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Response of three Faba bean Varieties to Number of irrigations on Physiological traits, Yield and Yield Components, and Water Productivity under Calcareous Soil Conditions

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ABSTRACT

A field experiment was conducted at the experimental farm of Nubaria Agricultural Research Station, Agricultural Research Centre, Ministry of Agriculture and Land Reclamation, El-Behiera Governorate, Egypt, during the two successive winter seasons of 2017/2018 and 2018/2019 to study the effect of three irrigation treatments (I_1: three, I_2: two, and I_3: one irrigation after sowing irrigation) on the physiological response, productivity, amounts of applied irrigation water, water consumption, and productivity of irrigation waterof three faba bean varieties (Nubaria 3, Nubaria 1, and Giza 716).

Results could be summarized as follows:

- Deficit irrigation treatment (I_3) significantly decreased leaves chlorophyll content, seed protein content, plant height (cm), number of branches/plant, number of pods/plant, number of seeds/plant, seed yield/plant, seed yield, relative water content (RWC), and transpiration rate (TR) in both seasons. While, proline content, total soluble carbohydrate of leaves and stomatal resistance were significantly increased.
- Increasing irrigation water led to decrease in water use efficiency values. Maximum productivity of irrigation water (PIW) values were obtained from applying I_3 irrigation treatment with Giza 716 variety.
- Regarding the effect of varieties, Nubaria 3 recorded the highest values of protein percentage (%), total soluble carbohydrates, chlorophyll content, and RWC. However, the highest values for proline content, number of seeds/plant and seed yield (ardab/fed) were recorded from Nubaria 3 and Giza 716 varieties. The maximum values of stomatal resistance (SR) were recorded for Nubaria 3 followed by Giza 716, and Nubaria 1. An opposite trend was observed for transpiration rate (TR).
- The interaction effects between irrigation treatments and varieties were found to be significant in all tested traits. Maximum values of protein of seeds content, plant height, no of pods/plant, no of seed/plant, and RWC were obtained when Nubaria 3 and Giza 716 varieties irrigated with three irrigations after sowing irrigation (I_1). Nubaria 1 recorded the highest number of branches/plant under such treatment. The highest accumulation of total soluble carbohydrates and proline contents in leaves, the highest values of stomatal resistance and lowest transpiration rate recorded in Nubaria 1 variety under the dry treatment (I3).
- In the light of the present study, the maximum faba bean yield and its components were obtained from Nubaria 3 and Giza 716 irrigated by treatment I_1 (three irrigations after sowing irrigation) followed by medium treatment I_2 (two irrigations after sowing irrigation) with insignificant difference. On the other hand, the maximum values of Productivity of irrigation water (PIW) were obtained from Giza 716 followed by Nubaria 3 under I_2 (two irrigations after sowing irrigation) compared to Nubaria 1. However, sowing Nubaria 3 and Giza 716 varieties irrigated with two irrigations after sowing irrigation is recommended under calcareous soil conditions and surface irrigation system, while if irrigation water is the limiting factor for faba bean production, or if the farmer is facing water scarcity, we recommend sowing Nubaria 3 variety with only one irrigation, which gave an average seed yield 7.82 (ard/fad) (2.88 ton/hectare) for the two years, and saved about 412 m^3 of irrigation water compared to three irrigations after sowing irrigation.

Key words: Faba bean, Water stress, Varieties, Stomatal resistance, Transpiration rate, Water Productivity, Proline and Protein Content.

INTRODUCTION

Faba bean (*Vicia faba L.*) is considered as one of the most extensively grown legume and multipurpose crop over the world (Toker, 2004). Because of its high content of protein, minerals and vitamins, faba bean is used for both human food and animal feed nutrition (Bond et al., 1985). Also, faba bean as a leguminous crop plays a great role in soil fertility since it represents a major source of nitrogen input in agricultural soil. Faba bean, ranks as the most important grain legume in Egypt on the basis of annual tonnage produced and the fifth rated on world basis. The cultivated area over last year (2020/2021) was (120000)* feddans.

Due to global warming and the rising human population, water availability is becoming an increasing issue for agriculture. One of the main challenges of modern agriculture is to maintain growth and crop productivity under adverse environmental stress conditions such as water deficit. It has been reported that more than 50% of the average yield of most major crops is lost due to drought stress (Fita et al; 2015). Growth inhibition is often associated with altered plant water status, with a decrease in the relative water content of leaves (Sanchez-Blanco et al; 2002; and Dichio et al; 2003). Also, drought stress progressively decreases CO_2 assimilation rates due to reduced stomatal conductance (Migdadi et al; 2016). Total chlorophyll and carotene content were also found to decline under water stress (Hasegawa et al 2000).

Plants have evolved many mechanisms for water stress tolerance including a number of physiological and biochemical processes such as maintenance of water use efficiency, osmotic adjustment and protection of cellular machinery (Bohnert et al., 2006; Farooq et al., 2009., and Horie et al., 2011). Osmotic adjustment is involved in plant resistance to lower soil water potential which decreases water availability and allow a partial maintenance of turgor dependent processes water stress conditions (Gholami et al; 2012).

Water shortage is one of the major abiotic stresses that affecting faba bean production in Egypt.

In this context, development of faba bean genotypes tolerant to water limited conditions is an important strategy for improving faba bean production. Also, direct measurement of physiological processes involved in response to water stress is a useful and pragmatic option for screening genotypes. The main objectives of the present investigation were to study the physiological response, crop productivity and water productivities of three faba bean varieties as affected by number of irrigations under calcareous soil conditions at Nubaria region.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of Nubaria Agricultural Research Station (30° 54´ N, 29° 57´ E, and 15m above sea level), Agricultural Research Centre (ARC), Ministry of Agriculture and Land Reclamation (MALR), El-Behiera Governorate, Egypt, during the two winter seasons of 2017/2018 and 2018/2019. The objective of this investigation was to evaluate the effect of number of irrigations (I_1: three irrigations after sowing irrigation (wet), I_2: two irrigations after sowing irrigation (medium), and I_3: One irrigation after sowing irrigation (dry) on productivity, seed quality, physiological characters, amounts of applied irrigation water, and water productivity of three faba bean varieties (Nubaria 3, Nubaria 1 and Giza 716) under calcareous soil conditions.

Soil samples were collected from two depths (0-30 and 30-60cm) to determine soil physical and chemical properties at the experimental site. The soil physical parameters (particle size distributions and soil texture class) were determined according to the FAO (1970), soil-moisture constants (field capacity (FC), wilting point (WP), and available soil moisture (ASM) were determined on mass basis by a pressure extractor apparatus), and soil bulk density (BD) values were determined in undisturbed soil samples using the core method and soil hydraulic conductivity (Kh) was measured according to (Black and Hartge, 1986). The soil chemical parameters (electrical conductivity (EC), soil reaction (pH), cations, and anions concentrations) were determined according to Page et al. (1982). The main physical, chemical properties and water relation of the soil at the experimental site are listed in Tables 1 and 2.

The main agrometeorological data during the two growing seasons at the experimental site are presented in Table 3.

Table 1: Bulk density (BD), field capacity (FC), wilting point (WP), available soil moisture (ASM), hydraulic conductivity (KH), particle size analysis, and soil texture classes of the soil at the experimental site.

Soil Depth (cm)	BD g cm^{-3}	FC %	WP %	ASM %	Kh cm h^{-1}	Particle size analysis			Texture class
						Sand %	Silt %	Clay %	
0 -15	1.26	23.58	11.51	12.07	4.83	58.2	16.7	25.1	Sandy clay loam
15 – 30	1.28	24.56	11.94	12.62	4.64	56.4	17.2	26.4	
30 – 45	1.35	23.14	11.31	11.83	5.04	5٤.9	17.2	27.9	
45 - 60	1.37	24.16	11.36	12.80	4.90	54.3	20.5	25.2	

Table 2: Chemical properties at the experimental site before planting.

Soil depth cm	EC dS/m	Soluble cations, meq/l				Soluble anions meq/l				pH	$CaCO_3$ (%)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3	HCO_3^{-}	Cl^{-}	SO_4^{--}		
0 - 30	1.75	7.69	2.65	6.04	1.14	-	5.30	8.75	3.47	8.36	21.83
30 – 60	1.91	5.93	2.12	8.65	2.43	-	4.27	10.24	4.62	8.24	20.46

Table 3. Monthly average agrometeorological data at the experimental site.

Parameter	Tmin ºC	Tmax ºC	Wind m/s	RH %	Rainfall Total mm/mon.	Rainfall Effective mm/mon.	Sunshine h
Month				2017/2018			
Oct. 2017	18.49	27.72	3.31	61.37	21.10	20.4	11.33
Nov. 2017	14.75	23.03	2.72	66.16	20.90	20.2	10.55
Dec. 2017	12.89	20.34	3.03	70.26	8.60	8.5	8.00
Jan. 2018	10.25	18.11	5.15	69.10	40.98	38.3	10.23
Feb. 2018	10.82	20.72	3.63	65.21	11.60	11.4	10.90
Mar. 2018	12.41	24.86	4.00	55.56	1.27	1.3	17.77
Apr. 2018	14.49	27.06	3.98	54.67	5.63	5.6	12.70
				2018/2019			
Oct. 2018	19.82	28.98	4.16	61.38	13.06	12.8	11.33
Nov. 2018	16.06	24.46	3.51	63.13	20.73	20.0	10.43
Dec. 2018	12.60	19.38	4.71	67.21	33.43	31.6	10.03
Jan. 2019	7.82	17.08	5.06	61.45	10.13	10.0	7.20
Feb. 2019	8.68	18.72	4.53	63.49	21.84	21.1	10.97
Mar. 2019	10.54	20.80	4.73	63.40	6.91	6.8	11.83
Apr. 2019	12.83	24.58	4.60	56.36	4.26	4.2	12.83

Experimental design and studied treatments.

The experiment was laid out in split plot design with four replicates. The main plots were occupied by three irrigation treatments, i.e. (three, two and one irrigation after sowing irrigation), while sub plots contained three faba bean varieties (Nubaria 3, Nubaria 1, and Giza 716). Plots were separated from each other by 2 meters distance to avoid the interference between irrigation treatments. The area of each sub-plots was 16.8 m^2 containing 4 ridges (7 m length and 60 cm apart).

Faba bean seeds were inculcated by Rhizobium before sowing and irrigated immediately after inoculation, sowing date was 21/10/2017 and 25/10/2018, in both seasons, respectively. Hills spaced at 20 cm with one seed/hill. 150 kg/fed was added as Calcium super phosphate (15.5 % P_2O_5) through soil preparation, 20 kg N/fed in the form of ammonium sulfate (20.2% N) was added before sowing and 24 kg K_2O/fed was add in the form of potassium sulfate (48% K_2O). All other cultural practices recommended by the Ministry of Agriculture and Land Reclamation for growing faba bean at Nubaria region were followed.

Record data

Chemical and physiological traits.

1- Total chlorophyll content of leaves: 100 days after sowing (DAS), total chlorophyll of leaves (mg/m^2) was determined as SPAD unit using SPAD 502 apparatus (Soil and Plant Analysis Development, Minolate Co). The SPAD unit was transformed to mg/m^2 as described by Monge and Bugbe (1992) using the following relation:

$$\text{Total Chl.} = 80.05 + 10.4\ (\text{SPAD } 502)$$

2- Proline content of leaves: 100 DAS, free proline (mg/g fw) was assayed in fresh leaves according to Bates et al. (1973).

3- Seeds crude protein: was determined according to the methods outlined by A.O.A.C. (1990).

4- Total soluble carbohydrates: was determined according to Dubois et al., (1956).

Harvesting took place on 11/4/2018 and 15/4/2019 in the first and second seasons, respectively. At harvesting time, ten individual guarded plants were randomly taken from the 2 central rows in each sub-plot to determine:

1- Plant height (cm).
2- Number of branches/plant.
3- Number of pods/plant.
4- Number of seeds/plant.
5- Seed yield/plant (gm).
6- Seed yield/fed (ardab/fed). Plants of central area (8.4 m^2) in each sub-plot were harvested to determine seed yields.

Plant-Water measurements:

100 days after sowing, the following measurements were done:

A- Relative water content of leaves (RWC, %)

Leaf samples were collected and immediately weighed (fresh weight, FW) and transferred into sealed flasks, then rehydrated in water for 5 h until fully turgid at 4ºC, surface swabbed and reweighed (turgid weight, Tw). Leaf samples were oven dried at 70 ºC for 48 h and reweighed (dry weight, DW). RWC% was calculated according to Lazcano-Ferrat and Lovatt (1999) as follows

$$RWC\% = \frac{(Fw-Dw)}{(Tw-Dw)} X100$$

B- Stomatal resistance (SR) and transpiration rate (TR):

The SR (S/cm), and TR (mg $H_2O/cm^2/s$) were measured by a portable steady state parameter (LI-COR model LI 1600).

Water relations:

Amounts of applied irrigation water (AIW):

The amount of irrigation water applied at each irrigation was calculated according to the equation given by Vermeiren and Jopling (1984) as follows:

$$AIW = \frac{ETp * Kc * I}{Ea\,(1 - LR)}$$

where:

AIW= depth of applied irrigation water in (mm)

ETp= potential evapotranspiration (mmd^{-1})

Kc = crop coefficient values at the experimental site.

I= irrigation intervals (days)

Ea= irrigation application efficiency of the surface irrigation system (Ea = 60% for surface irrigation system).

L.R.= leaching requirements, (10% of the calculated irrigation water).

Potential evapotranspiration (ETp) values were calculated from class A pan measurements according to Doorenbos and Pruitt (1984) as follows:

ET_p = Epan × Kpan.

where:

Epan is the measured pan evaporation values (mm/day).

Kpan is the pan coefficient that equals 0.75 for the experimental site.

Irrigation time was calculated before each irrigation event by the following equation:

$$t = \frac{AIW \times A}{1000 * q}$$

where:

t = irrigation time (h).

A =plot area (m^2).

q = pump discharge (m^3/h).

AIW = applied irrigation water (mm).

Total water applied (AIW_t) to the crop is expressed as:

$$AIWt = AIW + Reff$$

where:

Reff: is the effective rainfall (mm/period). It is calculated according to the formula reported by USDA-Soil Conservation Services (Dastane, 1974) as:

$$Reff = Rmonth * \frac{(125 - 0.2 * Rmonth)}{125} \qquad \{for\ Rmonth < 250\ mm\}$$

$$Reff = 125 + 0.1 * Rmonth \qquad \{for\ Rmonth > 250\ mm\}$$

Water consumptive use (WCU):

Gravimetric soil samples, from soil surface down to 60cm depth at 15cm intervals, were collected from all treatments after sowing, before and after each irrigation and at harvest to determine water consumptive use (WCU) or as considered equal to actual evapotranspiration (ETa). Water consumptive use values were calculated according to Israelson and Hansen (1962) using the following equation:

$$WCU = \sum_{i=1}^{i=4} \left(\frac{\theta_2 - \theta_1}{100} \right) \times Bd \times D$$

Where:

WCU = water consumptive use (cm)

i = number of soil layers

Θ_2 = soil moisture content after irrigation (%)

Θ_1 = soil moisture content before irrigation (%)

D = depth of soil layer (cm)

Bd = bulk density (g cm^{-3})

The productivity of irrigation water (PIW): The PIW values were calculated according to Jensen (1983) as follows:

$$\text{Productivity of irrigation water (PIW)} = \frac{\text{Faba bean seed yield (kg/fed)}}{\text{Applied irrigation water } (m^3/fed)}$$

Statistical analysis:

The collected data were statistically analyzed using ANOVA according to Snedecor and Cochran (1995). Averages were compared using the least significant difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Physiological characters.

1. Proline content of leaves

Results in Table (4) showed that, leaf proline content was significantly affected by the two factors under study. Exposing faba bean plants to low amount of irrigation water I_3 (dry treatment) significantly increased leaf proline content compared to the wet (I_1) and medium (I_2) treatments. These results are in harmony with those obtained by Manivannan et al. (2007) who found that proline content increased under water deficit condition in root, stem and leaf of all sunflower varieties under study. They added that the decrease in proline oxidase activity with increasing Y-glutamyl kinase activity might be the reason for higher proline accumulation in drought stressed.

Regarding the response of varities, leaf proline contents were significantly higher in Nubaria 3 variety as compared with the other two varieties. The lowest mean leaf proline values of 28.84 and 28.97 mg/g FW were recorded for Nubaria 1 variety in the 1^{st} and 2^{nd} seasons, respectively.

The results of interaction effect of tested variables for leaf proline content recorded a significant effect and showed that, I_3 and Nubaria 3 treatment recorded the highest proline content values (37.78 and 37.90 mg/g FW) in the two seasons. The obtained result can indicate that Nubaria 3 variety is more tolerant to water stress condition as compared to the other two varieties. The obtained results were in line with those reported by Yancy et al. (1982) and Jalaal et al. (2007), who indicated that accumulation of proline has been advocated as a parameter of selection for stress tolerance.

2. Leaf chlorophyll content

Data in Table (4) showed that the both irrigation and varieties had significant effects on chlorophyll content of leaves in the both seasons. Total chlorophyll significantly decreased when faba bean plants watered by dry treatment (one irrigation). The decrease in chlorophyll under drought stress is mainly the result of damage to chloroplasts caused by active oxygen species (Smirnoff,1995). Moreover, Iturbeormaetxe et al., (1998) suggested that, severe drought stress inhibits the photosynthesis of plants by causing changes in chlorophyll content by affecting chlorophyll components and by damaging the photosynthetic apparatus.

Concerning the effect of varieties, data indicated that the highest chlorophyll content was found in Nubaria 3 compared to the other two varieties under study. While, Nubaria 1 had the lowest values in two seasons.

The interaction between water stress and varieties on chlorophyll content was found to be significant. Maximum value of such trait was obtained from Nubaria 3 under wet treatment.

3. Soluble carbohydrates of leaves

Soluble carbohydrates of plant leaves of three cultivars increased by increased water stress as shown in Table (4). EL-Haddeh and O' Leary (1994) found that soluble sugars increased in Sorghum more than in a triplex, as effect by water deficit .

Concerning the effect of varieties, soluble carbohydrates significantly different.Nubaria 3 gave the highest soluble carbohydrate. On the contrary, Nubaria 1 gave the lowest value as compared to the other tested varieties during two seasons. In this concern,the water tolerant varieties had generally greater soluble sugars than the water sensitive one. Trehaloes, a disaccharide,: accumulates in many organisms under various abiotic stress have been reported by Vermeirn and Gopling (1984) and Hounsa et al., 1998) which protects membranes and proteins in cells exposed to stress that cause water deficits (Garcia et al., 1997, Goddijn and Dunk., 1999) and reduces aggregation of denatured proteins. Recently, Yamada et al., (2003) have reported that, trehalose has a suppressive effect an apoptotic cell death. There is now conclusive evidence that trehalose is present in trace amounts in vascular lands, including major crops, but the actual role of this osmolyte in metabolism of these plants is still un clear. These organic solutes may contribute to osmotic adjustment, protecting cell structure as well as, function, and or may serve as metabolic or energetic reserve (Hasegawa et al., 2000). Inorganic and organic solutes concentrations maintained during water stress, therefor may be important during the water stress recovery period (Pardossi et al., 1998).

Result in Table (4) revealed that the interaction effect between water regime and faba bean varieties was significant. Nubaria 3and Giza716 had the highest soluble carbohydrates under (dry treatment) I_3 with insignificant difference. On the other hand Nubaria 1 had the lowest soluble carbohydrates of leaves under (wet treatment) I_1 in the two seasons.

4. Protein content of seeds:

Data in Table (4) indicated that protein content of seeds was significantly affected by irrigation water treatments. This significant deficiency in protein content may be due to drought condition which decrease water potential where, the cell of plant cease to divide as a result of these conditions, protein breakdown is enhanced, (Ashraf, 1994). Generally nitrogen content decreased with increasing water stress (Nayeem and Bopal, (1986) and Scapim et al., 1998).

Data in table (4) indicated that varieties varied in the mean value of protein content. The highest values of protein content recorded by Nubaria 3 followed by Giza 716 with insignificant difference. It is worthy to note that the variety Nubaria 1 showed almost the lowest protein content at the two seasons. The decrease in the total protein percentage in stressed varieties in relation to the control (wet condition) may be attributed to hydrolysis of weakened protein matrix as suggested by Somani *et al*., (1993).

Data in Table (4) revealed that the interaction effect among irrigation water levels and faba bean varieties significantly affected protein content. Nubaria 3 and Giza716 had the highest protein content under I_1 (wet treatment) with insignificant difference. On the other hand, Nubaria 1 gave the lowest protein content under I_3 (dry treatment) in two seasons.

Yield and its attributes:

Result in Tables (5&6) revealed that water irrigation regimes treatment had a significant effect on plant height (cm), number of branches/plant, number of pods/plant, number of seeds/plant, seed yield /plant (gm) and seed yield (ard./fed.). Such these characters significantly decreased when plants exposed to water deficit (I_3).

Table 4. Proline (mg/g Fw) chlorophyll, carbohydrates(%) of leaves and protein (%) of seeds for three faba bean varieties as affected by three irrigation treatments during the two successive winter seasons of 2017/2018 and 2018/2019.

Treatment		Proline mg/g Fw		Chlorophyll mg/m^2		Soluble Carbohydrates %		Protein %	
Irrigation treatment	Varieties	2017/18	2018/19	2017/18	2018/19	2017/18	2018/19	2017/18	2018/19
I_1 (wet)	Nubaria 3	24.81	25.20	467.10	478.15	40.87	41.30	28.37	27.80
	Nubaria 1	24.39	24.56	455.80	463.11	38.24	38.20	25.60	25.63
	Giza 716	25.26	25.79	460.31	473.22	39.87	40.47	28.10	27.70
	Mean	24.28	25.18	461.07	469.49	39.66	39.99	27.36	27.04
I_2 (medium)	Nubaria 3	32.61	33.36	459.66	464.11	43.67	43.50	27.8	28.23
	Nubaria 1	29.03	29.32	445.18	451.28	42.37	42.10	24.07	23.30
	Giza 716	30.70	31.67	449.25	453.18	43.13	43.10	27.30	28.5
	Mean	30.78	31.45	451.36	458.19	43.06	42.90	26.40	26.47
I_3 (dry)	Nubaria 3	37.78	37.90	431.60	436.88	44.10	44.63	25.60	27.53
	Nubaria 1	33.11	33.02	412.33	409.88	43.57	43.33	22.07	19.81
	Giza 716	35.21	36.33	426.18	431.80	43.91	44.60	25.03	23.63
	Mean	35.37	35.75	423.38	426.20	43.86	44.11	23.90	23.63
Mean of varieties	Nubaria 3	31.73	32.15	452.79	459.71	42.88	43.14	27.24	27.02
	Nubaria 1	28.84	28.97	437.77	443.42	41.39	41.21	23.58	23.64
	Giza 716	30.39	31.26	445.25	450.74	42.30	42.64	26.81	26.48
	L.S.D (I)	0.601	1.389	6.07	7.93	0.764	0.505	0.529	0.423
	L.S.D (V)	0.357	0.699	3.26	4.76	0.436	0.263	0.811	1.0 88
L.S.D (I x V)		0.62	1.21	6.81	8.24	0.52	1.24	1.40	2.05

Table 5: Plant height (cm), no. of branches/plant, and no. of pods/plant for three faba bean varieties as affected by three irrigation treatments during the two successive winter seasons of 2017/2018 and 2018/2019.

Treatment		Plant height cm		No. of branches/plant		No. of pods/plant	
Irrigation treatments	Varieties	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
I_1 (wet)	Nubaria3	134.36	134.65	7.39	7.67	30.67	30.33
	Nubaria1	119.25	114.38	9.25	9.67	17.18	20.15
	Giza716	130.67	129.62	7.19	7.25	31.26	32.30
	Mean	128.09	126.22	7.92	8.19	26.37	27.59
I_2 (medium)	Nubaria3	130.39	120.09	6.83	6.97	27.67	28.17
	Nubaria1	119.23	123.63	8.75	8.92	14.15	16.09
	Giza716	128.17	123.63	7.11	5.79	28.30	27.24
	Mean	126.21	122.45	7.56	7.23	23.37	23.83
I_3 (dry)	Nubaria3	115.67	116.67	5.42	5.67	26.19	25.13
	Nubaria1	99.46	108.33	7.19	7.34	11.06	12.10
	Giza716	109.92	116.67	6.20	9.67	21.67	22.26
	Mean	108.35	113.89	6.27	6.22	19.64	19.83
mean of varieties	Nubaria3	126.81	123.80	6.55	6.80	28.18	27.87
	Nubaria1	112.67	115.45	8.49	8.64	14.13	16.11
	Giza716	122.92	123.31	6.83	6.24	27.08	27.27
L.S.D (I)		7.34	5.49	1.19	0.98	3.50	3.62
L.S.D (V)		6.33	nS	1.39	0.98	3.16	4.02
L.S.D (I x V)		10.96	14.72	1.52	1.40	5.46	7.01

Table 6: No. of seeds/plant, seed yield/plant and Seed yield (ardab/fed) for three faba bean varieties under three irrigation treatments during the two successive winter seasons of 2017/2018 and 2018/2019.

Treatments		No. of seeds/plant		Seed yield/plant		Seed yield (ardab/fed)	
Irrigation treatment	Varieties	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
I_1 (wet)	Nubaria3	127.20	127.67	90.33	93.67	9.97	9.77
	Nubaria1	85.59	90.29	90.34	91.67	8.24	9.18
	Giza716	116.18	117.39	94.67	95.23	10.07	9.87
	Mean	109.66	111.78	91.77	93.52	9.43	9.61
I_2 (medium)	Nubaria3	117.33	111.67	78.33	79.83	9.25	9.44
	Nubaria1	70.71	80.36	75.24	76.46	8.80	9.12
	Giza716	111.33	111.45	81.33	81.51	9.89	9.70
	Mean	99.79	101.91	78.30	79.67	9.32	9.42
I_3 (dry)	Nubaria3	103.61	102.10	66.39	65.36	7.89	7.75
	Nubaria1	55.29	65.21	63.33	66.47	6.88	6.98
	Giza716	97.33	98.67	65.67	65.13	7.44	7.15
	Mean	85.41	88.66	65.13	65.63	7.40	7.29
Mean of varieties	Nubaria3	116.05	113.80	78.35	79.62	9.04	8.99
	Nubaria1	70.53	78.62	76.30	78.20	7.97	8.43
	Giza716	108.28	109.16	80.56	80.62	9.14	8.91
L.S.D (I)		9.93	12.39	13.40	13.90	1.67	0.68
L.S.D (V)		7.68	9.92	NS	NS	0.66	0.41
L.S.D (I x V)		13.21	17.18	18.67	18.36	1.14	0.68

ardab = 155 kg.

However, the maximum values of all the previous characters were achieved when plants watered by wet treatment I_1 (three irrigations) and medium treatment I_2 (two irrigations) with insignificant difference while, the lowest values were achieved by dry treatment (I_3).These results due to that increasing soil moisture deficit which reduced faba bean growth and in turn affected yield components traits which decreased seed yield. In addition, water deficit imposed (I_3) during the reproductive development of dry beans can decrease the number of flowers, pods and number of seed/pod abortion which can reduce final seed yield, this opinion accompanied with severe effects on yield, because the young flowers and young pods are weaker sinews for assimilates in comparison with other plant organs (Karamanos and Gimenez, 1991). Therefore, the consequences of a possible shortage of assimilates at the initial stages of flowering and pod setting will be more severe on the reproductive organs and it is the main cause for poor fruit setting and consequently low seed yield. On the other hand, plant under irrigation treatment (I_1) enhanced growth plants there by improved yield attributes. These results are in line with those reported by Mafakheri et al., (2010) and Hegab et al., (2014). Also, Afiah et al., (2016) and Ouji et al., (2017) who, suggested that higher water status throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield.

Concerning faba bean varieties, it could be noticed that there was a significant difference among the three varieties in all characters expect plant height in the second season and seed yield (gm /plant) in the two seasons. Also results indicated that Nubaria 1 surpassed the other varieties for number of branches/plant in the both seasons. However, Nubaria 1 followed by Giza 716 gave the highest values for number of seed/plant and seed yield (ard/fed) in the second season with insignificant difference while, seed yield/plant recorded no significant differences among all the varieties in both seasons. Similar results were obtained by Belal et al., (2018) who recorded that the two faba bean cultivars. Giza 843 and Giza 716 surpassed Misr 1 and Sakha 1 under drought stress in each of pod number / plant, 100 seed weight and seed yield (kg/ha).

As for the interaction effect between irrigation regimes and faba bean varieties, results in Tables (5 & 6) show that there were significant interaction effects on all traits under study the highest values of plant height, No of pods/ plant and No of seeds/ plant were obtained from Nubaria 3 and Giza716 with water regime (I_1) while, Nubaria 1 recorded the highest number of branches, seed yield/ plant and seed yield / fed with water regime (I_1), However, Nubaria 1recorded the lowest value for the same traits under water (I_3) regime.

Water relations:

1- Relative water content of leaves (RWC)

RWC% was proposed as a good indicator of plant water status because RWC through its relation to cell volume, may be more closely reflects the balance between water supply to the leaf and transpiration rate. Table (7) showed that RWC significantly affected by two factors under study. Regarding the effect of water regime on RWC, results indicated that increasing amount of irrigation water significantly increased RWC. Such finding show that the water status in plant cells is affected by water regime conditions. In this respect Abid et al (2017) observed that soil water at (90%) from field capacity reduced RWC compared with water stress of 60% and 30% field capacity on faba bean plant. Similar results were obtained by Seham et al., (2020) on faba bean plants.

Concerning the effect of varieties, RWC% significantly differ, where Nubaria 3 had the highest RWC % compared to other varieties in two seasons. While, the lowest values of RWC% were recorded for Nubaria 1 in two seasons.

The interaction between soil moisture regime and varieties on RWC of leaves was significant. The highest values of RWC were scored from Nubaria 3 followed by Giza 716 under I_1 (received three irrigations) and with insignificant difference between the two varieties in two seasons.

Transpirational rate (TR) and Stomatal resistance (SR)

Results in Table (7) showed that the values of TR was significantly decreased, while SR values was significantly increased in the three varieties under study when plants imposed to drought conditions. As one of the first responses of plants to drought is stomatal closure, restricting gas exchange between the atmosphere and inside of the leaf, Mafakheri et al., (2010). In addition, such result may explained on the basis that when water supply is short, by exposed plants to drought conditions, RWC of leaves decrease which causing guard cells loses its turgidity thereby stomatal close lightly to prevent water loss which in turn decreased TR. In this regard Mourad and Anton (2007), and Abdo Fatma and Anton (2009) mentioned that plants exposed to drought condition increased SR and decreased TR values. Also, Robert (2005) reported that under natural water supply conditions, K moves into the guarded cells around the stomatal, the cells accumulate water and swell, causing the pores to open and allowing gases to move freely in and out. Morovere, when water supply is short, K is pumped out of the guard cells, the pores close lightly to prevent loss of water and minimize drought stress effect to the plant.

Table 7: Relative water content (RWC), transpiration rate (TR) and Stomatal resistance (SR) for three faba bean varieties under three irrigation treatments during the two successive winter seasons of 2017/2018 and 2018/2019.

Treatment		**Relative water content RWC %**		**Transpiration rate (TR) µg $H_2O/cm^2/s$**		**Stomatal resistance (SR) s/cm**	
Irrigation treatments	**Varieties**	**2017/2018**	**2018/2019**	**2017/2018**	**2018/2019**	**2017/2018**	**2018/2019**
I_1 (wet)	Nubaria3	84.42	86.12	3.02	3.10	1.78	1.83
	Nubaria1	82.18	85.04	3.38	3.42	1.36	1.40
	Giza716	84.21	86.08	3.15	3.19	1.80	1.85
	Mean	83.60	85.75	3.18	3.24	1.65	1.69
I_2 (medium)	Nubaria3	80.14	83.22	2.49	2.53	2.20	2.46
	Nubaria1	78.22	80.41	2.71	2.67	1.97	2.10
	Giza716	79.60	82.66	2.66	2.71	2.15	2.32
	Mean	79.32	82.10	2.62	2.67	2.11	2.29
I_3 (dry)	Nubaria3	78.04	79.16	1.96	2.03	3.68	3.81
	Nubaria1	69.28	73.20	2.11	2.15	3.09	3.11
	Giza716	74.03	77.18	2.06	2.10	3.44	3.46
	Mean	73.79	76.51	2.04	2.09	3.40	3.46
Mean of varieties	Nubaria3	80.87	82.83	2.49	2.55	2.55	2.70
	Nubaria1	76.56	79.55	2.73	2.78	2.14	2.20
	Giza716	79.29	81.97	2.62	2.67	2.46	2.54
L.S.D (I)		0.138	0.280	0.089	0.022	0.035	0.021
L.S.D (V)		0.337	0.453	0.067	0.037	0.034	0.030
L.S.D (I x V)		0.590	0.775	0.112	0.064	0.059	0.141

Concerning the effect of varieties, the maximum value of SR was obtained from Nubaria 3 followed by Giza 716, whereas the lowest value achieved in Nubaria 1. Reverse trend was observed with respect to TR. Similar results were obtained by Mafakheri et al (2010) who suggested that chickpea varieties significantly differed in transpiration and stomatal conductance when imposed to water deficit.

The interaction effect between soil moisture regime and varieties recorded a significant effect on both SR and TR. The highest value of TR scored from Nubaria 1 irrigated by I_1. On the other hand, the maximum values of SR were obtained from Nubaria 3 under I_3 (dry treatment).

Applied irrigation water (AIW):

Irrigation dates, depths of applied irrigation water (cm), and effective rainfall (cm) for faba bean in the first and second seasons are given in Table 8. Results show for each irrigation treatment that, the AIW for both seasons was almost the same. The total applied irrigation water values was 37.44cm (1572 m^3/fed) and 37.79cm (1587 m^3/fed) for I_1, 33.6cm (1411 m^3/fed) and 33.56cm (1410 m^3/fed) for I_2, and 26.84cm (1129 m^3/fed) and 26.78cm (1125 m^3/fed) for I_3 treatment in the first and second seasons, respectively. The applied irrigation water for faba bean crop was in close agreement with that reported by Hegab et al. (2014) who found that the water requirement was 30.1cm for the best irrigation treatment (irrigation at 100% of crop requirements).

Convert the total of applied irrigation water (cm) to m^3 fed^{-1} multiply the value by 42 Water consumptive use (WCU):

Water consumptive use values, as determined by soil moisture depletion, during the two growing seasons are given in Table 9. Results indicated that, increasing water available to the plants increased the consumed water. Average water consumption values were 28.3 and 28.13cm for I_1 treatment, 27.14 and 27.74cm for I_2 treatment, and 18.05 and 16.86cm for I_3 treatment in the 1st and 2nd seasons, respectively. Results revealed that, the highest amounts of consumed water occurred during the yield formation period in both seasons. Results showed also that, water consumption by Giza 716 variety was higher than Nubaria 3 and Nubaria 1 varieties. These results are in agreement with the results of Hanan et al. (2017).

Convert the total of water consumption (cm) to m^3 fed^{-1} multiply the value by 42 Productivity of irrigation water (PIW):

Results in Table 10 represent the effect of irrigation treatments on productivity of irrigation water (*PIW*) expressed as kg of faba bean seed yield per cubic meter of applied irrigation water. The 2-season average *PIW* values were 0.93, 1.03, and 0.98 kg seed/m^3 applied water for I_1, I_2, and I3 irrigation treatments, respectively. The obtained results are in agreement with those reported by Hegab et al. (2014) and Hanan et al. (2017). Results indicated also that, Giza 716 variety was the most efficient water utilization variety at the high (I_1) and moderate (I_2) applied water amounts, while Nubaria 3 was most efficient under water stress (I_3) conditions.

CONCLUSION

In the light of the present study, the maximum faba bean yield and its components were obtained from Nubaria 3 and Giza 716 irrigated by treatment I1 (three irrigations after sowing irrigation) followed by medium treatment I_2 (two irrigations after sowing irrigation) with insignificant difference. On the other hand, the maximum values of Productivity of irrigation water were obtained from Giza 716 followed by Nubaria 3 under I_2 (two irrigations after sowing irrigation) compared to Nubaria 1. However, sowing Nubaria 3 and Giza 716 verities irrigated with two irrigation after sowing irrigation are recommended under calcareous soil conditions and surface irrigation system, while if irrigation water is the limiting factor for faba bean production, or if the farmer is facing water scarcity, we recommend that sowing Nubaria 3 variety with only one irrigation, which gave seed yield of 7.82 (ard/fad) (2.88 ton/hectare) can save about 412 m3 of irrigation water compared of three irrigations after sowing irrigation.

Table 8: Dates, depths of applied irrigation water (cm), and effective rainfall (R_{eff}, cm) to faba bean crop as affected by irrigation treatments during the 2017/2018 and 2018/2019 growing seasons.

Irrigation treatments.	2017/2018						2018/2019					
	Irrigation date						Irrigation date					
	Sowing 25/10/17	1st 25/12/17	2nd 12//2/18	3rd 26/3/18	R_{eff}	Total cm	Sowing 25/10/18	1st 24/12/18	2nd 12/2/19	3rd 23/3/19	R_{eff}	Total (cm)
I1 (wet)	9.0	4.83	6.25	6.76	10.6	37.44	9.0	4.63	6.68	6.78	10.7	37.79
I2(medium)	9.0	--	7.24	6.76	10.6	33.60	9.0	--	7.08	6.78	10.7	33.56
I3 (dry)	9.0	--	7.24	--	10.6	26.84	9.0	--	7.08	--	10.7	26.78

Table 9: Water consumption (cm) by faba bean varieties as affected by irrigation treatments during 2017/2018 and 2018/2019 growing seasons.

Treatments		**2017/2018**					**2018/2019**				
		Irrigation period					**Irrigation period**				
Irrigation treatment	**Varieties**	**21/10/17 to 25/12/17**	**25/12/17 to 12/2/18**	**12/2/18 to 26/3/18**	**26/3/18 to 15/4/18**	**Total**	**25/10/18 to 24/12/18**	**24/12/18 to 12/2/19**	**12/2/19 to 23/3/19**	**23/3/19 to 15/4/19**	**Total**
I_1 (wet)	Nubaria 3	8.00	6.60	8.95	4.76	28.31	8.13	6.57	8.34	5.06	28.10
	Nubaria 1	7.52	6.05	9.02	5.41	27.99	7.43	6.20	8.50	5.13	27.26
	Giza 716	8.05	6.85	8.86	4.84	28.60	8.52	7.74	7.71	5.60	29.57
Mean						28.30					28.13
Irrigation treatment	**Varieties**		**21/10/17 to 12/2/18**	**12/2/18 to 26/3/18**	**26/3/18 to 15/4/18**			**25/10/18 to 12/2/19**	**12/2/19 to 23/3/19**	**23/3/19 to 15/4/19**	
I_2 (medium)	Nubaria 3	-	8.80	7.96	10.22	26.98	-	9.06	9.11	9.63	27.80
	Nubaria 1	-	8.04	8.17	10.26	26.47	-	8.71	8.29	10.37	27.37
	Giza 716	-	9.09	8.91	9.96	27.96	-	9.09	9.54	9.42	28.05
Mean						27.14					27.74
Irrigation treatment	**Varieties**		**21/10/17 to 12/2/18**		**12/2/18 to 15/4/18**			**25/10/18 to 12/2/19**		**12/2/19 to 15/4/19**	
I_3 (dry)	Nubaria 3	-	7.99	-	9.88	17.87	-	7.89	-	9.14	17.03
	Nubaria 1	-	3.43	-	4.16	17.59	-	7.21	-	9.14	16.35
	Giza 716	-	3.95	-	4.75	18.70	-	8.16	-	8.99	17.15
Mean						18.05					16.84

Table 10: Productivity of irrigation water (*PIW*, *Kg/m³/fed)* of three varities values as affected by irrigation treatments during 2017/2018 and 2018/2019 growing seasons.

Irrigation treatment	Faba bean varieties	2017/2018 AIW (m^3/fed)	2017/2018 (*PIW*)	2018/2019 AIW (m^3/fed)	2018/2019 (*PIW*)	2-season average *PIW* (kg seed/m^3 fed)
I_1 (wet)	Nubaria 3	1572.48	0.98	1587.18	0.95	0.97
	Nubaria 1	1572.48	0.81	1587.18	0.90	0.85
	Giza 716	1572.48	0.99	1587.18	0.96	0.98
	Mean		0.93		0.94	0.93
I_2 (medium)	Nubaria 3	1411.20	1.02	1409.52	1.04	1.03
	Nubaria 1	1411.20	0.97	1409.52	1.00	0.98
	Giza 716	1411.20	1.09	1409.52	1.07	1.08
	Mean		1.02		1.04	1.03
I_3 (dry)	Nubaria 3	1211.28	1.01	1124.76	1.07	1.04
	Nubaria 1	1211.28	0.88	1124.76	0.96	0.92
	Giza 716	1211.28	0.95	1124.76	0.99	0.97
	Mean		0.95		1.01	0.98

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الملخص العربى

أستجابة ثلاث أصناف من الفول البلدى لعدد الريات على الصفات الفسيولوجية والمحصول وانتاجية المياه تحت ظروف الأراضى الجيرية

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اجريت تجربة حقلية بمزرعة محطة البحوث الزراعية بالنوبارية خلال موسمي ٢٠١٨/٢٠١٧، ٢٠١٩/٢٠١٨ لدراسة الإستجابة الفسيولوجية لانتاجية ثلاث أصناف من الفول البلدى وهم (نوبارية٣، نوبارية ١، جيزه ٧١٦) تحت ثلاث كميات من مياة الرى السطحى (١، ٢،٣ ريات بعد رية الزراعة) ويمكن تلخيص النتائج المتحصل عليها كما يلى:-

- أدى تطبيق رية واحة فقط بعد رية الزراعة الى نقص معنوى فى محتوى الأوراق من الكلوروفيل ومحتوي البروتين بالبذره وطول النبات وعدد الفروع/ نبات وعدد القرون/ نبات وعدد البذور/ نبات ومحصول البذور/ نبات ومحصول البذور/ الفدان (أردب/فدان) والمحتوى المائى للأوراق ومعدل البخرنتح فى خلال موسمى الدراسه فيما لوحظ زيادة معنوية فى محتوى البرولين في الأوراق ومحتوى الكربوهيدرات الذائبة في الأوراق ومقاومة الثغور وكذلك انتاجية مياه الرى.
- الصنف نوباريه ٣ سجل أعلى معدل قيم فى محتوى الأوراق من البرولين و الكربوهيدرات الذائبة والكلورفيل خلال موسمى الدراسه وكذلك لوحظ عدم وجود فروق معنويه بين الأصناف نوباريه٣ وجيزه ٧١٦ فى محتوى البروتين بالبذره وعدد البذور/ نبات ومحصول البذره (أردب/فدان). كما لوحظ ان الصنف نوباريه٣ يليه الصنف جيزه ٧١٦ سجلو أعلى معدل لمقاومه الثغور وأقل معدل من البخرنتح.
-أظهر التفاعل بين معدلات الرى والأصناف فروق معنويه فى كل الأصناف تحت الدراسه وسجل أعلى معدل للبروتين فى البذره وطول النبات (سم) وعدد القرون/ نبات وعدد البذور/ نبات وكذلك معدل البخر نتح فى كلا الصنفين نوباريه٣ وجيزه ٧١٦ عند تطبيق ثلاث ريات بعد رية الزراعه بينما كان أعلى معدل لتراكم الكربوهيدرات والبرولين بالأوراق وكذلك أعلى معدل لمقاومة الثغور واقل معدل من البخرنتح سجل لهذه الأصناف ولكن تحت المعامله ريه واحده بعد رية الزراعه ولقد تفوق الصنف نوبارية ١ فى عدد الأفرع/ نبات تحت نفس مستوى الرى والصنف نوبارية ٣ سجل أعلى معدل من الكربوهيدرات الذائبة فى الأوراق وأعلى معدل مقاومة للثغور وأقل معدل بخرنتح بتطبيق رية واحدة خلال الموسم ودائما سجل الصنف نوبارية ١ أقل قيم فى كل الصفات تحت الدراسة تحت رية واحدة خلال الموسم.
-في ضوء الدراسة الحالية ، تم الحصول على أعلى معدل من محصول الفول البلدى ومكوناته من معاملة الري I_1 (ثلاث ريات بعد رية الزراعة) تليها المعاملة المتوسطةI_2 (ريتان بعد رية الزراعة) مع عدم وجود فرق معنوى فى المحصول. من ناحية أخرى، تم الحصول على أعلى قيمة لانتاجية مياه الرى (PIW) عند تطبيق معاملة الرى المتوسطة (ريتان بعد رية الزراعة) مع توفير حوالى ١٧٠ متر مكعب/فدان
- في ظل ظروف الأراضى الجيرية ونظام الري السطحي يوصى بزراعة أصناف الفول البلدى (نوبارية ٣ و جيزة ٧١٦) مع تطبيق ريتان بعد رية الزراعة، أما إذا كانت مياه الري هي العامل المحدد أو إذا كان المزارع يواجه ندرة في مياه الرى يوصى بزراعة الصنف نوبارية ٣ بتطبيق معاملة الرى I_3 (ريه واحده بعد رية الزراعة)، حيث أنه أعطى متوسط ٧,٨٢ أردب للفدان (٢,٨٨ طن / هكتار) مع توفير حوالي ٤١٢ متر مكعب من مياه الري مقارنة بتطبيق ثلاثة ريات بعد رية الزراعة.