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EFFECT OF WATER STRESS AT DIFFERENT GROWTH STAGES ON THREE FABA BEAN CULTIVARS

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ABSTRACT

Two field experiments were carried out at the Agricultural Experimental Station of National Research Centre at Shalakan (Kalubia Governorate) during two successive seasons of 1996/97 and 1997/98 to study the effect of water stress (omitting one irrigation either at flowering, pod formation or pod filling stages) on three faba bean cultivars (Giza 3, Giza 643 and Giza 714). The results indicated that water stress at any studied reproductive stage showed harmful effects on yield and its components. The adverse effect of water stress was more pronounced whenever drought conditions were coincided with pod filling stage. Generally, the exposure to water deficits decreased significantly the total carbohydrate content in faba bean seeds, whereas an inverse relationship was noticed as for the protein content. On the other hand, significant differences was found among the tested faba bean cultivars with respect to yield and its components as well as the chemical composition of seeds. Giza 643 cultivar produced the highest seed yield which characterized by a conspicuous content of crude protein compared with the other two cultivars. However, the differences were not distinct enough to use as an index of the drought resistance of the cultivars tested.

INTRODUCTION

In arid and semi-arid regions of limited water resources, there has been an increasing interest in scheduling irrigation to conserve water supply and to minimize the excessive soil water movement that might lead to groundwater pollution. The use of drought tolerant crop with improving the cultural practices would be the more effective approach. Thomson *et al*. (1997) reported that the crop adaptation to drought stress conditions is dependent on the pattern and efficiency with which plants use water and the introduction of drought tolerant crop could be gained from selecting and breeding within species. Faba bean is considered a drought sensitive crop. Many workers have recorded great reduction in faba bean yield and its components due to decreasing the level of water supply (Salih, 1985, Kortam, 1995 and Abd El-Fattah *et al*. 1997). More recently, Grzesiak *et al*. (1997) and Amede *et al*. (1999) discussed the possible identification of faba bean characteristics responses to moisture deficits that reveal cultivar X moisture stress interactions. If such interactions could be available, plant breeders may incorporate these characteristics into their breeding programs to develop cultivars that respond more favourably under moisture stress conditions. On the other hand, there are differing views in the published literature on the effect of irrigation timing upon the magnitude of yield response of faba bean. Some workers (Sammler *et al*. 1982), suggested that faba bean was more sensitive to drought during flowering than at other times of the season, but others (Mwanamwenge *et al*., 1999), suggested that early podding stage of development was the most sensitive to water deficits, while Xia (1994) demonstrated that late irrigation is the critical time for adequate water supply to achieve optimum yields.

Thus, with a view to evaluating the possibility of reducing water consumption during reproductive growth stages, this study was to investigate the yield and its components as well as seed chemical composition of three faba bean cultivars as influenced by water stress imposed at different reproductive growth stages to identify the critical timing for irrigation.

MATERIALS AND METHODS

Two field experiments were carried out at the Agricultural Experimental Station of the National Research Centre at Shalakan (Kalubia Governorate) during the two successive growing seasons of 1996/97 and 1997/98 in order to study the response of three faba bean cultivars to water stress imposed at different reproductive stages. Each experiment included 12 treatments which were the combination of four irrigation treatments with three faba bean cultivars (Giza 3, Giza 643 and Giza 714). Four irrigation treatments were as follows : 1- Control where faba bean plants received 5 irrigations during the season, 2-Omitting one irrigation at flowering stage (55 days from sowing), 3- Omitting one irrigation at pod formation stage (85 days from sowing), 4- Omitting one irrigation at pod filling stage (115 days from sowing). The experiments were layed out in split-plot design with four replications. Irrigation treatments were arranged in the main plots, while the faba bean cultivars were randomly distributed in the sub-plots. The sub-plot area was 10.5 m^2 (i.e. 3.0 X 3.5 m). To avoid the effect of lateral movement of irrigation water, the plots were isolated by borders of 1.5 m in width from all sides.

Faba bean seeds (*Vicia faba L*.), which were previously inoculated with the specific strain of *Rhizobium leguminosarum L*., were sown on 20 and 23 November in the 1^{st} , 2^{nd} seasons, respectively in hills, 20 cm apart. Thinning to one plant per hill was done at 25 days after planting. The normal agricultural practices for growing faba bean were followed as recommended in the region. At harvest, random samples each containing four plants represented every replicate for all treatments were taken. The following characters were recorded; Plant height, number of branches per plant, number and weight of pods per plant, weight of seeds per plant, weight of 100-seeds. Each plot was harvested and threshed separately, then weight of seed, straw and biological yield per feddan were recorded. Total carbohydrates content in the seeds was determined using the method adopted by Dubois *et al*. (1956). Total nitrogen was estimated by using micro-kjeldahl according to A.O.A.C. (1975). Crude protein was calculated by multiplying N-content of seeds (%) by 6.25.

The data obtained were subjected to the proper statistical analysis of variance as described by Snedecor and Cochran (1980) and the combined analysis of the two seasons was calculated according to the method of Steel and Torrie (1960).

RESULTS AND DISCUSSION

I. Yield and its components

Data presented in Table (1) showed clearly the effect of water stress (omitting one irrigation at different reproductive stages) on yield and its related characters of various faba bean cultivars. Examination of these data reveal that, at harvest time, there was a pronounced decrease in plant height and number of branches per plant as a result of water stress. However, the decrease in number of branches per plant was not great enough to reach the level of significance at 5 %. These results are in agreement with the findings of Abd El-Haleem (1994). In this concern, Kramer (1995) attributed the effect of water stress on plant growth to its effect on cell enlargement which in turn decreases shoot elongation.

Concerning the number and weight of pods per plant, all drought treatments caused significant decrease in both criteria compared with those of control plants. Also, seed yield per plant and weight of 100 seeds followed the same trend. Furthermore, data showed that seed, straw and biological yields per feddan were significantly decreased with decreasing number of irrigation (omitting one at different reproductive stages). These results suggested that exposing faba bean plants to insufficient water supply during vegetative growth adversely reduced the yield and its related characters. These results are in full agreement with those obtained by Salih (1985), Abd El-Haleem (1994) and Mwanamwenge *et al*. (1999). In this regard, Kortam (1995) reported that soil moisture deficits reduces the capacity of plants for building up metabolites and this might account in turn to depress the photosynthetic efficiency of the leaves with consequent reduction in yield and its components of faba bean plants. In addition, Simpson (1981) previously reported that water stress resulted in a disturbance in most of the physiological processes e.g. photosynthesis, protein synthesis, enzyme activity …etc. and these affect the metabolites translocation to the end product.

It could be observed, in addition, that the extent of reduction in yield was greatly governed by the time of water withholding. Thus, seed yield was more reduced as the stress period was delayed from flowering to pod formation and filling. The lowest seed yield (kg/fed.) was obtained from omitting one irrigation at pod filling stage. The decrement was about 59.78% less than the normally irrigated plants. The next lower yields resulted from stressing faba bean plants during pod formation and flowering where the yield was reduced by about 48.84 and 31.44 %, respectively. The present results are in agreement with the findings of Xia (1994) who reported that the response of faba bean to drought varied during the different reproductive growth stages. Plants subjected to drought before flowering were less affected than those at other stages, while plants subjected to drought at pod-set stage were most sensitive to drought which reduced seed yield by about 45 % relative to the control plants. Also, AbdEl-Fattah *et al*. (1997) indicated that stress early in reproductive development had most effect on vegetative growth, whereas later stress reduced pod yield. Furthermore, Knott (1999) concluded that irrigation applied during or post-flowering gave statistically significant yield increases.

Regardless of water stress treatments, the present data clearly show significant differences among the tested cultivars with respect to yield and its components. In this concern, Giza 714 cultivar exceeded significantly the two other cultivars in plant height whereas Giza 643 cultivar showed a significant increase in number of branches per plant. Moreover, a similar picture could be noticed when comparing these criteria in the studied cultivars at the same water stress conditions. The conspicuous differences among these cultivars suggest the presence of genetic differences since the experiment was run under similar conditions. Ahmed *et al* (1997) reported that the differences among faba bean cultivars in growth parameters may be due to the differences in number of nodules formed on the roots of the tested cultivars, consequently, the growth of each cultivar may depend mainly on nitrogen fixation. On the other hand, the differences in the morphological characteristics among faba bean cultivars in response to drought were observed by Grzesiak *et al*. (1997) who demonstrated that the cultivars were characterized by variation of certain morphological characteristics regarded as xeromorphic feature associated with the ability of plants to survive under drought. Concerning seed yield, it is clear that Giza 643 cultivar was superior to the other two cultivars, as it recorded the highest seed yield of 1071.85 kg/fed comparing with 886.40 and 988.93 kg/fed for Giza 3 and Giza 714 cultivars, respectively. The superiority of Giza 643 cultivar in seed yield/fed might be due to the increase in number and weight of pods per plant as well as weight of seeds per plant. Furthermore, a similar tendency could be observed when comparing the yield of the different faba bean cultivars after the exposure to water stress at similar reproductive stages but the differences were not distinct enough to use as an index of the drought resistance of the tested cultivars. The results obtained by Gej (1992), Al-Abdulsalam *et al*. (1996) and Amede *et al*. (1999) confirm our findings. In this regard, Mwanamwenge *et al*. (1999) reported that there is considerable variation among faba bean genotypes in tolerance to water stress, and that maximizing the number of flowers, pods and seeds is among the most important trials for maintaining stable and high seed yields under water deficits conditions.

The interaction effect between faba bean cultivars and water stress treatments was statistically significant except number of branches per plant. However, Giza 643 cultivar plants produced the highest seed yield when constantly irrigated as in the control treatment.

2. Seed chemical constituents

Data in Table (2) reveal that, in all tested cultivars, the exposure to water stress at any investigated reproductive stage significantly decreased the total carbohydrates content and increased crude protein content in faba bean seeds compared with the control. These results are in agreement with those obtained by El-Zeiny *et al*. (1987) and El-Noemani *et al*. (1990). The

reduction in carbohydrate accumulation due to water stress could be attributed to a reduction in photosynthetic efficiency. Siddique *et al*. (1999) reported that exposure of plants to drought stress led to a significant decrease in photosynthetic rate and stomatal conductance. Moreover, the effect of water stress on the metabolic products in faba bean seeds varied according to the reproductive stage during which the plants were held under drought conditions. The greatest significant reduction in total carbohydrate was recorded whenever water shortage applied during pod formation, while the favourable effect of water stress on protein content was more obvious when the plants were exposed to drought conditions during pod-filling stage. In this connection, Shaw and Laing (1966) found that maximum protein percentage occurred when plants were stressed at pod filling stage.

It is worthy to mention that there were significant differences among faba bean cultivars in the contents of carbohydrate and protein in the seeds. Giza 643 cultivar recorded the highest value for protein content while Giza 3 cultivar recorded the highest value for total carbohydrate content as compared to the other two cultivars. However, the difference between Giza 643 and Giza 714 cultivar in carbohydrate content was not significant. A similar tendency could be observed when comparing between the tested cultivars after the exposure to water stress conditions. Several investigators recorded that faba bean cultivars are greatly differed in their yield potential (Ahmed *et al*., 1997). Furthermore, the interaction effect between

Table (2) : Effect of water stress at different reproductive stages on the seed chemical composition of three faba bean cultivars. (Combined analysis of 1996/97 and 1997/98 seasons).

Water stress treatments	Cultivars	Total carbohydrate content (%)	Crude protein content (%)
Control	Giza 3	55.46	26.11
	Giza 643	51.15	27.10
	Giza 714	50.93	23.03
	M	52.51	25.41
Omission at flowering stage	Giza 3	53.26	26.12
	Giza 643	47.88	27.55
	Giza 714	49.02	23.80
	M	50.05	25.83
Omission at pod formation stage	Giza 3	43.74	28.23
	Giza 643	40.33	29.41
	Giza 714	41.44	26.70
	M	41.83	28.11
Omission at pod filling stage	Giza 3	45.14	29.01
	Giza 643	42.67	29.89
	Giza 714	41.88	27.09
	M	43.23	28.66
Mean values for cultivars	Giza 3	49.40	27.37
	Giza 643	45.51	28.49
	Giza 714	45.82	25.15
L.S.D. at 5 % for :	WS	0.37	0.18
	C	0.32	0.22
	WS X C	0.64	0.45

WS = Water stress, C = Cultivars , WS X C = Interaction

cultivars and water stress treatments was significant. In this regard. Seeds of Giza 643 cultivar produced the highest protein content when the plants subjected to water stress at pod filling stage.

From the above-mentioned results, it is worthy to note that water stress imposed late in the season appeared to have a serious effect on seed yields particularly when drought conditions were coincided with pod filling stage. Therefore, the key to water management for faba bean is to keep the irrigation supply since time of flowering to full seed filling.

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تأثير الاجهاد المائى عند مراحل النمو المختلفة لثلاث اصناف من الفول البلدى

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اجرى هذا البحث بمزرعة المركز القومى للبحوث بشلقان (محافظة القليوبية) خلال موسمى ٩٦ / ١٩٩٧ و ٩٧ / ١٩٩٨ بهدف دراسة تأثير الاجهاد المائى (اسقاط رية عند مرحلة الازهار او تكوين او امتلاء

القرون) على ثلاثة اصناف من الفول البلدى (جيزة ٣ ، جيزة ٦٤٣ وجيزة ٧١٤)٠ اوضحت النتائج ان اسقاط رية واحدة عند اى مرحلة من المراحل المشار اليها ادى الى تأثيرات سلبية على المحصول ومكوناته وكان هذا التأثير اكثر وضوحا عندما تم منع الرى عند مرحلة امتلاء القرون وعموما ادى التعرض للاجهاد المائى الى نقص معنوى فى محتوى البذور من الكربوهيدرات الكلية بينما ظهرت علاقة عكسية بالنسبة لمحتوى البروتين ومن الناحية الاخرى لوحظت اختلافات معنوية بين اصناف الفول البلدى تحت الدراسة من حيث مقاييس المحصول ومكوناته وكذلك المحتوى الكيميائى للبذور وفى هذا المقام انتج الصنف جيزة ٦٤٣ اعلى محصول بذور تميزت بمحتواها العالى من البروتين مقارنة بالصنفين الاخريين .

Table (1) : Effect of water stress at different reproductive stages on the yield and its components of three faba bean cultivars. (Combined analysis of 1996/97 and 1997/98 seasons).

Water stress treatments	Cultivars	Plant height (cm)	No. of branches /plant	No. of pods/plant	Wt. of pod/plant (g)	Wt. of seeds/plant (g)	Wt. of 100-seeds (g)	Seed yield (kg/fed.)	Straw yield (kg/fed.)	Biological yield (kg/fed.)
Control	Giza 3	133.33	4.00	23.66	22.13	18.59	64.46	1313.96	1607.39	2921.36
	Giza 643	105.00	4.33	28.83	23.58	16.93	66.11	1691.74	1863.04	3542.15
	Giza 714	150.83	3.00	19.16	18.96	17.57	65.56	1529.73	1745.12	3274.85
	M	129.77	3.77	23.88	21.56	17.70	65.38	1511.81	1738.52	3246.12
Omission at flowering stage	Giza 3	114.16	3.83	15.66	18.55	14.23	63.88	0931.46	1024.90	1956.37
	Giza 643	97.50	4.16	20.33	21.83	17.10	65.58	1094.04	1228.55	2322.59
	Giza 714	130.00	2.83	17.33	19.99	15.78	64.69	1083.71	1211.01	2294.73
	M	113.88	3.61	17.77	20.12	15.71	64.72	1036.40	1154.82	2191.23
Omission at pod formation stage	Giza 3	100.83	3.66	11.66	14.39	12.18	59.57	728.62	969.92	1698.54
	Giza 643	82.50	4.16	14.66	16.57	13.38	60.01	841.44	1056.32	1897.79
	Giza 714	111.66	2.83	15.16	16.46	12.66	60.27	750.10	1035.06	1785.16
	M	98.33	3.55	13.83	15.80	12.74	59.95	773.38	1020.43	1793.83
Omission at pod filling stage	Giza 3	104.16	3.83	14.66	12.46	10.15	57.56	571.56	892.91	1464.47
	Giza 643	92.50	4.16	15.83	14.46	10.08	57.88	660.18	965.54	1625.73
	Giza 714	113.33	2.66	15.16	13.39	9.77	57.55	592.19	985.81	1578.01
	M	103.33	3.55	15.22	13.44	10.00	57.67	607.98	948.09	1556.07
Mean values for cultivars	Giza 3	113.12	3.83	16.41	16.88	13.79	61.37	886.40	1123.78	2020.18
	Giza 643	94.37	4.20	19.91	19.11	14.37	62.39	1071.85	1278.36	2347.06
	Giza 714	126.45	2.83	16.70	17.20	13.95	62.02	988.93	1244.25	2233.19
L.S.D. at 5 % for :	WS	2.06	N.S	0.58	0.36	0.42	0.24	17.82	30.73	36.90
	C	2.09	0.23	0.43	0.34	0.33	0.18	21.07	20.29	30.58
	WS X C	4.18	N.S	0.86	0.68	0.67	0.37	42.13	40.59	61.16

WS = Water stress, C = Cultivars , WS X C = Interaction