET_o at South Tahrir Region (I_1), 75% ET_o of Faba bean crop (I_2) and 50% ET_o of Faba bean crop (I_3). The value of ET_o was calculated according to the data obtained from reference evapotranspiration and crop factor ($Et_c = ET_o \times K_c$). The Sub-main treatments included three rates of Calcium-humate 0, 10, 20 liters $acre^{-1}$. Some physical and chemical properties of the experimental soil at the depth of 0-30 cm were determined according to [19, 20] as shown in Table (1).

Cultural Practices: Inorganic fertilizers were applied to soil as follows: Superphosphate (15.5% P_2O_5) at a rate of 150 kg $acre^{-1}$ before sowing, potassium sulphate (48% K_2O) at a rate of 50 $kgacre^{-1}$ and ammonium sulphate (20.6% N) at a rate of 30 kg $acre^{-1}$ asstarterdose. All cultivation practices (*i.e*., weeds and diseases control, *etc*...) were carried out, following the common field practices recommended by the Ministry of Agriculture and Land Reclamation. Application of different treatments started after full emergence of Faba bean plants. The values of the reference evapotranspiration (ET_o) were calculated using weather data obtained from South El-Tahrir Metrological Station using Penman-Monteith equation, CROPWAT 8 [21], Based on meteorological data from the Central Laboratory for Agricultural Climate and presented in Table 2.

Crop-Water Relation: The crop evapotranspiration (ET_c) values were calculated according to the following equation [4].

Table 1: The main physical and chemical properties of the field experimental sitefor two growing seasons

	Particle size distribution			EC	$CaCO_3$	OM	Available nutrient (mg kg^{-1})		
	%		pH	dSm^{-1}	%	%	N	P	K
2016/17	Sand	91.5	8.7	0.36	5.1	0.10	10.6	2.5	15.5
	Clay	4.1							
	Silt	4.4							
	Texture	Sandy							
2017/18	Sand	92	8.6	0.34	4.0	0.19	12.1	3.1	18.0
	Clay	5							
	Silt	3							
	Texture	Sandy							

Table 2: The monthly average values of reference evapotranspiration (ET_omm day^{-1}) of the experimental site at the two growing seasons and applied irrigation water (AIW m^3acre^{-1})

	November	December	January	February	March	April	AIW m^3acre^{-1}		
			Et_o mm day^{-1}				100% ET_o	75% ET_o	50% ET_o
2016/2017	1	1	1.2	1.4	2.4	3.2	1404.48	1053.36	702.24
2017/2018	1.1	0.9	1.2	1.6	2.6	3.3	1486.87	1115.15	743.44
Mean							1445.67	1084.26	722.84

$$Etc = Eto \times Kc$$

where; ET_c: crop evapotranspiration (mm day^{-1}), ET_o: reference evapotranspiration (mm day^1), K_c: crop coefficient values for Faba bean crop (Table 2).

The amounts of applied irrigation water (AIW) were calculated according to the equation given by [52] as follows:

$$AIW = \frac{ETc \times Kr \times I}{Ea} \times L$$

where: AIW: depth of applied irrigation water (mm), ET_c: crop evapotranspiration (mm day^{-1}), K_r: evaporation reduction coefficient that depends on ground cover. A value of 1.0 was used "where the spacing between drip lines is less than 1.8 m, I: irrigation intervals (day), E_a: irrigation efficiency of the drip irrigation system, "an average value of 90 % was used" and LR: leaching requirements, "10% of the calculated applied irrigation water was additionally applied per-irrigation during the growing season for leaching purposes".

The total amount of applied irrigation water under the studied water regimes (50, 75 and 100% ET_o) Where: AIW: depth of applied irrigation water (mm), ET_c: crop evapotranspiration (mm day^{-1}), K_r: evaporation reduction coefficient, that depends on ground cover. A value of 1.0 was used "where the spacing between drip lines is less than 1.8 m, I: irrigation intervals (day), Ea: irrigation efficiency of the drip irrigation system, "an average value of 90 % was used" and LR: leaching requirements, "10% of the calculated applied irrigation water was additionally applied per-irrigation during the growing season for leaching purposes". The total amount of applied irrigation water under the studied water regimes (50, 75 and 100% ET_o) was calculated on the basis of m^3 $acre^{-1}$.

Irrigation time was determined before each irrigation event by measuring the actual emitter discharge according to the equation given by [22] as follows:

$$t = \frac{AIW \times A}{q}$$

where; t: irrigation time (h), AIW: applied irrigation water (mm), A: wetted area (m^2) andq: emitter discharge (liter h^{-1}).

Drought Tolerance Efficiency (DTE): Was estimated by using the formula given by [23] as follows:

$$DTE(\%) = \frac{Yield\ under\ stress}{Yield\ under\ non\ stress} x100$$

Water use efficiency values were estimated according to [30] as follows:

Water use efficiency (kg m^{-3}) $= \frac{seed\ Yield\ (kg)}{Water\ applied\ (m^3)}$ calculated on basis m^3 $acre^{-1}$.

Sampling Andanalysis

Soil: Soil samples (0-30 cm) were collected before planting and after plant harvest, for the main physical, chemical analysis. The particle size distribution (sand, silt and clay) was measured by the hydrometer method [24]. The electrical conductivity was measured in 1:2.5 soil –water suspension using conductivity meter and the pH was measured in 1:2.5 soil-water suspension by pH- Meter [25]. The amounts of available N in soil was determined by Kjeldahl method, the amount of available phosphorus in soil was extracted by 0.5 N $NaHCO_3$ pH 8.5 as described by [26] and the concentration of P was measured colorimetrically using the ascorbic acid method [27] and the amount of available K was extracted with neutral normal NH_4-Acetate solution and measured by a flame photometer [28, 29]. The amount of organic matter was determined by Walkley- Black method [30]. Total carbonate was measured by calcimeter [31]. Soil respiration was carried out by elevation of CO_2 (mg CO_2 100 g $soil^{-1}$ $Week^{-1}$) procedure [32]. The main physical and chemical properties of the experimental soil, in the two growing seasons, are shown in Table 2.

Plant: Plant samples prepared as described by [33]. Morphological characters and yield components were measured using plants at harvest. These included; plant height, weight of plant, number of branches $plant^{-1}$, root length, weight of root, number of pods $plant^{-1}$, weight of seeds $plant^{-1}$, weight of 100 seeds and seeds yield.

Total nitrogen was determined using the micro-Kjeldahl method [34] and the concentration of protein was obtained by multiplying total N by 6.25 as a standard factor. Total phosphorus was determined colorimetrically using Vanado-Molybdate yellow color method [35] and total potassium was measured by a flame photometer [34]. Leaf-free proline was determined according to the method outlined by [36, 37].

Statistical Analysis: The obtained data were subjected to statistical analysis as described by [38]. After testing the homogeneity of the error according to Bartlett's test, combined analysis for both seasons were done. LSD test was adopted for means comparison at 5 % probability.

RESULTS AND DISCUSSION

Effect of Irrigation Levels and Calcium-humate on Vegetative Growth Characters

Plant Fresh Weight: Data presented in Table (3) showed that increasing the amount of applied irrigation water significantly affects the increased fresh weight of faba bean plants, where mean values of the two growing seasons, from 79.97 and 89.81 to 95.17 g for I_{50}, I_{75} and I_{100} treatment, respectively. The same trend was found for the effect of calcium-humate where the plant weight increased from 69.55 and 90.69 to 104.70 g for Ca-H_0, Ca-H_{10} and Ca-$H_{20,}$ respectively. Also, the effects show clear positive interaction between irrigation level requirements and calcium-humate application rates. These positive increases in plant weight may be due to increasing the amount of applied irrigation water and calcium-humate rates, which also increased the amount of soil organic matter and available NPK (Table 6) and enhanced plant fresh weight.

Plant Height: From the same table, data revealed that increasing the amount of applied irrigation water significantly increased the height of faba bean plants where it increased from 118.05 cm at I_{50} to 124.05 cm at I_{100} as mean values of the two growing seasons. Also, there were significant effects of calcium-humate on plant height where it increased from 109.33 cm at Ca-H_0 to 127.27 cm at Ca-H_{20} as mean values of the two growing season. Table (3) showed also that there was a significant interaction between irrigation level regime and calcium-humate application rate treatments.

Number of Branches of Plants: The number of branches significantly increased with increasing the amount of applied irrigation water (Table 3), whereas as mean values of the two growing seasons, it increased from 7.3 at I_{50} to 8.6 at I_{100}. Table (3) revealed also that calcium-humate had a significant effect on the number of branches, whereas the number of branches, as mean values of the two growing seasons, was 5.9, 8.2 and 9.6 for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. There was also a significant interaction between irrigation requirements and calcium-humate application regime.

Roots Weight of Plant: Root weight significantly increased with increasing the amount of applied irrigation water, whereas mean values of the two growing seasons, were 29.66, 32.70 and 37.21 g for I_{50}, I_{75} and I_{100} respectively. Calcium-humate also significantly increased the root weight of Faba bean plants, whereas mean values of the two growing seasons, were 25.03, 3 .91 and 42.63 g for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. Table (3) showed also that there were significant interaction effects on root weight because of irrigation regime and calcium-humate application treatments.

Root Length: Root length significantly increased with increasing the amount of applied irrigation water, whereas mean values of the two growing seasons, were 20.18, 21.22 and 22.64 cm for I_{50}, I_{75} and I_{100} respectively.

Table 3: The mean value of vegetative growth characters of faba bean treated with calcium-humate under irrigation water regime (combined means of two seasons)

Treatments						
Water regime %	Calcium humate	Plant weight (g)	Plant height (cm)	No. of branches plant^{-1}	Root weight (g plant^{-1})	Rootlength (cm plant^{-1})
50	Ca-H 0	55.16 g	103.33 g	4.8	21.73 h	16.95 i
	Ca-H 10	85.25 d	118.33 d	7.8	29.76 ef	19.41 g
	Ca-H 20	99.49 b	123.50 c	9.2	37.48 c	24.16 c
Mean		79.97 C	118.05 C	7.3 B	29.66 C	20.18 C
75	Ca-H 0	72.55 f	110.83 f	6.0	25.08 g	17.91 h
	Ca-H 10	91.22 c	122.66 c	8.0	32.28 de	20.33 f
	Ca-H 20	105.66 a	126.16 b	9.6	40.74 b	25.43 b
Mean		89.81 B	119.88 B	7.9 AB	32.70 B	21.22 B
100	Ca-H 0	80.94 e	113.83 e	6.9	28.29 f	18.41 h
	Ca-H 10	95.60 b	126.16 b	8.9	33.68 d	22.08 e
	Ca-H 20	108.96 a	132.16 a	10.1	49.66 a	27.42 a
Mean		95.17 A	124.05 A	8.6 A	37.21 A	22.64 A
Mean of Ca-H		69.55 C	109.33 C	5.9 C	25.03 C	17.76 C
		90.69 B	122.38 B	8.2 B	31.91 B	20.61 B
		104.70 A	127.27 A	9.6 A	42.63 A	25.67 A
LSD at 0.05	Irr	1.61	1.75	1.0	2.11	0.40
	Ca-H	2.95	1.51	0.65	1.47	0.38
	Irr x Ca-H	4.26	2.43	ns	2.56	0.60

Numbers with the same later is not significant

Calcium-humate also significantly increased root length of Faba bean plants, whereas mean values of the two growing seasons, were 17.76, 20.61 and 25.67 cm for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. Table (3) showed also that there were significant interaction effects on root length between irrigation regime and calcium-humate application treatments.

Effect of Irrigation Levels and Calcium-Humate on Yield Components: Effect of irrigation levels and calcium-humate on yield components was presented in Table(4) showed that faba bean total yield significantly increased with increasing the amount of applied irrigation water, as mean values of the two growing seasons, were 1597, 1672.5and 1797 kgacre^{-1} for I_{50}, I_{75} and I_{100}, respectively. Also, there were significant effects of calcium-humate on total yield, whereas mean values of the two growing seasons, were 1353, 1725and 1989 kg acre^{-1} for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. The relative increases for I_{75} and I_{100}were 4.72 and 12.52 % as compared with I_{50} and were 27.49 and 47.00 for Ca-H_{10} and Ca-H_{20}, respectively relative to the control. The increases in total yield may be due to the positive effects of NPK availability. Table (4) indicated also that there were significant positive interaction effects between water irrigation regime and calcium-humate application treatments. All tested attributes of yield component (no. of pods, no. of seeds, 100 seeds weight and total seed weight) was significantly increased with increasing the amount of applied irrigation water and calcium-humate application rates. These increases may be due to adequate moisture availability in the soil leads to an increase in various physiological processes, better nutrients uptake, higher rates of photosynthesis, which might be reflected on more number and area of leaves and higher yields.

Available Macronutrients Content in Soil

Available Nitrogen: Table (5) showed that the irrigation regime significantly increased the amounts of available N in the soil as mean values of the two growing seasons since the amount of available N increased to 94.48, 97.15 and 100.41 mg kg^{-1} soil for I_{50}, I_{75} and I_{100}, respectively. This may be due to the fact that increasing the amount of irrigation water, has increased the activities of microorganisms which indicated by increasing SOM and soil respiration. Table (5) also, showed that the amount of available N significantly increased with increasing calcium-humate application rate and since that, as mean values of the two growing seasons it increased from 85.67 to 107.06 for Ca- H_0 and Ca- H_{20}, respectively. This may be due to the ability of calcium- humate to absorb nitrogen from soil solution onto the absorption sites. Also, there were significant interaction effects between irrigation regime treatments and Ca-H applications whereas the amount of available N increased from 81.6 at Ca-H_0I_{50} to 109.45 at Ca-$H_{20}I_{100}$.

Table 4: The mean value of yield and yield components of Faba bean treated with calcium humate under irrigation water regime at the two growing seasons.

Treatments						
Water regime %	Calcium humate	No. of Pods plant^{-1}	No. of Seedsplant^{-1}	Weight of seedsplant^{-1} (g)	Weight of 100 seeds (g)	Total Yield (kg acre^{-1})
50	Ca-H 0	12.6	47.0	49.00	104.18	1227.00
	Ca-H 10	16.1	64.3	66.50	103.47	1645.55
	Ca-H 20	19.2	76.8	80.50	104.71	1918.50
Mean		15.96 b	62.7 c	65.33 c	104.12 a	1597.00c
75	Ca-H 0	13.7	52.4	54.66	104.36	1335.00
	Ca-H 10	16.3	66.2	68.00	102.73	1698.00
	Ca-H 20	20.2	81.2	83.50	102.87	1987.50
Mean		16.7 b	66.6 b	68.72 b	103.32 a	1672.50 b
100	Ca-H 0	14.2	54.2	56.68	104.61	1498.50
	Ca-H 10	18.2	70.8	73.00	103.04	1833.00
	Ca-H 20	21.7	85.0	87.50	102.94	2055.00
Mean		18.0 a	70.0 a	72.39 a	103.53 a	1797.00 a
Mean of Ca-H		13.5 C	51.2 C	53.45 C	104.38 A	1353C
		16.9 B	67.1 B	69.16 B	103.08 B	1725B
		20.4 A	81.0 A	83.83 A	103.51 AB	1989A
LSD at 0.05	Irr	0.88	2.40	3.05	1.35	0.47
	Ca-H	0.98	1.76	1.94	1.11	0.51

** LSD-Interaction (Irr x Ca-H) not significant, Numbers with the same later is not significant

Table 5: The mean value of the amount of available macronutrients, organic matter and soil respiration in soils treated with calcium-humate under irrigation water regime at the two growing seasons

Treatments		Av-N	Av-P	Av-K		
Water regime %	Calcium humate	---------------- mg kg^{-1}		--------------	OM %	Soil respiration mg CO2 100g soil^{-1}. Week^{-1}
50	Ca-H 0	81.61i	3.96	39.24f	0.35g	34.44 g
	Ca-H 10	97.13f	6.12	63.50e	0.49e	41.35 ef
	Ca-H 20	104.71c	8.73	86.58c	0.67c	56.38 c
Mean		94.48C	6.27C	63.11C	0.50C	44.06C
75	Ca-H 0	85.40h	4.82	46.94f	0.40fg	34.65 g
	Ca-H 10	99.04e	6.82	73.94d	0.55de	45.71 de
	Ca-H 20	107.03b	9.22	109.37b	0.83b	67.65 b
Mean		97.15B	6.95B	76.75B	0.59B	49.34B
100	Ca-H 0	90.00g	5.63	55.11ef	0.46ef	37.15 fg
	Ca-H 10	101.79d	7.66	75.75d	0.61cd	50.93 d
	Ca-H 20	109.45a	9.98	132.74a	0.94a	86.37 a
Mean		100.41A	7.75A	87.87A	0.67A	58.15A
Mean of Ca-H		85.67C	4.80C	47.10C	0.40C	35.41C
		99.32B	6.87B	71.06B	0.55B	46.00B
		107.06A	9.31A	109.56A	0.81A	70.13A
LSD at 0.05	Irr	1.35	0.13	4.06	0.06	4.28
	Ca-H	0.53	0.17	6.09	0.04	3.20
	Irr x Ca-H	1.33	ns	8.90	0.07	5.41

Numbers with the same later is not significant

Available Phosphorus: Table (5) showed that the amount of available P as mean values of the two growing seasons increased with increasing the amounts of applied irrigation water where the amounts of available P were 6.27, 6.95 and 7.75 mg kg^{-1}soil for I_{50}, I_{75} and I_{100}, respectively. Table (5) also showed that increasing calcium-humate application rate significantly increased that the amount of available P in the soils. That is, the available P as mean values of the two growing seasons increased and was 4.80, 6.87 to 9.31 for Ca-H_0, Ca-H_{10} and Ca-$H_{20,}$ respectively. Such increase may be due to the increase of applied irrigation water and calcium-humate application rate, which enhanced microbial activity and accumulation of SOM in the soil. Concerning the interaction effect between irrigation regime and calcium-humate application on soil available P showed that no significance.

Available Potassium: Table (5) showed that the amount of available K, as mean values of the two growing seasons, increased with increasing the amount of applied water, where it increased from 63.11 and 76.75 to 87.87 for I_{50}, I_{75} and I_{100}treatments respectively. Table (5) also showed that the amount of available K significantly increased with increasing calcium-humate application rate where available K, as mean values of the two growing seasons had increased from 47.10 and 71.06 to 109.56 mg kg^{-1}soil for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. The increases of available K, due to increasing the amount of applied irrigation water and calcium humate application rate may have led to increasing soil moisture and consequently the increase of microbial soil biomass and SOM. The interaction among the different treatments increased the availability of K in the treated soil compared with the non-treated soil (control). Thus, the amount of available K increased from 39.24 to 132.74mgkg^{-1} due to Ca-H_0I_{50} and Ca-$H_{20}I_{100}$ treatments, respectively.

Soil Organic Matter Contents: Table (5) showed significant effects of irrigation regimes on soil organic matter content, the mean values of the two growing seasons were 0.5, 0.59 and 0.67% for I_{50}, I_{75} and I_{100}, respectively. This increase may be due to increasing applied irrigation water, which enhances the growth of microbes and root activity resulting in increasing SOM contents in soils. Table (6) also, indicated that increasing the application rate of calcium-humate significantly increased the amount of SOM in soil. SOM as mean values of the two growing seasons increased from 0.50 and 0.59 to 0.67 for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. The increase of SOM may be due to the rise in calcium-humate. The activity and growth of soil microorganisms that is indicated by increasing soil respiration in Table (5).

Soil Respiration: Soil respiration increased by increasing applied irrigation water (Table 5). As a mean value, of the two growing seasons, it is significantly increased from 44.06 and 49.34 to 58.15 mg CO_2 100 g $soil^{-1}$ $Week^{-1}$ for I_{50}, I_{75} and $I_{100,}$ respectively. The same trend was found for Ca-H application as mean values, of the two growing seasons, it is significantly increased from 35.4 and 46.00 to 70.13 mg CO_2 100 g $soil^{-1}$ $Week^{-1}$for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. Increasing soil respiration by increasing the amount of applied irrigation water and calcium-humate application rate may be due to that both Ca-H and irrigation regime had positive significant effects on soil organic matter which increased from 0.35 % at Ca-H0 I50 to 0.94 at Ca-H20 as mean values of the two growing seasons and consequently increased the growth of soil microorganisms and soil respiration.

Macronutrients Concentration in Leaves

Nitrogen Content: Table (6) revealed that increasing amount of applied irrigation water significantly increased the percent of nitrogen in leaves of Faba bean plants where it increased as mean values of the two growing seasons from 0.87and 0.97 to 1.05 % for I_{50}, I_{75} and $I_{100,}$ respectively. Also, Table (6) showed that application of calcium-humate had a significant positive effect on Faba bean leave nitrogen content, as mean values of the two growing seasons, it increased from 0.62 and 0.97 to 1.18 % for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. Increasing nitrogen in Faba bean leaves may be due to increasing nitrogen uptake and translocation from the soil as a result of increasing nitrogen availability in the soil Table (6). In addition, there was a significant interaction effect between irrigation treatments and calcium-humate applications, since leave nitrogen content increased from 0.62 % at I_{50}Ca-H_0 to 1.30 % at I_{100}Ca-H_{20}.

Phosphorus Contents: Table (6) showed a positive significant effect in Faba bean leaves as a result of increasing the amount of applied irrigation water on phosphorous content, where phosphorous content in leaves as mean values of the two growing seasons and were 28.49, 34.52 and 43.54 mg kg^{-1} for I_{50}, I_{75} and $I_{100,}$ respectively. Table (6) also declared that phosphorous content in leaves significantly increased with increasing calcium-humate application rates as mean values of the two growing seasons, it increased from 22.13 and 31.14 to 53.27 mg Kg^{-1} for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. There were significant interaction effects between irrigation regimes treatments and calcium-humate application since phosphorous content in leaves increased from 17.78 mg kg^{-1} at I_{50}Ca-H_0 to 70.23 mg kg^{-1} at I_{100}Ca-H_{20} as mean values of the two growing season.

Potassium Contents: Data clear that there was a positive significant effect of increasing the amount of applied irrigation water on potassium percent in Faba bean leaves (Table 6), where potassium content in leaves (as mean values of the two growing seasons) has increased from 0.23% at I_{50} to 0.40 5 at I_{100}. Table (6) also

Table 6: The mean value of macronutrients contents in leaves and seeds and protein and proline contents in leaves as affected by calcium-humate under irrigation water regime treatments at the two seasons

Treatments		Leaves			Seed %				
Water regime	Calcium humate	N %	P mg kg^{-1}	K %	N	P	K	Protein%	Proline (µg g^{-1})
50 %	Ca-H 0	0.62 i	17.78 g	0.15 d	3.22 g	0.19 h	0.88 g	20.20 g	91.73 a
	Ca-H 10	0.92 f	27.58 ef	0.22 cd	3.72 de	0.23 e	0.96 de	23.29 de	54.60 d
	Ca-H 20	1.08 c	40.12 c	0.34 bc	3.96 c	0.26 c	1.00 c	24.79 c	37.57 f
Mean		0.87 C	28.49 C	0.23 B	3.63 B	0.23 C	0.95 C	22.76 B	61.30 A
75 %	Ca-H 0	0.76 h	23.08 fg	0.19 d	3.50 f	0.21 g	0.92 f	21.90 f	78.00 b
	Ca-H 10	0.98 a	31.00 de	0.23 cd	3.77 de	0.23 e	0.97 cd	23.59 de	50.68 d
	Ca-H 20	1.16 b	49.47 b	0.46 b	4.05 b	0.28 b	1.08 b	25.38 b	32.61 g
Mean		0.97 B	34.52 B	0.29 B	3.77 B	0.24 B	0.99 B	23.62 B	53.76 B
100 %	Ca-H 0	0.84 g	25.54 f	0.20 d	3.62 ef	0.22 f	0.93 ef	22.65 ef	65.96 c
	Ca-H 10	1.01 d	34.85 d	0.25 cd	3.85 cd	0.24 d	0.98 cd	24.13 cd	44.69 e
	Ca-H 20	1.30 a	70.23 a	0.76 a	4.30 a	0.31 a	1.19 a	26.89 a	27.09 h
Mean		1.05 A	43.54 A	0.40 A	3.92 A	0.26 A	1.03 A	25.6 A	45.91 C
Mean of Ca-H		0.62C	22.13 C	0.18 B	3.45 C	0.21 C	0.91 C	21.58 C	78.56 A
		0.97 B	31.14 B	0.23 B	3.78 B	0.23 B	0.97 B	23.67 B	49.99 B
		1.18 A	53.27A	0.52 A	4.10 A	0.28 A	1.09 A	25.68 A	32.42 C
LSD at 0.05	Irr	0.04	3.27	0.10	0.14	0.006	0.01	0.90	2.79
	Ca-H	0.03	3.54	0.08	0.08	0.009	0.03	0.56	2.65
	Irr x Ca-H	0.05	5.40	0.13	0.16	0.009	0.03	1.03	4.17

Numbers with the same later is not significant

declared that potassium content in leaves significantly increased with increasing calcium-humate application rates where potassium content in leaves (as mean values of the two growing seasons) had increased from 0.18 % and 0.23 % to 0.52 % for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. There were significant interaction effects between irrigation regimes treatments and calcium-humate application since potassium content in leaves increased from 0.15 % at I_{50}Ca-H_0 to 0.76 % at I_{100}Ca-H_{20}, as mean values of the two growing seasons.

Macronutrients Content and Seeds Quality

Nitrogen Contents: Table (6) cleared that N content in Faba bean seeds was significantly increased by irrigation regimes treatments. Seed N content, as mean values of the two growing seasons, were 3.63 %, 3.77 % and 3.92 % for I_{50}, I_{75} and I_{100} respectively. Nitrogen content in seeds significantly increased with increasing calcium-humate application rates, where it increased from 21.58 % at Ca-H_0 to 25.68 % at Ca-$H_{20,}$ as mean values of the two growing seasons. Table (6) also declared that the interaction effect between irrigation regime treatments and calcium-humate application rate was significant.

Phosphorus Contents: Phosphorus contents in Faba bean seeds significantly increased with increasing applied irrigation water, thus as mean values of the two growing seasons, it increased from 0.23 % and 0.24 % to 0.26 % for I_{50}, I_{75} and I_{100}, respectively (Table 6). As shown in Table (6) application of calcium-humate significantly increased phosphorus content in seeds from 0.21 % at Ca-H_0 to 0.28 % at Ca-H $_{20}$ In addition, there was a significant interaction effect between irrigation regime treatments and calcium-hamate application rate (Table 6).

Potassium Contents: Table (6) showed that irrigation regime treatments and calcium-humate application had a significant effect on the amount of potassium in seeds. There was also a significant interaction effect between irrigation regime treatments and calcium-humate application.

Protein Contents: Concerning the effect of irrigation levels, data showed that increasing irrigation level led to a gradual reduction in protein content in seeds. Data presented in Table (6) showed decreasing the amount of applied irrigation water significantly increased protein content from 22.76 % and 23.62 % to 25.60 % for I_{100}, I_{75} and I_{50}, respectively as mean values of the two growing seasons. The calcium-humate application had a significant effect on protein content in Faba bean seeds (Table 6), whereas as mean values of the two growing seasons, it increased from 21.58 %, 23.67 % to 25.68 % for Ca-H_0, Ca-H_{10} and Ca-H_{20}, respectively. Table (6) declared also that there was a significant interaction effect between irrigation water regime treatments and application of calcium-humate on protein content in seeds.

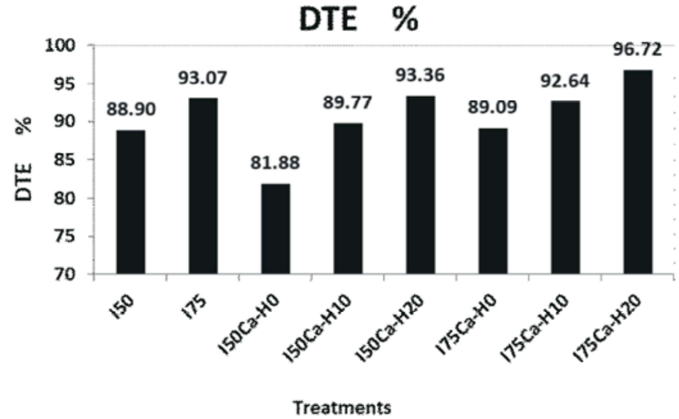

Fig. 1: Drought tolerate efficiency (DTE) as affected by irrigation treatment and calcium-humate in the two growing seasons

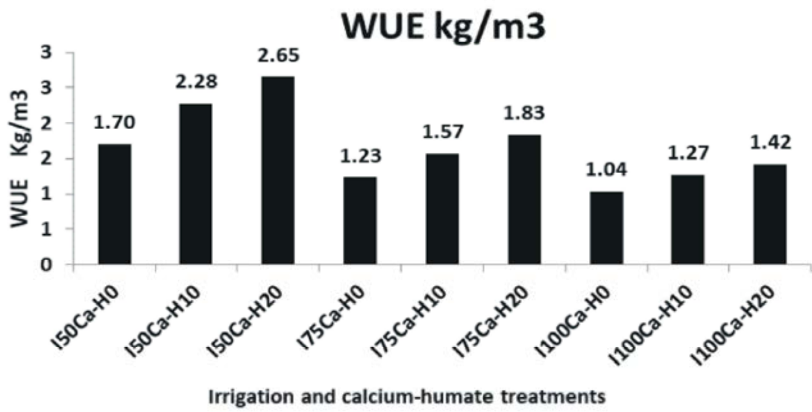

Fig. 2: Water use efficiency as affected by irrigation treatment and calcium-humate in two seasons

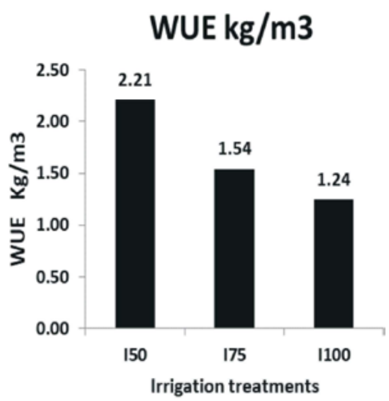

Fig. 3: Water use efficiency as affected by irrigation water regime in two seasons

Proline Contents: Proline content significantly increased with decreasing the amount of applied irrigation water, whereas as mean values of the two growing seasons, it increased from 45.91 and 53.76 to 61.30 μgg^{-1} for I_{100}, I_{75}, I_{50}, respectively (Table 6). Calcium-humate application significantly decreased proline content in Faba bean plants, whereas as mean values of the two growing seasons, it increased from 32.42 to 78.56 μg g^{-1} for Ca-H_{20} and Ca-H_0, respectively, there were also significant interaction effect between irrigation regime treatment and calcium-humate application.

Drought Tolerance Efficiency: Figure (1) showed that increasing applied irrigation water had a positive effect on the values of DTE (percentage), which increased from 88.90 % at I_{50} to 93.07 % at I_{75}. In addition, there was a positive effect of increasing calcium humate application rate, under water stress treatments where DTE were 81.88, 89.77, 93.36, 89.09, 92.64 and 96.72 % for I_{50}Ca-H_0, I_{50}Ca-H_{10}, I_{50}Ca-H_{20}, I_{75}Ca-H_0, I_{75}Ca-H_{10} and I_{75}Ca-H_{20}, respectively.

Water Use Efficiency: Fig. (2) showed that the highest water use efficiency value (2.65 kg m^{-3}), as mean values of the two growing seasons, were recorded for I_{50} Ca-H_{20}. Thus, decreasing the amount of applied irrigation water

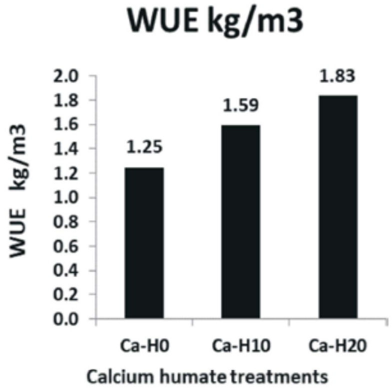

Fig. 4: Water use efficiency as affected by Calcium-humate in two seasons

and increasing of calcium-humate application has a highly positive effect on water use efficiency. The effect of increasing applied irrigation water on the values of water use efficiency (WUE) for Faba bean plants Fig. (3). It indicated that increasing the amount of applied irrigation water have a negative effect on the values of water use efficiency, where WUE as mean values of the two growing seasons were 1.21, 1.54 and 1.24 kg m^{-3} for I_{50}, I_{75} and I_{100} , respectively.

Fig. (4) showed the effect of calcium humate application rates on the values of water use efficiency (WUE) and indicated that increasing calcium-humate application rate increased the values of water use efficiency, where WUE values were 1.25, 1.59 and 1.83 kg m^{-3} for Ca-H_0, Ca-H_{10} and Ca-$H_{20,}$ respectively. Fig. (4) also showed that calcium-humate application has more effect on water use efficiency (WUE) values compared with other water irrigation treatments (Fig. 3).

DISCUSSIONS

A positive interaction between irrigation regimes and calcium-humate application treatments on the mean value of vegetative growth characters of Faba bean at the two growing seasons. These positive effects may be due to increasing soil organic matter, available. NPK (Table 3) which led to increasing plant height. These results agree with [39, 40] findings, they showed that plant height was highly and significantly affected with irrigation treatments. Dawood *et al.* [41] found that humic acid application caused marked increases in weight, height, number of branches of the plant. Megawer *et al*. [42] showed also that irrigation every 20 days surpassed the other treatments where it produced higher values of plant height (87.34cm). While irrigation every 40 days produced the highest plant height (106.82 cm) and the number of branches $plant^{-1}$ (3.07). The obtained results are in agreement with the finding of [43, 44, 45], they indicated that a significant increase in growth characters of Faba bean plant was observed with 100% WR followed by 75% WR, respectively. Ca-H increased significantly growth characters of Faba bean as compared to the control treatment.

These results are consistent with those reported by [45] who concluded that the seed yields of Faba bean was increased significantly by 0.80 irrigation rate during the two season and that low irrigation level (0.6 IR) sharply decreased seed yields in the first season. The increase of yield in the current study may be due to the role of humic materials in stimulating root growth and organic acid exudates, which in turn led to increased nutrient uptake and improve growth and yield. Canellas *et al.* Karakurt *et al*. Eldardiry*et al*. [46, 47, 47] reported that deficit irrigation treatments could be useful to obtain the most suitable yield characters of Faba bean under experimental conditions. EL-Mansoury [39] noted that concerning the effect of irrigation treatments, the highest values 1843.8 $kgacre^{-1}$ for yield was obtained with three irrigations after sowing (given three irrigations following sowing irrigation plus rainfall.). Dawood *et al*. [41] found that humic acid treatments caused obvious increases of seed yield $acre^{-1}$ by 110.16% relative to control. Megawer *et al*. [42] found that irrigation every 20 days surpassed the other two where it produced higher values of seed yield (1.81 Mg $acre^{-1}$). Abdel Nabi [48] found that humic acid concentrations 2 and 4 g L^{-1}gave a significant increase in the total yield (24.40 Mg ha^{-1}). These findings are in agreement with those of [28] where the highest values of pods and seeds weight $plant^{-1}$ were 57.04 and 45.32g, as well as 100- seed weight (g) and seed yield (Mg $acre^{-1}$) were 118.37 g and 2.04 Mg $acre^{-1}$ respectively, obtained by irrigation every 30 days with early sowing with Nubaria 1 variety. EL-Mansoury [39] showed that the number of pods $plant^{-1}$ was highly affected with irrigation treatments. Humic acid treatments caused obvious increases of pod number $plant^{-1}$ relative to control [42]. Irrigation every 40 days gave the highest values in the number of pods $plant^{-1}$ [28]. Abdel Nabi, Obaid [2] reported that humic acid concentrations of 2 and 4 g L^{-1} gave a significant increase in the number of $podsplant^{-1}$ and yield $plant^{-1}$ (259.9 g) in addition to the total yield (24.40 Mg ha^{-1}).

Irrigation regime and Ca-H generally increased the amount of available N, P and K in the soil as compared to the control treatment [44, 49]. These results are in agreement with those indicated by [17] who found that increasing water stress led to the decrease of organic matter content gradually by decreasing the amount of irrigation water. In addition, organic matter was enhanced by adding Ca-H alone or when applied in combination with 75% N as compared to the control. It has been reported that treating the soil with calcium or organic amendments or both, for the long-term has improved aggregation through calcium bridging effect and stabilization [50].

These observations were noticed by [17] who found that application of 75% WR gave the lower value of NPK uptake in Faba bean straw as compared to 100% WR irrigation treatment. The highest values of NPK uptake in straw was due to 75% ETc followed by 100% ETc and the lowest values with 50% ET_C. mineral uptake in straw increased significantly under the 75% water stress except for K uptake [26]. Similar results were obtained by [25] who found a reduction in NPK reached 12.7%, 8.81 % and 11.3% in the seed with 75% WR, respectively. The irrigation regime and Calcium-humate (at 100 WR) generally increased NPK total contents in seeds as compared to 75% WR. Eldardiry *et al.* [17] revealed that NPK content decreased with increasing water deficit from 90 to 75 and 60 % ET_o .

These results are in good agreement with those obtained by [17, 25] who showed an increase in protein content with reduced irrigation water amount. Application of 75% N+ Ca-H treatment was superior of both protein percentage as compared to either the control or the other treatments under all irrigation regime. There was an increase in protein content of Faba bean with a low supply of water 75% ET_c water regime had more protein content than 100% ET_c water treatment [26]. It was found that irrigation every 20 days presented the highest values in protein 26.90 % [18].

This increase may be due to water stress as in adequate water supply, which caused hydrolysis and catabolism in proteins and released free amino acids and ammonia as well as proline [28]. Dawood *et al*. [42] found that humic acid treatment increased proline content 24.33% relative to the control. Humic acid is an essential organic substance essential for retaining water, thus improving root growth and enhancing the ability of sandy soils to retain and not filter vital plant nutrients [35].

Eldardiry *et al.* [17] cleared that the deficit-irrigated treatments produced higher WUE in comparison to full irrigated in all treatments. Increased water deficit from 90 to 60% associated with a decrease in WUE from 3.54 to 2.68 and from 3.44 to 2.41 kg m^{-3} during the first season and from 3.67 to 2.25 and from 3.67 to 2.65 kg m^{-3} for the second one. Generally, it was observed that the highest values of WUE for grain yield and straw yield were obtained by irrigating Faba bean plants by 75% of the ETc (1015 m^3 $acre^{-1}$). Using 75% of the ETc is saving 25% from used irrigation water for the other uses in agriculture in Egypt, these data in the same concern with [51, 52]. Moreover, water use efficiency was 0.70, 0.82 and 0.85, respectively at 4, 6 and 8 days of irrigation [53]. Also, [54] showed that the maximum yield of Faba bean was produced from traditional irrigation of five irrigations (1102.71 kg $acre^{-1}$) and the minimum yield was obtained under rainfall (503.86 kg $acre^{-1}$).

CONCLUSION

It is now clear that, under drip irrigation conditions in sandy soil at El-Bostan, El-Buhira Governorate, irrigating of Faba bean with mean value at two seasons 1445.67 $m^3 acre^{-1}$ with 100 % ET_o at sprayed on the soil surface with calcium-humate ($Ca\text{-}H_{20}$) gives the highest yield of 2055 (kg $acre^{-1}$) and highest water use efficiency (WUE) of 2.65 kg seeds m^{-3} of applied water at 50 % Et_o and calcium-humate $Ca\text{-}H_{20}$. Drought tolerance efficiency is affected by irrigation treatment and calcium-humate. Therefore, I_{75} $Ca\text{-}H_{20}$ recorded the highest of values and were 96.72 %. While, irrigation water regime noted that I_{75} had high-value drought tolerance efficiency, which was 93.07 %. Using 75% of the ET_o is saving 25% of the water required for crops in Egypt. Accordingly, the Faba bean needs a quantity of water of 1084.26 m^3 $acre^{-1}$ for irrigation. Furthermore, an increasing of calcium-humate application has more effects on WUE values.

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