Effect of Water Deficit on Yield of Different Faba Bean (*Vicia faba* L.) Genotypes

Aref M. Alshameri, Salem S. Alghamdi[1], Abdelrhman Z. Gaafar, Bander M. Almunqedhi, Ahmed A. Qahtan, Mohamed S. Hodhod, Hussein M. Migdadi[1]

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ABSTRACT

Background: Faba beans (*Vicia faba* L.) are important grain legumes but, as with many crops, these are also susceptible to water deficit. The aim of this study was to evaluate the yield components of twenty faba bean genotypes grown under water deficit.

Methods: Three water treatments were applied, 25%, 50% and 100% of field capacity. A split-plot arrangement in a randomized complete block design with three replicates was used.

Result: The faba genotypes Gazira2, Kamline, L4, Cairo7 and Giza402 reached flowering earlier than other genotypes through stress-escape mechanisms. Genotypes L4, Gazira1, Kamline, X.735 and Gazira2 had the highest seed yield under water-deficit conditions. Genotypes L4, X.735, 989/309/95, Kamline and Gazira1 exhibited the highest levels of biological yield. Finally, the genotypes Kamline and L.4 had higher yields and yield components under water-deficit stress. Consequently, they should be considered for use in breeding programs aimed at developing new cultivars that are better adapted to harsh environmental conditions.

Key words: Biological yield, Economic yield, *Vicia faba*, Water deficit.

INTRODUCTION

Faba beans (*Vicia faba* L.) has become a popular crop due to its high yield and high protein content thus makes it attractive to consumers (Abdellatif *et al*., 2012). The period during which the crop's evaporative demand is high coincides with the end of the rainy season; thus, faba bean, like other leguminous field crops, experiences considerable soil moisture stress during the reproductive growth stage and often gives poor yields (Alzandi, 2018; Khan *et al*., 2010). Water is considered as one of the most important environmental factors, that reduces crop productivity more than any other factor (Saxena *et al*., 2019; Nkoana *et al*., 2019; Kiymaz *et al*., 2019; Jahantigh *et al*., 2020; Miladinov *et al*., 2020). The time from sowing to flowering in faba bean cultivars varies substantially (Patrick and Stoddard, 2010). It is possible to select cultivars that complete a substantial proportion of flowering and pod development before the onset of terminal drought. Days to flowering in faba bean depend on time of sowing and climatic factors (Suso *et al*., 1996). Faba bean genotypes grown under irrigated conditions take maximum number of days to flowering as compared with crops grown under rainfed conditions (Della, 1988; El-Gabry and Morsi, 2019). Number of pods per plant reduced significantly under drought stress compared with the irrigated plants. (Singh *et al*., 1987). Furthermore, Pilbeam *et al*. (1992) found that yield increased under irrigation were associated with higher pod number per plant. Drought affects seed yield by reducing total biomass production and therefore, the plant's capacity to sustain high yield depends on its stage of growth when exposed to drought (Khan *et al*., 2007). On the other hand, Hirich *et al*. (2012) reported that yield production recorded higher grain yield of faba bean with half of the required water supply as compared to crop plants with full irrigation during vegetative growth stages. Khan *et al*. (2007) reported that faba bean crop grown under non stress conditions recorded higher shoot dry matter as compared to crop grown under water stress conditions. Reductions in seed yield induced by water deficit were primarily the result of a corresponding reduction in number of pods (Shrestha *et al*., 2006). Number of pods of two common bean cultivars with contrasting growth habits was significantly reduced by water-stress conditions (Emam *et al*., 2010). Belachew *et al*. (2019) recorded significant effect of water deficit on the yield components in faba bean. Susceptibility testing demonstrated that the faba bean variety "Giza 3" was the most susceptible to drought, whereas the Giza 843 variety was the most tolerant.

Department of Botany and Microbiology, College of Science, King Saud University, Riyadh-11451, Saudi Arabia.
[1]Legume Research Group, Plant Production Department, College of Food and Agricultural Sciences, King Saud University, Riyadh-11451, Saudi Arabia.

Corresponding Author: Aref M. Alshameri, Department of Botany and Microbiology, College of Science, King Saud University, Riyadh-11451, Saudi Arabia. Email: aalshameri@ksu.edu.sa

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Keeping the above facts in forefront, the study was conducted to assess the effect of water deficit on yield of faba bean genotypes.

MATERIALS AND METHODS

This study was carried out in the King Saud University in the seasons of 2018/2019. Twenty faba bean genotypes were selected to compare their performance with respect to yield components under controlled and water-stressed conditions. The experiment was laid out as a split-plot arrangement in a randomized complete block design with irrigation as the main unit factor and genotypes as the split unit factor with three replicates for each. The treatments applied were: field capacity treatment (FC), 50% of field capacity (50% FC) and 25% of field capacity (25% FC). Five seeds were sown and three seedlings from each genotype were retained in poly phenyl chloride (PVC) pots (with dimensions of 15 cm diameter and 50 cm depth). The (- 0.1 bar and -15 bars) were measured to determine the field capacity and permanent wilting point for the soil used. Number of days to flowering was estimated for two out of three plants (>50% of flowering). Dry pods were collected manually from each pot. Biological and economic yields were measured.

The data were subjected to analyses of variances (ANOVA) using SAS® Version 9.0 (SAS Institute, 2002). Means comparisons were conducted using Fisher's least significant differences (LSD).

RESULTS AND DISCUSSION

Our findings revealed that there were high significant differences in the days to flowering between irrigation regimes (P = 0.0047) (Table 1). Plants grown under 25% FC took the longest days (mean = 54 days) to flower, followed by those under 50% FC (mean = 48.7 days) and FC (mean = 46.1 days) conditions. Moreover, highly significant differences were found among the tested genotypes (P< 0.0001). Under FC, L. 4 genotype take minimum number of days to flowering (35 days) which was closely followed by Pop.3, Giza 402 and Gazira 2 (38, 38 and 38.33 days, respectively). Conversely, T.W rsc required nearly twice as long (60.33 days) to reach 50% flowering. Under stress conditions (25% FC), L4 also take the minimum number of days to flowering (36.33 days) followed by Kamline (40 days) and Cairo7 (42 days), whereas 985/252/95 took the longest (65 days). In contrast to previous studies, the plants exposed to water stress required longer periods of time to reach 50% of flowering than did well-watered plants. The genotypes × irrigation interaction had a highly significant (P< 0.0001) effect on the number of days to flowering.

Rapid development can be an escape mechanism for overcoming water-deficit stress. Patrick and Stoddard (Patrick and Stoddard, 2010) for instance reported that the time from sowing to onset of flowering among faba bean accessions varied substantially and that development responded to environmental factors. In our trial, number of days to 50% of flowering differed significantly among the

Table 1: Mean performance of days to flowering (days) and number of pods/plant of twenty faba bean genotypes grown at three irrigation regimes (FC, 50% FC and 25% FC).

Cultivars	Days to flowering (days)			Number of pods/plant		
	FC	50% FC	25% FC	FC	50% FC	25% FC
Sudan	42.00	59.00	56.33	13.67	12.00	6.00
Gazira 1	40.00	42.00	51.33	13.67	13.67	7.67
Gazira 2	38.33	44.00	47.33	16.67	12.00	10.67
Giza 4	42.33	51.33	53.33	15.00	9.00	3.33
Giza 402	38.00	42.00	50.00	13.67	10.67	5.00
Giza 461	46.00	42.33	59.00	9.00	9.00	3.00
Kamline	42.00	38.33	40.00	21.00	22.67	10.67
T.W rsc	60.33	60.00	57.33	18.00	7.67	4.67
ILB 4358	46.00	55.00	73.00	12.00	9.00	6.00
987/255/95	57.33	60.00	53.00	4.67	6.00	4.67
989/309/95	42.00	53.00	55.00	12.00	10.67	3.33
Sakha 4	50.00	55.00	57.33	12.00	13.67	4.67
L. 4	35.00	35.00	36.33	19.67	19.67	10.67
Pop. 3	38.00	46.00	50.00	18.00	9.00	4.67
Pop. 4	44.00	46.00	60.33	10.67	15.00	3.33
Cairo 7	47.33	40.00	42.00	12.00	13.67	7.67
X. 735	50.00	51.00	60.33	12.00	4.67	7.67
985/252/95	50.00	46.00	65.00	13.67	9.00	4.67
Misr 1	57.33	51.33	57.33	13.67	15.00	4.67
Giza 716	56.33	56.33	57.33	9.00	6.00	3.33
Irrigation P-Value		0.0047			0.0041	
Genotype P-Value		<.0001			<.0001	
Irrigation × Genotype P-Value		<.0001			0.0159	
Irrigation L.S.D		3.0627			2.8845	
Genotype L.S.D		4.941			3.1694	

three irrigation regimes, with plants subjected to the water-stress treatment (25% FC) taking significantly longer than plants in the other treatments (FC and 50% FC) with respect to the numbers of days to flowering. The T.W rsc, L.4, Pop.3, Giza 402 and Gazira2 can thus be thought of as genotypes that utilize drought-escape mechanisms under well-irrigated conditions given that theses genotypes typically flowered earlier than other genotypes. Whereas under water-stress conditions, L.4, Kamline and Cairo7 developed more rapidly than did the other genotypes. These results were in agreement with those of Al Barri and Shtaya (2012), who found significant difference in days to flowering among 19 Palestinian landraces of faba bean. In our study, L4, Kamline, Cairo7 and Gazira2 reached the 50% flowering stage earlier than did the other genotypes, indicating that these landraces can overcome water stress through the escape mechanism of comparatively rapid development. The irrigation regime had a highly significant effect (P = 0.0041) on the number of pods per plant (Table 1). Number of pods per plant differed greatly among genotypes (P< 0.0001). Under FC conditions, Kamline produced the highest number of pods per plant (21), followed by L4 (19.67 pods) and Pop.3 (18 pods), whereas 987/255/95 generated the lowest average number of pods per plant (4.67). Under 25% FC conditions, genotypes Kamline, L4 and Gazira 2 had the highest number of pods per plant (10.67 pods for each) and Giza 461 the lowest (3 pods). The genotypes × irrigation interaction also had a significant (P = 0.0159) influence on the number of pods produced per plant.

The number of pods per plant, is the most important component of yield diversity in faba bean (Belachew *et al*., 2019; Neal and McVetty, 1984). Water stress had pronounced effects on number of pods per plant. Moreover, plants grown under water stress required more time to develop pods compared to plants grown under FC and 50% FC conditions, with the differences being significant among irrigation treatments.

Biological yield (Table 2) differed significantly among the irrigation regimes (P = 0.0003). Highly significant differences in biological yield were detected between the genotypes (P< 0.0001). Under FC conditions, Giza 4 had the highest biological yield (45.60 g), followed by genotypes 989/309/95 and Sakha 4 (40.84 g and 40.21 g, respectively), with Kamline having the smallest (24.29 g). Under 25% FC conditions, L4 had the highest biological yield (19.75 g), followed by genotypes X. 735 and 989/309/95 (19.68 g and 19.52 g, respectively), with T.W rsc having the least (12.60 g). The genotypes × irrigation interaction had a highly significant (P< 0.0001) effect on biological yield.

Highly significant differences were found in economic yield (Table 2) between the irrigation regimes (P = 0.0023). Genotypes also had a highly significant effect on economic yield (P< 0.0001): for the FC treatment, Giza 4 had the highest economic yield (29.04 g) followed by L4 (25.77 g),

Table 2: Biological yield (g/plant) and economic yield (g/plant) of twenty faba bean genotypes grown at three irrigation regimes (FC, 50% FC and 25% FC).

Cultivars	Biological yield (g/plant)			Economic yield (g/plant)		
	FC	50% FC	25% FC	FC	50% FC	25% FC
Sudan	32.59	21.17	13.59	21.24	12.99	6.62
Gazira 1	35.95	30.51	18.81	21.99	19.32	12.17
Gazira 2	27.17	18.20	16.97	18.30	10.74	11.03
Giza 4	45.60	21.46	14.82	29.07	12.11	5.70
Giza 402	29.59	22.43	13.31	18.70	13.38	5.93
Giza 461	36.16	28.26	15.66	20.82	13.98	6.87
Kamline	24.29	23.75	18.90	15.05	17.12	12.06
T.W rsc	28.55	15.77	12.60	18.72	7.58	7.95
ILB 4358	31.04	20.18	17.39	16.58	11.18	8.40
987/255/95	25.86	24.65	17.45	8.30	10.61	7.10
989/309/95	40.84	25.69	19.52	20.39	14.33	7.09
Sakha 4	40.21	32.55	15.94	21.72	18.56	6.24
L. 4	37.19	26.13	19.75	25.77	17.16	12.71
Pop. 3	36.86	22.93	16.90	22.20	10.25	6.29
Pop. 4	30.62	28.86	14.45	15.41	15.92	4.50
Cairo 7	31.89	27.39	16.20	20.66	15.99	8.84
X. 735	29.52	21.36	19.68	15.29	8.12	11.63
985/252/95	37.46	24.44	16.89	22.64	12.96	6.18
Misr 1	34.89	28.41	16.28	18.06	17.81	6.45
Giza 716	29.23	21.05	15.35	13.59	8.42	5.63
Irrigation P-Value		0.0003			0.0023	
Genotype P-Value		<.0001			<.0001	
Irrigation × Genotype P-Value		<.0001			0.0008	
Irrigation L.S.D		3.0381			3.502	
Genotype L.S.D		3.3659			3.6311	

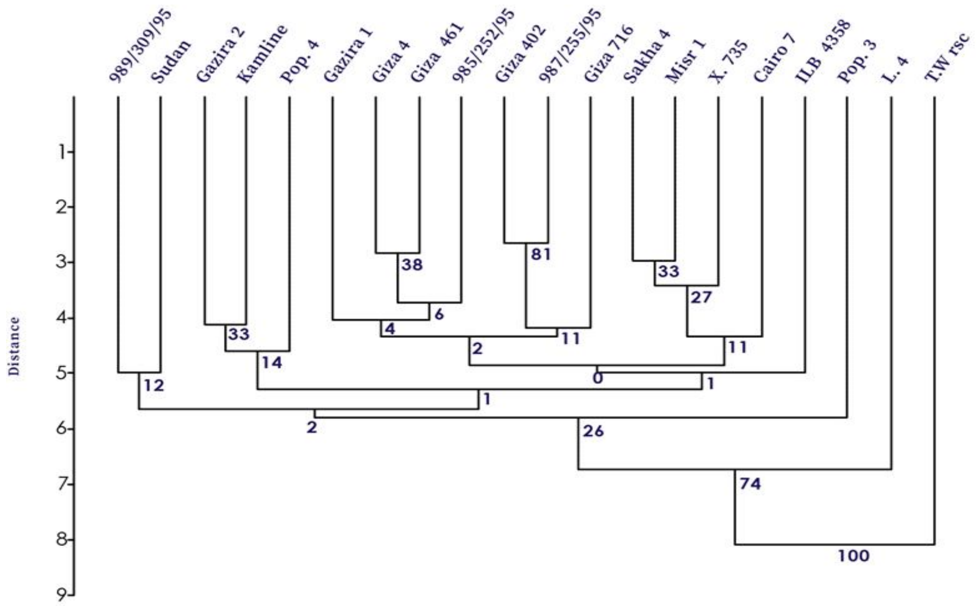

Fig 1: Dendrogram produced by cluster analysis based on Euclidean distance matrix for 20 faba bean genotypes grown at stressed treatment.

whereas 987/255/95 had the lowest (8.3 g). In the 25% FC treatment, L4 had the highest economic yield (12.71 g) followed by genotypes Gazira1 (12.17 g) and Kamline (12.06 g), with Pop.4 having the lowest (4.5 g). In addition, genotypes × irrigation had a highly significant effect (P = 0.0008) on economic yield.

The goal of plant-breeding programs is to improve the quantity and quality of yield and yield components of the crop in question. In this study, water deficit had negative effects on both biological and economic yield, which differed greatly among the genotypes. In terms of biological yield, Giza4, 989/309/95 and Sakha4 were the highest producers under FC conditions; however, L4, X.735, 989/309/95, Kamline and Gazira1 generated the highest biological yield under water-stress conditions. The highest seed yield under well-irrigated conditions was achieved by the Giza4 and L4 genotypes, whereas under water-deficit conditions, the seed yield of the L4 was comparable to that of the highest-yielding genotypes, Gazira1 and Kamline. Comparatively, Kamline performed better under water stress than under well-irrigated conditions and thus holds promise as a drought-tolerant of faba bean. These results were in agreement with those reported by Singh *et al*. (1987) and Alzandi (2018) who found that irrigated faba bean crops produced significantly higher grain and biological yields than did non-irrigated faba bean crops.

The hierarchical cluster was examined (Fig 1). The twenty genotypes could be grouped into three main clusters at 5 units of genetic Euclidean distance. The first main cluster included a combination of the Gazira2, Kamline and Pop3 genotypes. The genotypes Sudan and 989/309/95 genotypes were grouped in the second cluster. Cluster three companied most of the genotypes Gazira1,Giza4, Giza402, Giza461, ILB4358, 987/255/95, Sakha4, Cairo7 X735, 985/252/95, Misr1 and Giza716. However, TW, L4 and Pop3 genotypes failed to group in any of clusters and individually separated.

CONCLUSION

The purpose of this study was to assess the yield of twenty genotypes of faba beans grown under water deficit. Our findings showed that under water-deficit stress, the genotypes Kamline and L.4 had higher yields and yield components. These two genotypes should therefore be considered for use in breeding programs designed to grow new cultivars that are better suited to harsh environmental conditions.

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