Response of Some Faba Bean Genotypes to Irrigation Water Deficit Grown in Sandy Soil

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ABSTRACT

Field experiments were conducted at the Faculty of Agriculture, (Saba-Basha) - Alexandria University, Egypt during winter growing seasons of 2017and 2018. Drip irrigation system was used in sandy soil to rate the irrigation water usage and increase its use efficiency, and then maximize Faba beans productivity under water deficit conditions. Four Egyptian Faba bean ecotypes and a commercial cultivar (Cleopatra) were grown under a drip irrigation system for evaluation under water deficit conditions. Four irrigation rate treatments were applied; i.e., 100%, 80%, 60%, and 40% of the ET_0. The results revealed that the tested Faba bean genotypes differed among themselves in most of the studied traits, whether the vegetative characters, yield, and its component traits and pod characteristics. Most of the studied characters, especially the vegetative characters, leaves chlorophyll content and pods fresh yield/feddan trait were significantly affected by the irrigation rates. The obtained results showed that there was a significant decrease in the values of most of these characters by reducing irrigation rates from 3167 (100% of the ET_0) down to 1267 m^3 / fed. (40% of the ET_0) in the first season and from 3100 (100% of the ET_0) down to 1240 m^3/fed. (40% of the ET_0) in the second season. The results showed that the Cleopatra cultivar was the best-tested genotype in terms of irrigation water use efficiency (IWUE). Also, the same cultivar was significantly superior to most of the tested Faba bean ecotypes in terms of growth vigor and productivity, even with irrigation water shortage, down to 2534 m^3 / fed. or 2480 m^3 / fed. during the first and second seasons (80% of the ET_0), respectively. The results of this study showed that, under the conditions of this experiment, it is possible to rationalize irrigation water usage by 20.00% from the common irrigated treatment to reach the highest irrigation water use efficiency even with a decrease of yield, especially in semi-arid areas with limited water.

Keywords: Faba bean, *Vicia faba*, L., pod fresh yield, pod characteristics, water stress, water deficit, irrigation water use efficiency (IWUE).

INTRODUCTION

Faba bean (*Vicia faba*, L.) is a widely grown crop in Egypt, as beans are a staple food for the majority of the Egyptian people. Faba bean is one of the most important crops of leguminous vegetables. It has a long history of cultivation and used in feed and food (Siddiqui *et al*., 2015). Faba bean is a cheap source of high-quality protein with high calories and nutritive value for the great majority of the Egyptian people (Radwan and Wafaa, 2005). The seeds contain about 24% protein, 58% carbohydrates, and a high proportion of iron and calcium. FAOSTAT (2018) reported that Egypt is one of the main faba bean producing countries where the area harvested in Egypt reached to 40298 ha and the average total production is about 139303 tons.

Countries of the Mediterranean basin, especially the southern Mediterranean region, suffer from insufficient rainfall intensity and irregular distribution during the rainy seasons. This often exposes crops to prolonged periods of drought and subsequent high temperatures (Ricciardi, *et al*., 2001). Therefore, in semi-arid regions like Egypt, preserving irrigation water and rationing its use by following modern irrigation methods such as drip irrigation is very necessary to maximize the use of irrigation water and not to waste it.

Drought is an environmental stress that directly affect agricultural production, especially in semi-arid regions resulting from global climate change, and water use in agriculture is being reduced. It also severely harms the growth and productivity of crops on the one hand and the other hand does not seriously damage the crop and can lead to higher productivity (Nautiyal *et al*., 1999). Drought stress is one of the major abiotic stresses that are a threat to crop production worldwide. Drought stress impairs the plants' growth and yield (Siddiqui *et al*., 2015; Abdul Muktadir *et al*., 2020).

Water stress is one of the most important environmental stresses causing heavy losses to agriculture worldwide (Kumar *et al*., 2012; Abid *et al*.,

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2020). Water stress is often accompanied by relatively high temperatures, which increase the effect of drought and significantly reduces crop yields. Selection of drought-tolerant varieties includes choosing to reduce non-transpiration uses of water, reduce transpiration without reducing productivity, increase yields without increasing transpiration, and fluctuation of salinity leads to increase water use efficiency (WUE) (Sorrells *et al*., 2000; Bennett, 2003; Anjum *et al*., 2011 and Ghassen *et al*., 2017).

Faba bean is susceptible to moisture and high-temperature stresses (Loss and Siddique 1997). The water stress that occurs during the vegetative and reproductive stages is one of the main factors limiting the yield of Faba beans, and thus the stability of the cultivated area (Hawtin and Hebblethwaite, 1983 and Ricciardi and Steduto, 1988).

Water stress causes many different adverse effects on leaf stretching and stem elongation, plant photosynthesis activity, due to premature leaf aging, flowering, decrease in self-fertility and seed size and the root and node system (Tamaki and Naka, 1971; Elston *et al*., 1976 and Dennet, *et al*., 1979; Karamanos, 1978; Finch-Savage and Elston, 1982; Alvino *et al*., 1982; Stoddard, 1986; El Nadi, 1970; Tamaki and Naka, 1971; Sprent, 1972; Sprent, 1976; Sprent *et al*., 1977 and Nanda *et al*., 1988).

The present experiment evaluate the response of four Egyptian Faba bean local ecotypes and one of commercial cultivar to simulated water stress aiming at the possibility of expanding Faba bean cultivation in limited water areas. In addition, this experiment assigned to maximize irrigation water use efficiency of Faba beans in semi–aired areas.

MATERIALS AND METHODS

The present investigation was carried out during the two winter seasons of 2017 and 2018. The cultivation was carried out at the Faculty of Agriculture, Saba-Bash, Alexandria University, Alexandria Governorate, Egypt.

Some physical and chemical analyses of the experimental soil are presented in Table (1). Soil analysis demonstrated that the soil experiment was a sandy texture.

Genetic material source and Experimental layout

Field experiments were conducted at the Faculty of Agriculture (Saba-Basha), Alexandria University, during winter seasons of 2017and 2018. Planting materials of this study consisted of five Faba bean (*Vicia faba*, L.) genotypes, i.e., four local ecotypes named Alexandria, El-Behira, Kafr El-Shikh, and El-Menia, and one comercial cultivar, Cleopatra which was planted as a commercial cultivar for comparison. The seeds were planted in rows, 60 cm apart and at a spacing of 30 cm within rows at the rate of 1 seed per hill. The area of experimental unit was 12.6 m^2 consisted of three-rows (7.0 m long and 0.60 m width). Planting took place during the winter seasons of 2017 and 2018 on the 5th of November and was harvested on the 30th of March in the two growing seasons. The planting was protected from rainfall by a transparent plastic cover.

Irrigation regimes

A drip irrigation system was designed for the experiment. Distribution lines consisted of PVC pipe manifolds for each plot. The diameter of the polyethylene laterals was 16 mm and each lateral irrigated one plant row. The inline emitter discharge rate was 2 l h^{-1}.

The experimental layout was presented as a split-plot design with three replicates. Four irrigation treatments (100, 80, 60, and 40% of ET_0) were assigned in the main plots, whereas, five faba bean genotypes were random distributed in the sub-plots.

The values of reference evapotranspiration (ET_0) were calculated using the Penman-Monteith method (Allen *et al*., 1998) under climatic conditions (Table 2) obtained for the experimental site (NASA, 2020) according to the following equation (Eq. 1):

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1+0.34U_2)} \quad (1)$$

Where:

ET_0	Reference evapotranspiration, mm day^{-1}
R_n	Net radiation at the crop surface, MJ m^{-2} day^{-1},
G	Soil heat flux density, MJ m^{-2} day^{-1}, Generally very small and assumed to be zero).
T	Mean daily air temperature at 2.0 m height, °C,
U_2	Wind speed at 2 m height, m s^{-1} ,
e_s	Saturation vapor pressure at 1.5 to 2.5m height, kPa,
e_a	Actual vapor pressure at 1.5 to 2.5m height, kPa,
$e_s - e_a$	Saturation vapor pressure deficit, kPa,
Δ	Slope vapor pressure curve, kPa°C^{-1},
γ	Psychrometric constant, kPa°C^{-1},

Table 1. The main physical and chemical properties of the experimental soil.

Particle size distribution							
Sand %	**Silt %**	**Clay %**	**Textural class**	**pH (1:1, water suspension)**	**EC (dS/m^{-1}) (1:1, water extract)**	**O.M. %**	**Total $CaCO_3$ %**
91.1	4.0	4.9	Sand	8.0	0.4	0.4	28.0

Chemical analyses						
Soluble cations (meq/l)				**Soluble anions (meq/l)**		
Ca^{++}	**Mg^{++}**	**Na^{+}**	**K^{+}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4^{--}**
1.7	2.0	1.3	0.2	5.5	1.5	0.2

Available Nutrients (mg kg^{-1})		
KCl-extractable N	**$NaHCO_3$-extractable P**	**NH_4-Acetate extractable K**
115.7	27.5	475.0

Table 2. The climatic conditions of the experimental site during 2017 and 2018 growing seasons

Month	Pe mm	U2 m/s	RH %	Tdew C°	Tx C°	Tn C°	Tm C°	P kPa	RA $MJ/m^2/day$
2017 Growing season									
November	16.25	3.63	68.08	13.66	21.95	18.17	19.84	101.74	17.35
December	12.15	4.15	71.04	12.36	19.76	16.23	17.78	101.95	14.90
January	36.61	5.17	69.84	10.16	17.61	13.89	15.60	101.87	15.90
February	13.41	3.47	71.04	10.93	18.86	13.94	16.19	101.48	20.20
March	0.05	90.14	64.85	11.23	21.54	14.93	18.00	101.34	25.55
2018 Growing season									
November	22.96	3.33	65.87	14.61	23.30	19.45	21.17	101.61	17.41
December	63.58	4.86	68.71	11.68	19.06	16.01	17.43	101.77	14.92
January	24.92	5.37	65.39	7.79	16.64	12.07	14.21	101.54	15.90
February	17.43	4.35	68.98	8.92	17.22	12.40	14.56	101.67	20.30
March	7.42	4.17	70.47	10.25	18.25	13.40	15.55	101.68	25.65

The crop evapotranspiration (ET_c) is the daily use of water by Faba beans and calculated using the following equation (Allen *et al*., 1998), Eq. 2:

$$ET_c = K_c \times ET_0 \qquad (2)$$

Where:

K_c is the crop coefficient

The crop coefficient (Kc) values for different growth stages of the Faba bean (Allen *et al.*, 1998) are shown in Table (3).

Table 3. Crop coefficient of Faba bean according to the growth stages

Growing stage	Kc value
Initial stage	0.60
Mid-stage	1.15
End-stage	0.50

The crop water requirements were calculated according to the Penman-Monteith equation (Allen *et al*., 1998) using the following equation Eq.3; (Cuenca, 1989):

$$ET_{drip} = K_r \times K_c \times ET_0 \qquad (3)$$

Where:

ET_{drip} is the crop water requirements under the drip irrigation system.

K_r is the reduction factor that reflects the percentage of irrigation treatments.

According to the aforementioned equations, the quantities of irrigation water were calculated. The four irrigation rate treatments (100, 80, 60, and 40% of the ET_0) accounted as 3167, 2534, 1900, and 1267 m^3/fed in the first season and 3100, 2480, 1860 and 1240 m^3/fed in the second season, respectively.

Agricultural operations:

Phosphorus fertilizer was applied at the rate of 150 kg/fed in the form of super Phosphate (15.5 % P_2O_5) during soil preparation, plus 5 tons of compost/fed. Nitrogen fertilizer was applied at the rate of 50 kg N/fed to the soil in the form of ammonium sulfate (21.0% N) after 30 days of planting. Potassium fertilizer was added at the rate of 50 kg /fed. in the form of potassium sulfate (48% K_2O) throughout the drip irrigation system. All other agricultural practices for Faba bean production were followed as recommended.

MEASUREMENTS AND DATA RECORDED

Vegetative characters:

Vegetative characteristics were measured and recorded at 145 days after planting. The plants were randomly taken per each experimental unit, where five plants were taken for measuring plant height (cm), counting the number of branches/plant, the height of the 1^{st} pod (cm), and leaf chlorophyll content (mg/100g). The total chlorophyll content in leaf tissues was extracted with 100% N, N-dimethyl formamide and analyzed by UV–Digital spectrophotometer (Spectronic-601, Milton Roy), using the methodologies described by Moran (1982).

Yield and yield components:

Samples of randomly five plants were used, from each experimental unit to record the number of pods per plant, seeds weight per plant (g), and pods fresh weight per plant (g). Net ratio (%) was calculated by dividing seeds weight per plant on pods fresh weight per plant then multiplied by 100. Pods fresh weight yield per feddan was determined by calculating pods fresh weight per sub-plot then attributed to feddan.

Pod characteristics:

The following characteristics of pod were measured and recorded for randomly five plants per an experimental unit: Number of seeds per pod, pod weight (g), and pod length (cm).

Irrigation water – use efficiency (IWUE):

Irrigation water–use efficiency (IWUE) was calculated as kg of pods fresh weight yield produced per one cubic meter of applied water (Doorenbos and Kassem, 1979; Ahmed, 1987 and Sharma *et al*., 2015), using Eq.4.

$$IWUE\ (kg/m^3) = \frac{\text{Produced Pod fresh weight yield (kg/fed)}}{\text{Applied irrigation water } (m^3/fed)} \quad (4)$$

Statistical analysis

The collected data were statistically analyzed, using the analysis of variance method. Comparisons among the means of different clones were carried out, using the least significant differences (LSD) test procedure at $p \leq 0.05$ level of probability, as explained by Snedecor and Cochran (1980) using the Co-Stat software program (2004).

RESULTS AND DISCUSSIONS

Vegetative characters

Table (4) showed that the studied vegetative characters were affected by applied irrigation water treatments ($P \leq = 0.05$). In this respect; Irrigation water quantities of 3167 and 2534 m^3/fed gave the highest mean values for plant height (cm) trait during the two seasons.

The presented data showed that irrigation water quantities of 3167 and 2534 m^3/fed significantly produced the highest mean values for No. of branches/plant trait during the two seasons. As for the height of the 1^{st} pod; irrigation water quantity of 2534 m^3/fed significantly gave the highest mean values during the two seasons. The data of leaves chlorophyll content showed that the irrigation water quantity of 3167 m^3/fed significantly gave the highest mean values compared with the other tested irrigation water treatments during the two study seasons of the experiment. The decrease in growth parameters might be due to impaired cell division, cell enlargement caused by loss of turgor, and inhibition of various growth metabolism processes (Yordanov *et al*., 2003 and Farooq *et al*., 2012). These results reinforce the findings of Ali *et al*. (2013) and Ouzounidou *et al.* (2014) on beans; Farooq *et al.* (2008) on rice and Asrar and Elhindi (2011) on marigolds, who reported that drought stress reduced plant growth properties.

As for Faba bean genotypes, the results in Table (4) showed that Faba bean genotypes significantly differed from each other according to the studied vegetative characteristics. It was found that the two genotypes, Alexandria and Cleopatra, significantly outperformed the rest of the tested cultivars regarding the plant height characteristic during the two seasons of this study. The results showed that El-Behira genotype outperformed the rest of the tested genotypes in terms of the number of branches per plant trait during the two study seasons. As for the characteristic of the height of the 1^{st} pod, the results were very close, as the results obtained did not give any significant differences between the genotypes of Alexandria, El-Beheira, El-Minya, and Cleopatra.

Table 4. Mean values of vegetative characters of Faba bean genotypes recorded during the seasons of 2017 and 2018.

Treatments		Plant height (cm)		No. of branches / plant		Height of the 1st pod (cm)		Leaves chlorophyll content (mg/100g)	
		2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatment, % of ET_0									
100		127.00 a	112.60 ab	9.93 a	9.13 a	22.40 b	20.53 b	85.54 a	82.70 a
80		120.53 ab	117.40 a	9.87 a	9.20 a	26.13 a	23.40 a	83.65 b	81.41 b
60		113.60 b	110.07 b	8.60 b	7.73 b	17.47 c	15.33 c	77.75 c	75.43 c
40		79.53 c	77.67 c	6.47 c	5.93 c	15.40 d	14.13 c	66.18 d	63.66 d
Genotypes									
Alexandria		117.83 a	108.42 ab	10.17 b	9.17 b	22.33 a	19.33 a	77.88 b	75.36 c
El-Behira		110.58 b	103.92 bc	11.33 a	10.42 a	20.17 ab	18.17 ab	78.36 b	75.44 c
Kafr El-Shikh		108.00 b	103.08 c	6.58 d	6.25 d	18.00 b	17.25 b	78.17 b	76.28 b
El-Menia		98.17 c	95.25 d	7.75 c	7.17 c	20.17 ab	18.58 ab	75.36 c	72.40 d
Cleopatra		116.25 a	111.50 a	7.75 c	7.00 c	21.08 a	18.42 ab	81.63 a	79.52 a
Irrigation treatment, % of ET_0 X Genotypes									
100	Alexandria	133.00 abc	105.33 de	12.33 b	12.00 a	25.33 bcd	22.67 bcd	84.39 cde	82.17 cd
100	El-Behira	124.00 cd	105.33 de	14.00 a	12.33 a	17.67 ghij	16.33 gh	85.29 c	81.33 de
100	Kafr El-Shikh	124.33 cd	113.00 cd	6.00 fg	5.33 ij	24.00 bcde	22.33 cd	84.94 cd	83.16 c
100	El-Menia	115.00de	112.00 d	8.67 d	8.00 ef	24.67 bcde	23.00 bcd	81.64 g	77.59 f
100	Cleopatra	138.67 a	127.33 ab	8.67 d	8.00 ef	20.33 efg	18.33 fg	91.45 a	89.26 a
80	Alexandria	124.33 cd	121.33 bc	10.67 c	9.67 cd	27.67 abc	25.00 abc	82.99 f	80.38 e
80	El-Behira	125.33 bcd	121.67 bc	12.00 bc	11.33 ab	28.67 ab	26.33 a	84.25 de	82.05 d
80	Kafr El-Shikh	125.33 bcd	122.00 bc	6.67 ef	6.33 ghi	20.00 efgh	18.33 fg	83.70 ef	81.98 d
80	El-Menia	92.67 f	89.33 f	9.00 d	8.33 def	23.33 cdef	22.00 de	79.68 h	77.24 f
80	Cleopatra	135.00 ab	132.67 a	11.00 bc	10.33 bc	31.00 a	25.33 ab	87.62 b	85.40 b

Cont. Table 4. Mean values of vegetative characters of Faba bean genotypes recorded during the seasons of 2017 and 2018.

Treatments		Plant height (cm)		No. of branches / plant		Height of the 1st pod (cm)		Leaves chlorophyll content (mg/100g)	
		2017	2018	2017	2018	2017	2018	2017	2018
60	Alexandria	133.67 abc	128.67 ab	9.00 d	7.33 fgh	15.33 hijk	10.33 j	77.57 i	74.92 h
	El-Behira	112.00 e	111.33 d	10.67 c	10.00 bc	17.76 ghij	16.33 gh	77.33 i	74.49 h
	Kafr El-Shikh	111.67 e	107.67 de	9.00 d	9.00 cde	17.33 ghij	16.67 fg	77.47 i	76.07 g
	El-Menia	105.67 e	101.67 e	6.67 ef	6.00 hi	18.00 ghij	16.33 gh	76.80 i	74.26 h
	Cleopatra	105.00 e	101.00 e	7.67 de	6.33 ghi	19.00 fghi	17.00 fg	79.60 h	77.43 f
40	Alexandria	80.33 gh	78.33 gh	8.67 d	7.76 efg	21.00 defg	19.33 ef	66.59 k	63.97 j
	El-Behira	81.00 gh	77.33 gh	8.67 d	8.00 ef	16.67 ghij	13.67 hi	66.57 k	63.91 j
	Kafr El-Shikh	70.67 h	69.67 h	6.00 fg	4.33 jk	10.67 k	11.67 ij	66.57 k	63.93 j
	El-Menia	79.33 gh	78.00 gh	6.67 ef	6.33 ghi	14.67 ijk	13.00 ij	63.32 l	60.52 k
	Cleopatra	86.33 fg	85.00 fg	3.67 h	3.33 k	14.00jk	13.00 ij	67.83 j	66.00 i

Means followed by a similar letter within a column for each parameter are not significantly different at the 0.05 level of probability by L.S.D. test procedure.

Table (4) showed that Cleopatra cv. significantly gave the highest mean values for leaves chlorophyll content during the two study seasons; whereas, El-Menia ecotype gave the lowest mean values, in this respect, during the two seasons.

In terms of the interaction between the two studied independent variables (irrigation water treatments and Faba bean genotypes) on the vegetative traits, Table (4) showed that the studied vegetative traits significantly affected ($p \leq 0.05$) with these two independent variables during the two growing seasons. As for the first season, Cleopatra cultivar at 100% of ET_0 gave the highest mean value for plant height (cm) and at 80% of ET_0 in the second season. No. of branches reached a maximum value at 100% of the ET_0 in both seasons. Also, 80% of the ET_0 have highest values of the highest 1st pod for El-Behira and Celeopatra cultivars in both seasons. The leaf chlorophyll content was reached the highest value at 100 and 80% of the ET_0 in both seasons.

Yield and yield component characteristics

Table (5) showed that irrigation water treatments significantly affected most of the studied yield and yield component characters except for many pods per plant during the two growing seasons. In this respect; irrigation of Faba bean growing at 100% of ET_0 gave the highest mean values over a two-year trial regarding seeds weight/plant (g), pods fresh weight/plant (g), net ratio (%), and pods fresh weight yield/feddan (ton). The decrease in the yield (ton/fed.) a result of water shortage might be due to the remarkable weakness of the vegetative growth represented in the characteristics of plant height and the number of branches (Table 4), in addition to decrease in the percentage of chlorophyll in plant leaves (Table, 4).

Yield reduction could be due to the role of water stress in plant physiology, especially at flowering and grain filling stages which later reduced plant height through reduced translocation of assimilates to the reproduction sink. On the other hand, Mohan *et al*. (1982) attributed the reduction in seed yield, under water stress, to the depressive effect of soil moisture on plant stand and on the number of pods per plant. The crop was affected to the same degree of permanent stress from pre-flowering to harvest, indicating that flowering is highly sensitive to water stress. Water stress during pods filling difficulty affected nitrogen as activity and biomass production of the tested cultivars (Plies-Balzer *et al*., 1995; Ghassen *et al*., 2017).

In terms of the tested Faba bean genotypes; regarding yield and its component characters, Table (5) showed that most of the studied characters were significantly affected due to Faba bean genotypes, except for net ratio (%) during the second experimental season. Cleopatra cultivar gave the highest mean values for the trait of the number of pods/plant without any significant differences with each of Kafr El-Shikh and El-Menia ecotypes. Also, in the second season of the experiment, Cleopatra cultivar gave the highest values for No. of pods/plant without significant differences with Kafr El-Shikh ecotype.

As for seeds weight per plant (g) trait; the data of Table (5) showed that Cleopatra cultivar significantly possessed the highest mean values during the two seasons of this study. The same trend of results was obtained concerning pod fresh weight per plant (g) and pod fresh weight yield per feddan (ton), as Cleopatra cultivar significantly achieved the best mean values compared to the rest of the tested genotypes during the two study seasons.

As for the net ratio (%) characteristic, the significant differences were slight between the studied Faba bean genotypes during the first season of the experiment, while there were no significant differences between those genotypes during the second season. The obvious differences among the tested Faba bean genotypes concerning the most studied characters indicated that there are genetic variances among the tested genotypes.

The interaction between the two studied independent variables (irrigation water quantities and Faba bean genotypes) on the yield and its component characters, Table (5) showed that the studied traits significantly affected ($p \leq 0.05$) with these two independent variables during the two study seasons. Generally, Cleopatra cultivar × 100% of ET_0 significantly gave the highest mean values for most of the studied traits; i.e., [seeds weight/plant (g), pods fresh weight/plant (g) and net ratio (%)] during the two study seasons. As for No. of pods/plant, The results were not sufficiently clear during the two seasons of the study, as there were no significant differences between most of the applied treatments, and there was no clear direction for the conclusive results obtained, indicating that this trait needs further study to clarify its impact on the treatments under study. However, these results can be explained by the fact that the plant, in a state of water shortage (under conditions of water stress), is trying to give rapid production even before the completion of the vegetative growth phase, lest the end of its life cycle without production, and therefore the plant may accelerate the production of a large number of pods before The end of its life cycle, which explains the increase in the number of pods per plant even under conditions of severe water shortage.

Table 5. Mean values of yield and its components characteristics of faba bean genotypes recorded during the seasons of 2017 and 2018.

Treatments		No. of pods/plant		Seeds weight/plant (g)		pods fresh weight/plant (g)		Net ratio (%)		Pods fresh weight yield / feddan (ton)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
Irrigation treatment, % of ET0											
100		21.33 a	19.27 a	220.91 a	196.59 a	448.87 a	408.47 a	49.21 a	48.11 a	10.00 a	9.14 a
80		21.33 a	19.47 a	187.81 b	164.13 b	385.60 b	345.73 b	48.68 b	47.43 a	8.63 b	7.75 b
60		21.00 a	19.27 a	151.67 c	127.58 c	326.80 c	290.00 c	46.42 c	43.40 b	7.07 c	6.17 c
40		20.93 a	19.27 a	117.54 d	97.73 d	266.27 d	225.33 d	44.17 d	43.43 b	5.57 d	4.66 d
Genotypes											
Alexandria		19.92 b	18.17 c	160.65 c	136.28 d	338.25 d	297.67 d	47.23 ab	45.47 a	7.35 d	6.54 c
El-Behira		20.58 b	19.00 bc	163.89 c	140.40 c	345.25 c	307.00 c	47.08 ab	45.47 a	7.60 c	6.84 c
Kafr El-Shikh		21.92 a	19.83 ab	172.07 b	149.68 b	361.25 b	321.00 b	47.30 a	45.43 a	7.89 b	6.97 b
El-Menia		21.33 a	19.33 b	171.89 b	147.39 b	360.25 b	321.67 b	47.24 a	45.48 a	7.92 b	7.04 b
Cleopatra		22.00 a	20.25 a	179.51 a	158.78 a	379.42 a	339.58 a	46.75 b	46.13 a	8.32 a	7.43 a
Irrigation treatment, % of ET0 X Genotypes											
100	Alexandria	20.33 def	18.33 cd	216.13 bc	191.00 c	441.33 bc	398.00 b	48.97 ab	48.00 abc	9.74 c	9.12 ab
	El-Behira	21.33 bcd	19.00 bcd	216.67 bc	189.67 c	442.67 bc	403.33 b	48.95 ab	47.03 abcd	9.90 bc	8.97 b
	Kafr El-Shikh	21.00 cde	18.67 bcd	223.10 b	201.33 b	454.00 b	412.00 ab	49.14 ab	48.87 ab	10.14 b	9.17 ab
	El-Menia	21.00 cde	19.33 abcd	215.57 c	190.30 c	437.67 c	403.33 b	49.26 ab	47.07 abcd	9.75 c	9.00 b
	Cleopatra	23.00 a	21.00 a	233.07 a	210.63 a	468.67 a	424.67 a	49.73 a	49.60 a	10.47 a	9.46 a
80	Alexandria	20.00 def	18.33 cd	165.33 f	142.27 f	345.67 f	305.00 d	47.82 cd	46.64 bcde	7.74f	6.82 d
	El-Behira	21.00 cde	19.00 bcd	179.67 e	152.67 e	369.00 e	330.67 c	48.70 bc	46.17 bcdef	8.28 e	7.40 c
	Kafr El-Shikh	22.00 abc	20.33 ab	187.90 d	166.23 d	383.33 d	345.00 c	49.02 ab	48.18 abc	8.62 d	7.73 c
	El-Menia	21.00 cde	18.67 bcd	190.13 d	165.83 d	387.33 d	342.33 c	49.09 ab	48.44 ab	8.70 d	7.67 c
	Cleopatra	22.67 ab	21.00 a	216.00 c	193.67 c	442.67 bc	405.67 b	48.80 ab	47.74 abc	9.83 bc	9.12 ab

Cont. Table 5. Mean values of yield and its components characteristics of faba bean genotypes recorded during the seasons of 2017 and 2018.

Treatments		No. of pods/plant		Seeds weight/plant (g)		pods fresh weight/plant		Net ratio (%)		Pods fresh weight yield / feddan (ton)	
		2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
60	Alexandria	19.33 f	17.67 d	151.13 g	122.67 h	324.00 g	287.00 e	46.65 ef	42.79 ghi	6.85 h	6.09 e
	El-Behira	20.33 def	19.33 abcd	152.23 g	129.30 gh	326.00 g	288.67 e	46.71 ef	44.82 defg	7.08 gh	6.14 e
	Kafr El-Shikh	22.67 ab	20.33 ab	152.80 g	127.67 gh	326.00 g	291.67 de	46.86 de	40.70 i	7.29 gh	6.22 e
	El-Menia	21.33 bcd	19.67 abc	152.60 g	127.93 gh	331.67 g	295.00 de	46.01 efg	43.34 fghi	7.22 g	6.29 e
	Cleopatra	21.33 bcd	19.33 abcd	149.60 g	130.33 g	326.33 g	287.67 e	45.85 fg	45.35 cdefg	7.09 gh	6.12 e
40	Alexandria	20.00 def	18.33 cd	110.00 j	89.17 j	242.00 i	200.67 g	45.46 gh	44.44 defgh	5.05 j	4.12 h
	El-Behira	19.67 ef	18.67 bcd	107.00 j	89.98 j	243.33 i	205.33 g	43.97 i	43.84 efgh	5.15 j	4.22 h
	Kafr El-Shikh	22.00 abc	20.00 abc	124.47 hi	103.50 i	281.67 h	235.33 f	44.19 i	43.99 efgh	5.72 i	4.75 g
	El-Menia	22.00 abc	19.67 abc	126.87 h	105.50 i	284.33 h	245.00 f	44.60 hi	43.07 ghi	6.03 i	5.20 f
	Cleopatra	21.00 cde	19.67 abc	119.37 i	100.50 i	280.00 h	240.33 f	42.63 j	41.82 hi	5.92 i	5.03 fg

Means followed by a similar letter within a column for each parameter are not significantly different at the 0.05 level of probability by L.S.D. test procedure.

As for pod's fresh weight yield per feddan (ton), the obtained data showed that Cleopatra cultivar × 100% of ET_0 significantly gave the highest mean value in this respect during the first season (Table, 5). The data of the second season showed that Cleopatra cultivar × 100% of ET_0 gave the highest mean value for pods fresh weight yield per feddan (ton) character without significant differences with each of the treatments Alexandria genotype × 100% of ET_0, Kafr El-Shikh genotype × 100% of ET_0 and Cleopatra cultivar × 2764.28 m^3 irrigation water/fed.

The optimistic effects of the control irrigation treatment (100% of ET_0) on the pods' fresh weight yield/Fed. and its constituent properties (No. of pods/plant, seeds weight/plant, pods fresh weight/plant, and net ratio) could be linked to moderate soil moisture content, resulting in increased nutrient availability and uptake; also, Soil salinity is low compared to the low field capacity (40% of ET_0). Ghosh *et al*. (2000) illustrated that the higher values of field capacity increased growth indices, which was reflected in higher rates of photosynthesis and carbohydrate production resulting in higher final production. However, the decrease in total productivity due to water stress may be attributed to the decrease in leaf area due to fewer and smaller leaves, increased stomatal resistance (Abid *et al*., 2020), and gas exchange; In addition to a decrease in the transpiration rate, which led to a decrease in photosynthesis. The developmental stage of the plant and the magnitude of the water deficit determine the loss of Faba bean yield. The most susceptible stages of growth inhibition have been differently described as flowering (El-Nadi, 1969), early podding (Mwanamwenge *et al*., 1999), and pod setting (Xia, 1994), but all of these studies generally agree that the early reproductive stage is the most sensitive (Khan *et al*., 2007; Alghamdi *et al*., 2015). Moderate drought stress had a negative effect on the number of pods per plant trait but did not affect the size of the seeds or the number of seeds per pod traits (El-Nadi, 1969 and Adisarwanto and Knight, 1997). The extent of water deficit determined whether the plant partially suffered damage or completely death.

Pod characteristics

Table (6) showed that water treatments treatments significantly affected the studied pod characteristics ($P \leq = 0.05$) during the two study seasons. In this regard; irrigation of Faba bean plants at a rate of 3167 m^3/fed. (100% of ET_0) possessed the highest mean values over a two-year trial regarding pod weight (g) trait. As for No. of seeds/pod; the recorded data showed that irrigation water quantity of 3167 m^3/fed. (100% of ET_0) gave the highest mean values without significant differences with each of the irrigation treatments 2534 and 1900 m^3/fed during the first season (80% of ET_0 and 60% of ET_0). The result of the second season showed that irrigation treatment with 3167 m^3/fed significantly gave the highest mean value for No. of seeds/pod trait. Pod length (cm) trait significantly gave the highest mean values with each of the irrigation treatments of 3167 and 2534 m^3/fed during the first season (100% of ET_0 and 80% of ET_0). As for the second season; the obtained data showed that applying 3167 m^3 water/fed significantly gave the highest mean value for pod length (cm).

In terms of the tested Faba bean genotypes; regarding pod characteristics, Table (6) showed that each of No. of seeds/plant and pod length (cm) traits are significantly affected ($P \leq = 0.05$) with Faba bean genotypes during the two study seasons of this experiment. In this respect; the pod weight (g) trait did not affect the tested faba bean genotypes. Cleopatra cultivar significantly gave the highest mean values for No. of seeds/pod followed by El-Menia ecotype during the two study seasons. As for the pod length (cm) trait; the data of Table (6) showed that Kafr El-Shikh Faba bean ecotype gave the highest mean values in this regard without significant differences with most of the tested genotypes during the two study seasons.

Regarding the interaction between the two studied independent variables (irrigation water quantities and Faba bean genotypes) on the tested pod characteristics, Table (6) showed that the studied traits significantly affected ($p \leq 0.05$) with these two independent variables during the two study seasons. Generally, Cleopatra cultivar significantly gave the best results for No. of seeds characteristic with any of the irrigation treatments applied during the two study seasons. As for pod weight (g), the obtained data appeared that irrigation faba bean plants at 100% of ET_0 with most tested Faba bean ecotypes; i.e., Alexandria, El-Behira, Kaf El-Shikh, and El-Menia significantly gave the highest values for pod weight (g) during the two growing seasons. Regarding pod length (cm) characteristics, the data of Table (6) showed that the Irrigation of Faba bean plants at the rate of 3167 m^3/fed. (100% of ET_0) significantly gave the best mean values with both Alexandria and El-Behira ecotypes during the two study seasons.

Water requirements

The crop water requirements as calculated with the Penman-Monteith method (Allen *et al*., 1998) using the local climatic conditions during the growth stages of Faba been are presented in Table (7).

Table 6. Mean values of pod characteristics of faba bean genotypes recorded during the seasons of 2017 and 2018.

Treatments		No. of seeds/pod		Pod weight (g)		Pod length (cm)	
		2017	2018	2017	2018	2017	2018
Irrigation treatment, % of ET_0							
100		5.27 a	5.27 a	21.09 a	21.28 a	15.70 a	14.81 a
80		5.00 ab	4.73 b	18.07 b	17.76 b	15.67 a	14.17 b
60		5.00 ab	4.80 b	15.62 c	15.35 c	13.80 b	12.60 c
40		4.93 b	4.80 b	12.71 d	11.71 d	9.60 c	8.69 d
Genotypes							
Alexandria		4.42 c	4.33 c	16.99 a	16.43 a	13.54 ab	12.07 c
El-Behira		4.58 c	4.54 c	16.69 a	16.15 a	14.13 a	13.03 ab
Kafr El-Shikh		4.58 c	4.50 c	16.58 a	16.64 a	14.29 a	13.08 a
El-Menia		5.25 b	5.00 b	16.96 a	16.70 a	13.54 ab	12.49 abc
Cleopatra		6.42 a	6.13 a	17.15 a	16.70 a	12.96 b	12.18 bc
Irrigation treatment, % of ET_0 X Genotypes							
100	Alexandria	4.67 bc	4.67 cdefg	21.78 a	21.80 ab	18.33 a	16.90 a
	El-Behira	5.00 bc	5.00 cde	20.76 abc	21.27 ab	17.00 ab	16.13 ab
	Kafr El-Shikh	5.00 bc	5.17 bcd	21.65 ab	22.17 a	14.67 def	14.03 cd
	El-Menia	5.33 b	5.33 bc	20.87 ab	20.92 abc	14.50 ef	13.43 cde
	Cleopatra	6.33 a	6.17 a	20.40 bc	20.22 bc	14.00 efgh	13.57 cd
80	Alexandria	4.33 c	4.00 g	17.31 ef	16.72 efgh	12.50 h	12.67 def
	El-Behira	4.67 bc	4.33 efg	17.61 ef	17.40 ef	14.17 efg	15.10 bc
	Kafr El-Shikh	4.67 bc	4.50 defg	17.45 ef	16.98 efg	16.33 bc	15.03 bc
	El-Menia	5.00 bc	5.00 cde	18.44 de	18.35 de	13.33 fgh	14.07 cd
	Cleopatra	6.33 a	5.83 ab	19.53 cd	19.34 cd	12.67 gh	14.00 cd
60	Alexandria	4.33 c	4.33 ef	16.77 fg	16.25 fghi	15.33 cde	11.53 fg
	El-Behira	4.33 c	4.17 fg	16.02 gh	14.91 i	16.33 bc	12.83 def
	Kafr El-Shikh	4.33 c	4.33 efg	14.41 ij	15.65 ghi	16.17 bcd	14.17 cd
	El-Menia	5.33 b	4.83 cdef	15.60 ghi	15.05 hi	15.50 bcde	12.63 def
	Cleopatra	6.67 a	6.33 a	15.31 hi	14.89 i	15.00 cde	11.83 ef
40	Alexandria	4.33 c	4.33 efg	12.10 l	10.95 j	8.00 k	7.17 j
	El-Behira	4.33 c	4.67 cdefg	12.38 kl	11.01 j	9.00 jk	8.07 ij
	Kafr El-Shikh	4.33 c	4.00 g	12.80 kl	11.77 j	10.00 ij	9.07 hi
	El-Menia	5.33 b	4.83 cdef	12.92 kl	12.47 j	10.83 i	9.83 gh
	Cleopatra	6.33 a	6.17 a	13.35 jk	12.33 j	10.17 ij	9.30 hi

Means followed by a similar letter within a column for each parameter are not significantly different at the 0.05 level of probability by L.S.D. test procedure.

Table 7. Crop water requirements during growth stages of Faba bean

2017 growing season				
	Irrigation (% of ET_0)			
Growth Stages	**100%**	**80%**	**60%**	**40%**
Germination	185	148	111	74
Vegetative	521	417	313	209
Reproductive	640	512	384	256
Pod senescence	495	396	297	198
Stem senescence	1325	1060	795	530
Total	3167	2534	1900	1267
2018 growing season				
	Irrigation (% of ET_0)			
Growth Stages	**100%**	**80%**	**60%**	**40%**
Germination	215	172	129	86
Vegetative	592	474	355	237
Reproductive	633	507	380	253
Pod senescence	514	411	308	206
Stem senescence	1145	916	687	458
Total	3100	2480	1860	1240

The water requirements of Faba bean were calculated as 3167, 2534, 1900, and 1267 m^3/fed in the first season and 3100, 2480, 1860, and 1240 m^3/fed corresponding to 100, 80, 60, and 40% of ET_0, respectively.

Irrigation water-use efficiency (IWUE)

When water is the determining factor of crop production, deficit irrigation can improve WUE, so that available water is better allocated. Irrigation water use efficiency (IWUE) is calculated as the harvested yield (kg) per amount of irrigation water (m^3) according to the recommendations of the Food and Agriculture Organization (Doorenbos and Kassam, 1979). Among the many biotic and abiotic factors, one of the most important factors affecting productivity as well as the quality of production is the responsible and optimal management of water (Bhriguvanshi *et al*., 2012).

Table (8) indicated that IWUE significantly was affected by irrigation levels, in which the recoded values decreased with increasing the irrigation levels. The irrigation level of 3167 and 3100 m^3/fed in the two seasons possessed the lowest values of IWUE. As seen from Table (8), the IWUE ranged between 3.158 and 4.401 kg/m^3 in the first season and between 2.949 and 3.763 kg/m^3 in the second season. Decreasing the irrigation water level resulted in a significant effect on IWUE in which increasing IWUE due to less applied water and more yield.

Also, IWUE significantly affected by Faba bean genotypes (Table, 8). The IWUE ranged between 3.433 and 3.898 kg/m^3 in the first season and between 3.073 and 3.519 kg/m^3 in the second season. The highest values attained for Cleopatra cultivar and the lowest cultivar was Alexandria in the two seasons.

As for the interaction between irrigation water treatments and Faba bean genotypes, the obtained data of Table (8) showed that IWUE significantly affected these two independent variables during the two study seasons. El-Menia cultivar under more stress conditions (1267 and 1240 m^3/fed in the two seasons, respectively) significantly gave the highest IWUE during the two study seasons (4.758 and 4.199 kg/m^3). This result could be attributed to the effect of the genotypic characteristic of this cultivar. Thus, the main concern of deficit irrigation is that it maximizes water productivity, although some reduction in yields is observed. In regions where water is the limiting factor for crop production, maximizing water productivity by deficit irrigation is often more economically profitable for a farmer than maximizing yield.

Results of IWUE are presented in (Table, 8), indicated the importance of water deficit to achieve good yields and better usage of water, and this can be mainly attributed to adequate and homogeneous moisture distribution in the root zone in improving crop resistance to water stress (Abdelhamid *et al*., 2013 and Rahimizadeh *et al*., 2007).

Table 8. Irrigation water-use efficiency (IWUE) of Faba bean as affected by irrigation deficit, genotypes, and their interactions.

Treatments		**IWUE (kg/m^3)**	
		2017	**2018**
Irrigation treatment (% of ET_0)			
100		3.158 d	2.949 d
80		3.408 c	3.125 c
60		3.719 b	3.319 b
40		4.401 a	3.763 a
Genotypes			
Alexandria		3.433 d	3.073 c
El-Behira		3.548 c	3.147 c
Kafr El-Shikh		3.712 b	3.314 b
El-Menia		3.768 b	3.394 b
Cleopatra		3.898 a	3.519 a
Irrigation treatment (% of ET_0) X Genotypes			
100	Alexandria	3.076 kl	2.942 fgh
	El-Behira	3.126 jkl	2.894 gh
	Kafr El-Shikh	3.201 ijkl	2.957 fg
	El-Menia	3.080 kl	2.902 gh
	Cleopatra	3.307 hij	3.052 fg
80.	Alexandria	3.058 l	2.751 h
	El-Behira	3.268 ijk	2.985 fg
	Kafr El-Shikh	3.402 ghi	3.119 def
	El-Menia	3.433 gh	3.092 efg
	Cleopatra	3.880 cde	3.677 b
60	Alexandria	3.606 fg	3.277 cde
	El-Behira	3.728 ef	3.302 cd
	Kafr El-Shikh	3.733 ef	3.344 c
	El-Menia	3.799 def	3.383 c
	Cleopatra	3.734 ef	3.293 cde
40	Alexandria	3.991 cd	3.322 cd
	El-Behira	4.069 c	3.407 c
	Kafr El-Shikh	4.514 b	3.835 b
	El-Menia	4.758 a	4.199 a
	Cleopatra	4.671 ab	4.054 a

Means followed by a similar letter within a column for each parameter are not significantly different at the 0.05 level of probability by L.S.D. test procedure.

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CONCLUSION

It is clear from the results obtained in this research, that different quantities of irrigated water differently affected the growth, productivity, and pod characteristics of Faba bean genotypes, which indicated that the Faba bean genotypes differed in their ability to tolerate differed rates of water shortage. This would help to discover more growth and physiological parameters that might be related to water deficit sensitivity. In semi-arid areas as in Egypt, the use of modern irrigation methods such as the drip irrigation system is necessary due to the limited irrigation water in those areas. Also, calculating the irrigation water use efficiency (IWUE) is very important, so that the maximum water usage under the conditions of water shortage can be maximized even if yield decreased occurred. Cleopatra cultivar, based on the results of this experiment, might be preferred for cultivation compared to the tested Faba bean ecotypes under water deficit conditions.

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الملخص العربي

إستجابة بعض التراكيب الوراثية للفول لظروف نقص مياه الري المنزرع فى الأراضى الرملية

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الفول هو المحصول البقولي رقم واحد مصر من حيث المساحة المزروعة واجمالي الإنتاج والاستهلاك والاعتماد عليه بشكل كبير كمصدر رخيص للبروتين. الإنتاج المحلي من زراعته يغطي فقط ٤١٪ من حجم الاستهلاك والباقي ٥٩٪ مستورد من الخارج. أحد الأسباب الرئيسية التي تعيق التوسع الأفقي لزراعة المحاصيل في مصر هو نقص مياه الري. لذلك أجريت هذه الدراسة تحت نظام الري بالتنقيط لتقنين إستخدام مياه الري وزيادة كفاءة استخدامها، ومن ثم زيادة إنتاجية الفول في ظل ظروف عجز المياه. تمت الزراعة خلال الموسمين الشتويين ٢٠١٧ و٢٠١٨ في صوبة كلية الزراعة سابباشا محافظة الإسكندرية، مصر. زرعت أربعة سلالات محلية من الفول وصنف تجاري (كليوباترا) تحت نظام الري بالتنقيط لتقييمهم في ظل ظروف نقص المياه. نفذت أربع معاملات لمعدلات الري وهى: الرى عند ١٠٠%، ٨٠%، ٦٠%، ٤٠% من البخرنتح. أظهرت النتائج المكتسبة أن التراكيب الوراثية للفول المختبرة اختلفت فيما بينها في معظم الصفات المدروسة سواء الصفات الخضرية والمحصول ومكوناته وخصائص القرون. تأثرت معظم الصفات المدروسة وخاصة الصفات الخضرية ومحتوى الأوراق من الكلوروفيل والمحصول الطازج من القرون/ فدان معنويا بمعدلات الري. أظهرت النتائج المتحصل عليها وجود انخفاض معنوي في قيم معظم هذه الصفات مع خفض معدلات الري من ٣١٦٧ م ٣ / فدان(١٠٠% من البخرنتح) إلى ١٢٦٧ م٣/ فدان(٤٠% من البخرنتح) فى الموسم الأول، ومن ٣١٠٠ م٣ / فدان(١٠٠% من البخرنتح) الى ١٢٤٠ م٣ / فدان (٤٠% من البخرنتح) فى الموسم الثانى . أظهرت النتائج أن الصنف كليوباترا هو أفضل التراكيب الوراثية المختبرة من حيث كفاءة إستخدام مياه الرى . أيضا تفوق نفس الصنف معنويا على معظم السلالات المحلية من الفول من حيث قوة النمو والانتاجية حتى مع نقص كميات المياه وصولا الى ٢٥٣٤ م٣/ فدان أو ٢٤٨٠ م٣/ فدان (٨٠% من البخرنتح) خلال الموسمين الأول والثانى على التوالى. أظهرت نتائج الدراسة أنه تحت ظروف هذه التجربة، فإنه يمكن ترشيد استخدام مياه الرى بنسبة ٢٠% من معاملة الرى الشائعة للوصول الى اعلى كفاءة لإستخدام مياه الرى حتى مع حدوث نقص فى المحصول خاصة فى المناطق شبه الجافة محدودة المياه.