

Influence of Early Water Deficit on Seed Yield and Quality of Faba Bean under Arid Environment of Saudi Arabia

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Abstract: Under limited water resources of arid and semi-arid environment, the great challenge of developing agriculture is to increasing water use efficiency. For that field traits in Complete Randomize Block Design were carried out in Agriculture Research Station, Faculty of Food and Agriculture Sciences, Derab, near Riyadh, King Saud University. The experiments included six water irrigation schedules viz., 2000, 3000, 4000, 6000, 7000 and 7500 m³/ha. The aim of the study was to assess the influence of water regimes at different growth stages, starting from complete emergence to full maturity stage and its reflected on seed yield and quality of faba bean (*Vicia faba* L.). Seeds of Giza 957 variety were used in the present investigation. Data recorded included some growth parameters, at flowering stage i.e., plant height, no. of tillers, no. of leaves and leaf area. Whereas, at harvest time, seed yield as well as yield component were also determined. Seed quality was also considered by estimated protein content, fat and carbohydrate content in absolutely dry seeds. As expected, results indicated that, slight decrease in most yield and yield component characters viz., no. of pods/ plant, seed weight/plant in (g), 100-seed weight in (g). Concerning seed quality, data obtained reveal that, high crude protein and carbohydrate percent in seeds were accompanying with low water applied levels. In contrast, seed moisture content was increased with increasing water supply. Finally, we can conclude that influences of drought at the lowest level of applied water less than 4000 m³/ha severely retards seed yield, whereas water supply at 7000 m³/ha could be conserved for growing faba bean under arid environment of Saudi Arabia and gave the highest seed yield.

Key words: Faba bean • Seed yield • Seed quality • Water stress

INTRODUCTION

Faba bean (*Vicia faba* L.) is the most important pulse crop in the term of popularity, seed protein content (seeds provide substantial part of the protein in human diet) and world's cultivated area. FAO statistics show the total cultivated area occupied with faba bean was approximately 4-7 M/ha. The leader producing countries are China, Italy, Spain, the UK, Egypt (the area was decreasing due to many factors), Ethiopia, Morocco, USSR, Mexico and Brazil. Under Saudi Arabia condition, until recently, there is very little cultivation area in Medial and West Region [1]. Shortage of water is the most important and limitation factor for crop production in the arid and semi-arid regions. More land can become productive by using partial irrigation, under low rainfall condition at strategic times during growing season. This

may be accomplished if a proper index of crop sensitivity to water deficit at various growing stages is used. Moreover, Rahman and Islam [2] found that irrigation should aim at restoring the soil water in the root zone to a level at which the crop can fully meet its evapotranspiration (ET) requirement. The amount of water to be applied at each irrigation and how often a soil should be irrigated depend, however, on several factors such as the degree of soil water deficit before irrigation, soil types, crops and climatic conditions. French [3] reported that faba bean survived up to 8 weeks under drought condition following crop establishment with no plant death reduced crop growth by more than 75 % during the drought period and consequently affected the seed yield. In addition, Theib Oweis *et al.* [4] in field trial at arid environment of Syria, they reported that, the periods during which the crop evaporative demand is high

coincides with soil moisture stress during the reproductive growth stage and often produces poor yields. They also reported that, limited water supply through supplemental irrigation can boost and stabilize faba bean production. Under Saudi Arabia conditions many efforts concerning improving faba bean production through genetic and breeding programs, has been done in order to identify, select, create and adopting the most promising varieties [5,6]. On the other hand, little efforts were done concerning the effect of water limitation on water use efficiency, grain production and grain quality. In the respect, of the effect of water deficit on seed quality, Duc *et al.* [7] indicated that under water deficit condition, protein content of faba bean tended to increase. Such results, in general agree with the data obtained by Alghamdi [6], Durant and Cristina [8], Ibrahim and Kandil [9] and Sinaki *et al.* [10].

Therefore, the objective of this study was to assess the effect of water deficit on growth, productivity and seed quality of faba bean under arid condition of Saudi Arabia.

MATERIALS AND METHODS

Large-scale field trials were carried out during two successive seasons of 2005/2006 and 2006/2007 at Agricultural and Research Station, Faculty of Food and Agriculture Sciences, Derab, near Riyadh, King Saud University, Saudi Arabia (24°42'N latitude and 46° 44'E Longitudes, Altitude 600 m). The main objective of this study is to study the effect of different water deficit on seed yield and yield component as well as seed quality of faba bean. Before commencement the field experiment, sample of soil sites was taken for physical and chemical analyses using the methods described by Cottenie *et al.* [11] and But [12]. Results showed that soil texture was

sandy clay loam (50% sand, 26% silt and 24% clay) with high CaCO_3 (29.9%), soil pH in 1:25 soil water (8.15), EC (2.1 dS/m) in extracted soil paste (2:1). Soil macronutrients N, P and K were 120.6, 270.0 and 124.0 mg/kg soil, respectively. While soil micronutrients in mg/kg soil were 2.4, 15.1, 13.1 and 0.3 for Fe, Zn, Mn and Cu, respectively. Water irrigation was also analyzed according to the methods described by APHA [13]. Results is presented in Table 1.

Irrigation system was surface flow irrigation through line pipe provided with meter gages for measuring water applied. Number of irrigations for each treatment and amount of water supplied over the growing season in both seasons were recorded and presented in Table 2.

Seed bed was prepared as recommended according to the recommendation of the conventional production practices at the central region of Saudi Arabia. Recommended dose of 200 kg/ phosphorus fertilizer was applied as a form of calcium super phosphate. Recommended rate of nitrogen (150 Kg N/ha) was applied as a form of ammonium sulphate in three split equal doses (at sowing, during tillering and pod filling). Seeds of faba bean variety Giza 957 were sown at a rate of 150 Kg/ha, with three seeds in each hill on first and 05 November, for the first and second seasons, respectively. Preceding crop was maize in both seasons. Plants were thinned to leave one plant per hill after 21 days from sowing. Mean maximum and minimum temperature and relative humidity during the study of 2005/2006 and 2006/2007 seasons, data are shown in Table 3.

Experimental design was layout in Complete Randomize Block Design with four replications. Water irrigation was applied according to the experimental treatments (total amount of water over the growing seasons were calculated. Each plot consisted of 8 rows

Table 1: Chemical composition of water used in irrigation

EC dS/m	pH (1:25) soil water	SAR	Cations (meq/l)				Anions (meq/l)			
			Ca+	Mg+	Na+	K+	CO_3^-	HCO_3^-	CL^-	SO_4^-
1.4	6.2	2.7	100	30	121.4	13.7	-----	83.9	146.3	408.2

Table 2: Number of irrigation and amount of water used for each treatment over the growing season (2005/2006 and 2006/2007 seasons)

Irrigation treatment	Mean water apply. ($\text{m}^3/\text{ha.}$)	Number of Irrigation	
		First season	Second season
T ₁ Plants irrigated from sowing to complete emergency.	2000	4	4
T ₂ Plants irrigated from sowing to the end of tillering stage.	3000	6	6
T ₃ Plants irrigated from sowing up to the start of flowering stage.	4000	8	8
T ₄ Plants irrigated from sowing to complete pod filling.	6000	12	12
T ₅ Plants irrigated from sowing to starting maturity stage.	7000	14	14
T ₆ Plants irrigated from sowing to complete maturity.	7500	15	15

5 meters in length with 60 cm. apart. Total plot area was 24 m².

At harvest time, two central rows in each plot were harvested for determining seed yield and then, seed yield per hectare was calculated. Sub sample of 10 plants was taken from each plot for determining yield component viz., plant height in cm, No. of days to 50% of flowering, No. of days to 50% of maturing, plant weight, (g), No. of tillers/plant, No. of pods/ plant, seed weight/ plant, (g), 100-seed weight, (g), (using an electronic seed counter and balance), biological yield ton/ha, harvest index (%), seed yield t/ha., decreasing %. Harvest index was calculated by dividing seed yield by above ground biomass. Water use efficiency (WUE) kg/m³ was determined according to Bos [14], based on above ground biomass or final economic yield using the following equation:

$WUE_b = \text{seasonal biomass as dry matter/Kg divided by seasonal water used in ET.}$

$WUE_c = \text{economical yield by Kg divided by seasonal water used in ET.}$

ET = is an Equivalent dry land or rain-fed plot.

Seed chemical composition was determined as protein percentage by determining nitrogen content using Microkjeldahl method and then multiplying nitrogen percentage by 5.75 to calculate protein percentage in seed. Fats and carbohydrates were determined by the methods described by A.O.A.C. [15].

Data of the experiments were exposed to proper statistical analysis of variance according to the methods described by Gomez and Gomez [16]. Means of the treatments were compared by the Least Significant Differences Test at (0.05) level of significance.

RESULTS AND DISCUSSION

Effect on Some Growth Parameters: Growth parameters viz., plant height, number of leaves per plant, leaf area per plant, plant weight, number of days to 50% of flowering and number of days to 50% of maturing, presented in Table 4, were governed by prevailing total water supplied. Stressed plants recorded the lowest value of most growth parameters under investigation. Generally, plants under water stress were commonly shorter than those gives higher amount of water supplied. From the data obtained in the same Table, it is noticed also that plants under higher water supply recorded higher number of leaves per plant and consequently higher leaf area per plant. Thus, such increment reflected in increasing plant weight. On the other hand, plants grown under water deficit conditions had less leaves number and leaves area per plant. Reduced leaf expansion for plants under stress is beneficial which produced less-leaf area and resulted in reduced transpiration. Results obtained herein were in contrast with those reported by Hu *et al.* [17] and Ahmed *et al.* [18], they found that shoot fresh weight of plants grown under drought condition was reduced by 50% compared with the control plants. They attributed these results to the effect of water stress on the water content of the leaves. In addition, drought reduces the soil water potential, similar physiological mechanism such as the water deficit or osmotic effect in plants might explain the reduction in plant growth [19]. Mahajan and Tutejan [20], reported that physiological effect of drought on plants were the reduction in vegetative growth, particularly shoot growth, slower cell division due to reduce cyclin-dependent kinase activity. They also attributed that, above ground plant parts were generally more sensitive than the under ground part.

Table 3: Monthly maximum, minimum, mean temperature and relative humidity during 2005/2006 and 2006/2007 seasons

Month	Temperature (°C)						Total amount of Rainfall (mm)	
	Maximum		Minimum		Mean			
	2005/2006	2006/2007	2005/2006	2006/2007	2005/2006	2006/2007	2005/2006	2006/2007
November	29.42	29.21	12.80	13.75	21.11	21.48	0.00	4.57
December	20.28	25.45	8.04	6.94	14.16	16.20	10.67	0.00
January	20.37	21.83	6.52	6.71	13.45	14.27	8.12	0.25
February	21.25	22.37	8.53	7.87	14.89	15.12	4.22	2.12
March	23.14	24.83	9.54	10.46	16.34	17.65	4.67	2.29
April	27.38	29.10	14.04	14.24	20.71	21.67	5.59	0.00
May	34.69	33.33	18.96	18.02	26.83	25.68	0.25	2.54

Table 4: Influence of water deficit on some growth parameters of faba bean in two growing seasons, (combined analyses of two seasons)

Treatments	Parameters					
	Plant height (cm)	No. of leaves/plant	Leaf area /plant (cm ²)	Plant weight (g)	No. of days to 50% of flowering	No. of days to 50% of maturing
T ₁ total applied water 2000m ³	49.11	54.67	1222.67	978.30	44.63	123.25
T ₂ total applied water 3000m ³	51.75	44.33	1205.67	1132.30	46.13	124.38
T ₃ total applied water 4000m ³	62.58	105.33	2336.67	1325.30	46.38	125.13
T ₄ total applied water 6000m ³	76.10	112.67	2493.33	2176.10	45.50	130.38
T ₅ total applied water 7000m ³	82.16	112.98	2542.22	2706.90	45.25	137.50
T ₆ total applied water 7500m ³	85.25	111.67	2431.56	2581.30	45.88	140.63
LSD at 0.05	7.00	5.42	44.53	343.35	0.98	2.25

Table 5: Influence of water deficit on some yield parameters of faba bean in two growing seasons, (combined analyses of two seasons)

Treatments	Parameters				
	No. of tillers/ plant	No. of pods/ plant	Seed weight /plant (g)	100-seed weight (g)	Biological yield (t/ha)
T ₁ total applied water 2000m ³	5.11	9.41	508.3	72.66	3.23
T ₂ total applied water 3000m ³	5.94	8.95	553.3	82.99	3.74
T ₃ total applied water 4000m ³	6.05	11.79	612.1	87.44	4.37
T ₄ total applied water 6000m ³	6.61	13.60	902.5	86.10	7.18
T ₅ total applied water 7000m ³	7.19	15.29	1285.5	88.63	8.93
T ₆ total applied water 7500m ³	7.03	17.14	1210.1	93.21	8.52
LSD at 0.05	0.98	2.43	139.4	2.96	1.13

Concerning number of days to 50% of flowering and maturing, as expected, it is noticed that plants under water stress condition try to escape from unfavorable condition by ending their life few days earlier than those under normal or high soil moisture conditions. Results obtained under the present investigation are in general, in line with those obtained by Ahmed *et al.* [18]. They reported that water stress leads to significant decrease in number of days to flowering and maturity stages.

Effect on Yield and Yield Component Characters: Yield potential of faba bean, estimated as number of tillers per plant, number of pods per plant, seed weight per plant, 1000-seed weight and seed yield per hectare for early water deficit compared with different water supply treatments are presented in Table 5, generally, plants grown under either normal or high soil moisture content gave higher values of yield and yield component than the stressed plants. In this concern, Ahmed *et al.* [18] showed that water stress applied was more effective for faba bean plants than the variation between varieties or salt stress.

Present results also showed that, level of water stress imposed in this experiment T₁, T₂ and T₃ (Table 2), induced a significant reduction in the number of pods/plant, seed weight /plant, 100-seed weight and biological

yield t/ha. These results are parallel to De Costa *et al.* [21]. They decided that the analysis of yield components showed that the positive yield response to irrigation of mung bean was due to increase of the maximum total biomass.

Moreover, as shown in Table 6, data indicated significant differences between water deficit treatments in harvest index, reducing percent and water use efficiency. It is clearly that lower values of each were accompanying with less water supply. The highest reduction in seed yield was detected in T₁ and T₂ treatments. This may be attributed to the fact that plants under unfavorable condition of plant growth as the result of low water supply led to lower uptake of water and nutrients and this might have decrease the rate of photosynthesis, lower translocation of photosynthesis from stem and leaves to sink and thus yield and yield component parameters were decreased.

Effect on Seed Quality: Data manifested in Table 7, clearly indicated that there is significant differences between water stress treatments in protein contents of seeds. An increasing trend in seed protein content with less water supply i.e. 2000,3000 and 4000 m³/ha water regimes had more protein than those of high levels of water irrigation

Table 6: Influence of water deficit on some yield parameters of faba bean in two growing seasons, (combined analyses of two seasons)

Treatments	Parameters				
	Harvest index %	Seed yield (t/ha)	Reduction %	Water use efficiency (WUE _b)	Water use efficiency (WUE _c)
T ₁ total applied water 2000m ³	52.01	1.68	137.50	1.615	0.84
T ₂ total applied ater 3000m ³	48.93	1.83	118.03	1.257	0.61
T ₃ total applied water 4000m ³	46.22	2.02	97.52	1.093	0.51
T ₄ total applied water 6000m ³	41.51	2.98	33.89	1.197	0.50
T ₅ total applied water 7000m ³	47.48	4.24	5.90	1.276	0.61
T ₆ total applied water 7500m ³	46.83	3.99	-----	1.136	0.53
LSD at 0.05	-----	0.46	-----	-----	---

Table 7: Influence of water deficit on seed chemical composition of faba bean in two growing seasons, (combined analyses of two seasons)

Treatments	Parameters			
	Moisture %	Protein %	Fat %	Carbohydrates %
T ₁ total applied water 2000m ³	6.88	39.10	1.70	45.6
T ₂ total applied water 3000m ³	7.32	38.20	1.73	47.3
T ₃ total applied water 4000m ³	7.38	37.90	1.74	44.8
T ₄ total applied water 6000m ³	7.43	35.60	1.76	43.2
T ₅ total applied water 7000m ³	7.59	34.50	1.76	43.8
T ₆ total applied water 7500m ³	7.59	34.40	1.79	43.7
LSD at 0.05	0.19	0.18	NS	1.7

7000 and 7500 m³/ha. This may be attributed to the fact that plants under the 2000, 3000 and 4000 m³/ha had fewer seeds/plant than those of 7000 and 7500 m³/ha treatments. In addition, the allocation of photosynthetic substrates is expected to be high among plants under 7000 and 7500 m³/ha compared to plants under stress, seeds of these plants are also expected to have less protein but higher seed yield. These results are in agreement with those obtained by Alghamdi [6] and on contrast with those reported by Musallam *et al.* [22]. Finally, the present study clearly supported the previous results, which is in general indicated that less water regimes significantly enhanced seed protein content.

In the respect to seed moisture content, data obtained worthy clear that increasing soil moisture up to high level of water supply increased seed moisture content. This is attributed to plants up till harvest time seems to be juicy due to excess of water in growing condition and then increased water content in plant organs.

Concerning carbohydrates content in faba bean seeds under the present investigation, data in Table 7, clearly indicated that, increasing water supply up to the highest levels had the lowest values of total carbohydrates, while plants under water stress showed almost higher values of total carbohydrates content in seeds. This record, in general may be due to the

accumulation of total carbohydrates which was a result of some metabolic impairment affected its content in the leaves or its translocation. Liu *et al.* [23] reviewed that drought stress significantly decreased leaf sucrose and starch concentrations and translocation.

In the approach of fat concentration, data obtained showed that, the differences between treatments not reach to the level of significant (Table 7).

CONCLUSIONS

We can conclude that influences of drought at the lower level of applied water less than 4000 m³/ha severely retards seed yield, whereas water supplies at 7000 m³/ha could be conserved for growing faba bean under arid environment of Saudi Arabia and gave the highest seed yield. These results need to be validated in more extensive field experimentation included more than one variety. Additional target for use faba bean residue as animal fodder and green manure must be considered.

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