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Effect of Irrigation Scheduling on Growth Parameters and Water Use Efficiency of Barely and Faba Bean Crops in Al-Ahsa, Saudi Arabia

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Abstract: A field study was carried out to determine the effect of irrigation scheduling on growth parameters and Water Use Efficiency (WUE) of barley and faba bean crops for optimum production during the winter seasons of 2001-02 and 2002-03. Four irrigation treatments T_1 (application of water at field capacity soil moisture), T_2, T_3 and T_4 irrigation at 15, 30 and 45% soil moisture depletion of the available water at field capacity of soil, respectively were tested on a loamy-sand soil. Plant growth parameters of both the crops were significantly affected by the different irrigation treatments. Mean barley grain yield ranged from 4.52-6.72 Mg ha^{-1} and the faba bean seed yield from 0.86-1.45 Mg ha^{-1} in different irrigation treatments. The WUE, based on total grain/seed yield ranged between 0.90-148 kg m^{-3} of water for barley and 0.17-0.30 kg m^{-3} of water for faba bean in different irrigation treatments. There was no significant difference in WUE of barley and faba bean crops between T_1 and T_2 treatments. The WUE was slightly higher in T_2 (irrigation at 15% soil moisture depletion) than T_1 (irrigation at soil moisture of field capacity level). In conclusion, appreciable grain yield of barley and faba bean seed can be achieved if irrigated at 15% soil moisture depletion. The study provided useful information for scheduling irrigation of barley and faba bean crops under arid environment for efficient water use and management.

Key words: Irrigation scheduling, barley, faba bean, leaching requirement, soil moisture depletion, field capacity, crop characteristics, seed yield, biological yield, water-use-efficiency

INTRODUCTION

Sustainable crop production in arid and semi-arid regions of the world depends mainly on the availability of irrigation supplies and the adoption of water conservation practices to save more soil water during rainy period. In the Kingdom of Saudi Arabia, the main source of irrigation supplies is the groundwater which is limited and non-renewable. Excessive pumping experienced depletion of the groundwater aquifer in many potential agriculture areas of the Kingdom on long term basis. Therefore, adoption of improved irrigation practices is important for water conservation and efficient management. Generally, the term irrigation scheduling refers to the decision making process of when to irrigate and how much irrigation water to apply to a particular crop for optimal production. Normally, methods of irrigation scheduling are based on either direct measurements or indirect calculations of evaporation losses. The direct measurements involve either water balance techniques using hypsometers, (Norman, 1974) plot and catchment studies (Dunne and Leopold, 1978) or monitoring soil water (Merriam, 1960; Bauder and Lundstrom, 1977; Gear *et al*., 1977). Indirect methods include the use of various plant characteristics as indicators of water stress and/or formulae to calculate potential consumptive use of water by different crops using physical weather parameters. Among the most important field crops, both the barley grain and faba bean seed, utilized for human and animal consumption, are adopted to a wide range of climatic conditions. Sayed and Al-Sayed (1982) indicated that barley plant height and number of grains/spike were severely affected by withholding irrigation during boot stage. They further stated that the water stress period (several days during heading) did not affect the number of days to heading while other morphological characteristics such as days to maturity, plant height and spike length varied in their response but the effects were not pronounced. Singh and Tiwari (1987) stated that the Stress Day Index Method (SDIM) with 50% depletion of available soil moisture was statistically superior and had maximum water use efficiency. Ghandorah (1987) screened 21 barley (*Hordeum vulgare*) genotypes for drought resistance. He found that drought stress significantly affected the grain yield, kernel weight, number of days to heading and number of days to maturity of the different barley cultivars. Furthermore, water stress reduced the number of days to heading while the number of days to maturity were significantly different from one season to another. Wessolek and Rengar (1993) studied the influence of different irrigation schemes on crop yield of barley in a German sandy soil. They observed that (1) the soil moisture levels in the root zone and the amount of irrigation water applied significantly influenced the evapotranspiration and yield, (2) if irrigation is started at 50% available moisture at field capacity, the evapotranspiration is greater than the 30% available field capacity irrigation treatment, (3) for crops with high irrigation water demand, the irrigation application should be small to prevent high irrigation water losses and (4) high yields were often obtained with high irrigation inputs. In connection with the effect of irrigation treatments on faba bean, Ageeb *et al*. (1989) reported that irrigation to faba bean at 7-days interval increased seed yield and the number of plants m^{-2}, while the number of pods/plant and the 100-seed weight were decreased.

Recently, many researchers studied the benefits of irrigating crops at intervals much shorter or longer than those followed in the conventional practices. It may be possible, in cases where irrigation costs are high or water is limited, to increase net income by increasing the irrigation intervals while deliberately applying water stress to crop. Presently, a very little information is available in this area and the variation in results from different approaches advocated the need to further investigate the effects of irrigation intervals on crop growth and performance coupled with water use efficiency in arid environment. The main objective of this research was to study growth performance and determine WUE of two important field crops such as barley and faba bean as food both for human and animal consumption under Al-Ahsa climatic conditions, Saudi Arabia.

MATERIALS AND METHODS

The experiment was carried out at Agricultural and Veterinary Training and Experimental Station, King Faisal University, Al-Ahsa. The experimental station is situated about 20 km West of Hofuf town on Main Hofuf-Qatar Highway.

Experimental Design

The experimental treatments included two crops (barley and faba bean), four irrigation treatments [application of water at field capacity, T_1 (control treatment), 15% (T_2), 30% (T_3) and 45% (T_4) soil moisture depletion at field capacity to apply water stress to plants] and one soil (loamy-sand). The irrigation treatments were replicated three times. The crops (faba bean and barley) were planted during the winter seasons of 2001-02 and 2002-03. The experimental treatments were allotted randomly to each field. The experimental area was divided into 24 plots. Separate experiment was conducted for each crop. The size of each experimental plot was 6×6 m area. A border strip of 4 m was kept between plots to minimize irrigation interference and effects. The experiment was laid out by following A Complete Randomized Block Design. The experimental layout is presented in Fig. 1.

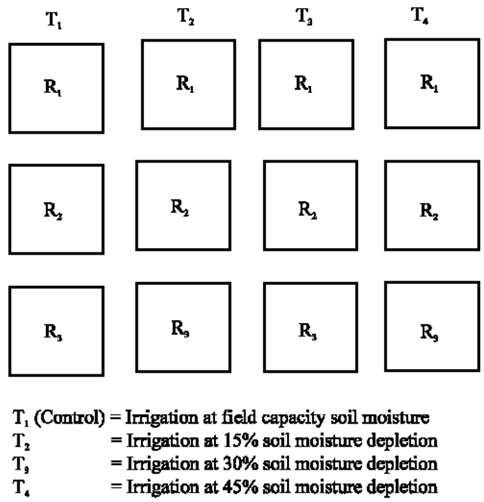

Fig. 1: Layout of experimental irrigation system

Table 1: Planting and harvesting dates of the experimental crops

Operation	Barley	Faba Bean
Planting	25 Nov, 2001	25 Nov., 2001
	5 Nov, 2002	10 Nov., 2002
Harvesting	31 March, 2002	31 March, 2002
	20 March, 2003	20 March, 2003

Cultural Practices

A fine seed bed was prepared by sub-soiling the soil up to a depth of 60 cm followed by plowing the top 30 cm soil layer. The farm yard manure was added at the rate of 50 Mg ha^{-1} in the top 15 cm soil, mixed it by harrowing and then leveled the soil. Later on, the experimental field was divided into the required number of plots according to the experimental treatments. Barley seeds were hand sown in rows 20 cm apart using the seed rate of 180 kg ha^{-1}. The phosphorus fertilizer was added at the rate of 400 kg triple super phosphate (45% P_2O_5) ha^{-1} and the nitrogen fertilizer was added at the rate of 500 kg N ha^{-1} in the form of urea (46% N). Weeds were controlled chemically in all the plots.

Dry method of planting was used for sowing faba bean on ridges. The distance between hills was 20 cm and the ridges width was 50 cm. During seed bed preparation, 30 kg triple super phosphate (45% P_2O_5) ha^{-1} was added. Nitrogen was added at the rate of 100 kg N ha^{-1} (as urea, 46% N) in two equal split doses. The planting and harvesting dates of the experimental crops are presented in Table 1.

Soil Analysis

Soil samples were taken randomly from 0-30 and 30-100 cm depth of soil from two different locations representing the surface and sub-surface soil layers, respectively. The soil samples were analyzed mechanically according to the procedure as described by Jackson (1973) and chemically by following the methods given in USDA (1954) Handbook No. 60. The physical and chemical characteristics of experimental soils are presented in Table 2. The soil moisture upper limits, lower limits and the total available water capacity of soil are presented in Table 3. The allowable soil moisture deficit is given in Table 4.

Soil moisture contents in the crop root zone were measured in situ by a Neutron Moisture Probe 3300 series before and after each irrigation followed by subsequent measurements at 2-3 days internal after each irrigation. The probe was calibrated by following methods as described by Eeles (1969) and Bell (1973, 1976).

Table 2: Physical and chemical properties of experimental soils

Depth (cm)	Mechanical analysis Sand (%)	Silt (%)	Clay (%)	Soil texture	SP (%)	FC (%)	PWP (%)	AWC (%)	Bulk density (g cm^{-3})	$CaCO_3$
0-30	81.76	16.00	2.24	Loamy sand	30.0	14.1	7.03	7.07	1.60	8.81
30-100	80.58	15.18	4.24	Loamy sand	37.5	17.3	8.50	8.80	1.56	12.13

Table 3: Upper and lower limits of soil moisture and available water capacity of experimental soils

	FC			PWP			AWC		
Depth (cm)	Weight (%)	Volume (%)	As irrigation depth (mm)	Weight (%)	Volume (%)	As irrigation depth (mm)	Weight (%)	Volume (%)	As irrigation depth (mm)
0-30	14.10	22.56	225.60	7.03	11.248	112.48	7.07	11.312	113.12
30-100	17.30	26.98	269.90	8.50	13.260	132.60	8.80	13.728	137.30

Table 4: Allowable Moisture Deficit (AMD), mm

T_1	T_2	T_3	T_4
----	18.78 mm	37.56 mm	56.34 mm

Leaching Requirements (LR)

Leaching requirement was considered to estimate proper amount of water to be applied during each irrigation. The EC of the irrigation water was 1.77 dS m^{-1} and the electrical conductivity of soil saturation paste extract (EC_e) was 4.17 dS m^{-1}. The leaching requirement, for the site under sprinkle irrigation came to 0.1 using the following Eq.

$$LR = \frac{EC_w}{5EC_e - EC_w} \times \frac{1}{LE}$$

Where:

EC_w = Electrical conductivity of irrigation water (dS m^{-1})
EC_e = Electrical conductivity of the soil saturation extract
LE = Leaching efficiency was assumed to be 90% for loamy sand soil

Irrigation System

Fully automated sprinkler irrigation system was designed and installed to achieve high irrigation application efficiency. The agronomic aspect of the design involves supplying the proper amount of water at the proper time. The system provided irrigation water to each experimental plot through PVC laterals, (5 cm diameter) and 30 m length, fitted with 3 impact sprinklers assigned to each plot. The laterals were connected to a sub-main pipe which was connected to the main line water supply line. The index used to evaluate the system was Christiansen's coefficient of uniformity (cu). This index shows how uniformly nozzles distribute water over the irrigated area. In general, the irrigation efficiency for sprinkle system is 70% under Saudi Arabia conditions (Al-Zeid *et al*., 1988). The evaluation test was done only once prior to the growing season to eliminate the influence of crop to the falling drops in the cans. This test was carried out during the early morning hours to minimize the effect of evaporation. The cu value for this system came to 98.1%. This means that the distribution of irrigation water was uniform in the whole area. The uniformity of water distribution from the permanent sprinkle irrigation system was tested in the field site.

Gross Irrigation Requirements (GIR)

The net depth of applied irrigation water must include the losses due to the system efficiency and the water required for leaching requirement. The Gross Irrigation Requirement (GIR) per unit area was calculated by the following equation for a period of time or for the whole growing season:

Table 5: The Gross Irrigation Requirement (GIR) in mm depth

T_2	T_3	T_4
29.81	59.62	89.43

$$GIR = \left(\frac{MAD}{\eta} \times \frac{1}{1 - LR}\right) - R_{eff}$$

Where:

MAD = Moisture allowable deficit (mm)
η = Efficiency of irrigation method 0.7
LR = Leaching requirement
R_{eff} = Effective rainfall = >5 mm

The GIR for the three water treatments is given in Table 5.

In order to initiate irrigation, the water content must be compared with the irrigation depth at field capacity which is 248 mm (Table 3). If the soil water content is less than 248 mm by 18.78, 37.56 and 56.34 mm for 15, 30 and 45% soil moisture depletion treatments, respectively; then water must be added to refill the soil reservoir to the field capacity level (248 mm).

Water Use Efficiency (WUE)

Water use efficiency is defined as the yield obtained per unit of water applied to the crop under study. Therefore, the WUE was calculated based on the total amount of water applied and the total grain/seed yield obtained for each crop as follows:

$$\text{Water Use Efficiency (WUE)} = \frac{\text{Total yeild (kg ha}^{-1}\text{)}}{\text{Total water applied (mm)}}$$

Crop Measurements

Crop growth measurements include tillers per plant, fresh and dry weight, spike length and spikes m^{-2}, spike weight, biological yield and grain yield for barley crop. Whereas, for faba bean crop, these measurements were number of pods m^{-2}, pods weight, 100 seed weight, biological yield and seed yield. Harvest index was calculated for both the crops. Random samples of barley and faba bean plants were taken from the inner 1 m^2 area from each plot at the time of harvesting. The experimental data were subjected to appropriate statistical analysis and the treatment means were compared using Duncan (1955) multiple range test as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Barley

Different plant growth parameters such as plant height (cm), leaf area index, 1000 grain weight (g) and harvest index of barley crop were significantly affected by different irrigation treatments during both the cropping seasons (Fig. 2a-d). There was no significant difference in these plant characteristics between the two seasons. The mean values of the two seasons show that the plant height decreased from 65.9-60.8, 54.8 and 48.6 cm, leaf area index from 7.1-6.4, 5.4 and 3.1 and the 1000 grain weight from 41.50-39.7, 37 and 35.7 g when receiving irrigation at 15, 30 and 45% depletion of total available soil water, respectively than the control treatment (daily irrigation to maintain soil moisture at field capacity). Harvest index and grain protein (%) decreased significantly with increasing water stress than the control treatment (irrigation to maintain soil moisture at field capacity.

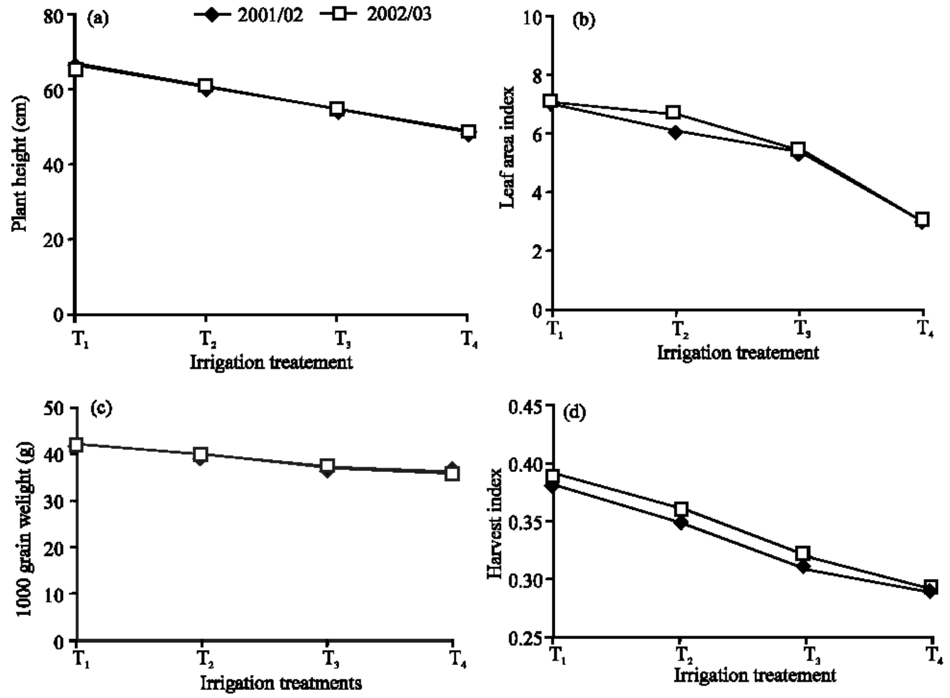

Fig. 2: Effect of different irrigation treatments on plant height (cm), leaf area index, 1000 grain weight (g) and harvest index of barley crop

Table 6: Effect of different irrigation treatments on growth parameters of barley crop during 2001-02 and 2002-03 cropping seasons

Irrigation treatments	Tillers/plant (No.)		Tillers m^{-2} (No.)		Plants fresh weight ($g\ m^{-2}$)		Plants dry weight ($g\ m^{-2}$)		Spike length (cm)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
T_1	2.2^a	2.2^a	914.7^a	912.3^a	2985.0^a	3005.0^a	1010^a	1007.0^a	6.8^a	6.7^a
T_2	2.0^b	2.0^b	649.3^b	648.3^b	2686.7^b	2658.0^b	905^b	910.1^b	5.8^b	5.9^b
T_3	1.5^c	1.6^c	431.7^c	433.3^c	2164.0^c	2163.3^c	735^c	735.3^c	4.5^c	4.5^c
T_4	1.2^d	1.3^d	320.0^d	321.7^d	1773.7^d	1773.0^d	555^d	536.3^d	3.8^d	3.8^d
F-test	**	**	**	**	**	**	**	**	**	**

The figures in a column followed by the same letter are not significantly different by $LSD_{0.05}$

Mean ranges of different plant characteristics were 1.3-2.2 (tillers/plant), 321-914 (tillers m^{-2}), 1773.4-2995.0 g m^{-2} (fresh weight), 546.7-1008.5 g m^{-2} (dry weight), 3.9-6.8 cm (spike length) in different irrigation treatments (Table 6, 7). Mean values of different plant characteristics such as number of tillers/plant, number of tillers m^{-2}, fresh and dry weight of plants (kg m^{-2}), spike length (cm), crude protein (%), number of spikes m^{-2}, spike weight (g m^{-2}), grain and biological yields (t ha^{-1}) of barley crop were significantly affected by different irrigation treatments (Table 6, 7). Mean values of all the plant growth parameters were significantly high in T_1 (irrigation at field capacity, the control treatment) as compared to T_2, T_3 and T_4 irrigation treatments, respectively. Among the various irrigation stress treatments (irrigation at soil moisture less than field capacity), the values of all the plant growth parameters were significantly higher in T_2 followed by T_3 and T_4 treatments, respectively. It was found that application of water stress to plants significantly affected the crop production.

Table 7: Effect of irrigation treatments on number of spikes m^{-2}, spike weight (g m^{-2}), grain yield , (Mg ha^{-1}), biological yield (Mg ha^{-1}) and crude protein (%) of barley plant during 2001-02 and 2002-03 cropping seasons

Irrigation treatments	Crude protein		Spikes (m^{-2} No.)		Spikes wt. (g)		Grain yield		Biological yield	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
T_1	10.75^a	10.69^a	525.0^a5	20.3^a	721.2^a	710.9^a	6.73^a	6.72^a	17.53^a	17.40^a
T_2	9.25^b	9.25^b	497.0^b	500.2^b	645.1^b	658.5^b	6.07^b	6.07^b	17.14^b	17.03^b
T_3	8.17^c	8.19^c	472.0^c	470.4^c	585.2^c	591.2^c	5.29^c	5.30^c	16.85^c	16.08^c
T_4	7.48^d	7.50^d	418.0^d	420.3^d	508.9^d	500.6^d	4.52^d	4.52^d	15.49^d	15.33^d
F-test	**	**	**	**	**	**	**	**	**	**

The figures in a column followed by the same letter are not significantly different by $LSD_{0.05}$

Mean number of spikes ranged from 419-523 m^{-2} and the spike weight ranged from 504.8-715.5 g m^{-2} in T_2, T_3 and T_4 irrigation treatments, respectively (Table 6, 7). The decrease in these two plant parameters was significant among the different irrigation treatments being highest in T_1 than the other water stress treatments (T_2, T_3 and T_4). Mean grain yield of barley decreased significantly with an increase in water stress as compared to T_1 (control treatment) in both growing seasons. The percent reduction in grain yield came to 9.74, 21.26 and 32.79% in T_2, T_3 and T_4, respectively than T_1 (control) treatment. Mean biological yield ranged from 15.41-17.46 t ha^{-1} in different irrigation treatments. The decrease in biological yield was significant among the various irrigation treatments and the trend for the effect of different irrigation was similar to that of grain yield. The percent reduction in biological yield came to 2.2, 5.7 and 11.8% in T_2, T_3 and T_4, respectively as compared to T_1 (control) treatment. This suggests that application of water stress to barley plants significantly affected the various physiological characteristics of barley plant. The results agree with those of Sayed and Al-Sayed (1982) who concluded that barley plant height and the number of grains per spike were severely affected by applying water stress during boot stage. They further stated that the stress period (several days during heading) did not affect the number of days to heading while others morphological characteristics of barley plant such as days to maturity, plant height and the spike length varied in their response but the effects were not pronounced. In conclusion, application of water stress (irrigation at soil moisture less than field capacity) seriously affected different plant growth parameters thus subsequently affecting the final grain yield and the biological yield of barley. Similar views were stated by Wessolek and Rengar (1993) who obtained high grain yield with high irrigation inputs. They further reported that it is useful to relate the increase of yield to the amount of irrigation water applied.

Faba Bean

Mean values of different plant parameters ranged from 49.80-91.50 number of pods m^{-2}, 118.50-197.60 pods weight m^{-2}), 67.60-89.75 g (1000-seed weight) and 0.29-0.39 (harvest index) at 15 (T_1), 30 (T_2) and 45% (T_4) depletion of the available water at soil field capacity, respectively (Fig. 3a-d, Table 8). Mean values of different plant parameters such as number of pods m^{-2}, weight of pods (g m^{-2}), 1000-seed weight (g), harvest index, seed and biological yields (t ha^{-1}) and seed protein (%) were significantly affected by different irrigation treatments (Fig. 3a-d, Table 8). Mean values of all the plant growth parameters decreased significantly with increasing irrigation interval than the control treatment (irrigation at field capacity of soil moisture).

The reduction in plant growth parameters was significantly less in T_1 (control treatment i.e., irrigation at field capacity) followed by T_2, T_3 and T_4 treatments, respectively in descending order. This suggested that application of water stress to plants at various growth stages seriously affected the plant growth thus resulting low production. Also, there was no significant difference in various plant growth parameters between the two cropping seasons.

Mean faba bean seed yield was 1.45, 1.25, 0.97 and 0.86 t ha^{-1} for T_1, T_2, T_3 and T_4 irrigation treatments, respectively. Similarly, the biological yield of faba bean followed the same trend as that

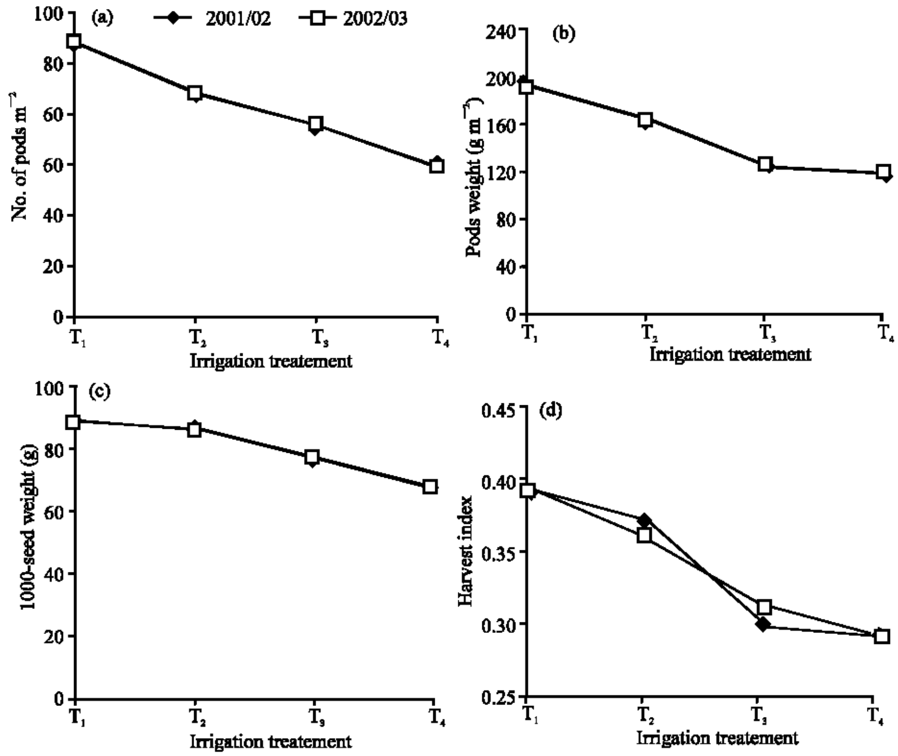

Fig. 3: Effect of different irrigation treatments on No. of ponds m^{-2}, pods weight (g m^{-2}), 1000 grain weight (g) and harvest index of faba bean crop

Table 8: Effect of irrigation treatments on faba bean seed yield (Mg ha^{-1}), biological yield (Mg ha^{-1}) and seed protein (%) during 2001-02 and 2002-03 cropping seasons

Irrigation treatments	Seed yield		Biological yield		Seed protein (%)	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
T_1	1.45^{a}	1.44^{a}	3.70^{a}	3.71^{a}	25.9^{a}	25.9^{a}
T_2	1.25^{b}	1.24^{b}	3.41^{b}	3.43^{b}	24.7^{b}	24.6^{b}
T_3	0.96^{c}	0.97^{c}	3.15^{c}	3.15^{c}	22.0^{c}	21.9^{c}
T_4	0.85^{d}	0.86^{d}	2.93^{d}	2.94^{d}	19.4^{d}	19.4^{d}
F-test	**	**	**	**	**	**

Figures in a column followed by the same letter are not significantly different by $LSD_{0.05}$

of seed yield with respect to different irrigation treatments. The seed protein (%) was significantly affected by different irrigation treatments. The seed protein decreased to 24.7 , 21.95 and 19.40% for T_2, T_3 and T_4 irrigation treatments, respectively as compared to 25.9% in T_1 (control treatment i.e., irrigation at field capacity soil moisture level). In conclusion, the faba bean crop performance was significantly better when irrigated at field capacity soil moisture level than the other water stress treatments i.e., irrigation at 15, 30 and 45% depletion of soil moisture, respectively. Data also showed that faba bean production was significantly affected under waster stress plant growth conditions. The results agree with those of Ageeb *et al.* (1989) who reported that irrigation to faba bean at 7-days interval increased seed yield and number of plants m^{-2}, while number of pods per plant and 100 seed weight were decreased.

Table 9: Effect of irrigation treatments on total quantity of water applied and the water use efficiency (WUE) of barley and faba bean crops

Irrigation treatments	Barley				Faba bean			
	Total quantity of water*(mm)		WUE (kg m^{-3})		Total quantity of water*(mm)		WUE (kg m^{-3})	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
T_1	578.77	474.37	1.16	1.42	590.59	487.07	0.25	0.30
T_2	518.09	409.94	1.17	1.48	525.54	430.10	0.24	0.29
T_3	511.76	393.87	1.06	1.35	509.99	438.80	0.19	0.22
T_4	503.40	391.21	0.90	1.16	514.90	389.70	0.17	0.22

*Quantity of total irrigation water applied is the irrigation water plus 38.1 and 38.6 mm rainfall in the first and second season, respectively

Water Use Efficiency (WUE)

Mean Water Use Efficiency (WUE) of barley crop ranged from 0.90-1.16 and 1.16-1.48 kg m^{-3} during 2001-02 and 2002-03 cropping seasons, respectively in different irrigation treatments (Table 9). The WUE was affected significantly by the different irrigation treatments during both the seasons. The difference in WUE was significant among all the treatments but it was not significant between T_1 and T_2 treatments, although the WUE was slightly higher in T_2 than T_1 treatment. Furthermore, the WUE was slightly higher in the second year (2002-03) than the first year (2001-02) cropping season. This could be due to the application of less amount of irrigation water in the second year than the first year of cropping. This shows that the crop performance, while irrigating at 15% soil moisture depletion, was identical to that of irrigation at field capacity soil moisture level. This further indicated considerable saving in irrigation water to obtain higher water use efficiency and increased crop production.

Mean Water Use Efficiency (WUE) of faba bean crop ranged from 0.17-0.25 and 0.22-0.30 kg m^{-3} of water applied during 2001-02 and 2002-03 cropping seasons, respectively in different irrigation treatments (Table 9). The WUE of faba bean crop was affected significantly by the different irrigation treatments during both the seasons. The difference in WUE was significant among all the treatments but it was not significant between T_1 and T_2 treatments, although the WUE was slightly higher in T_2 than T_1 treatment. This shows that the crop performance, while irrigating at 15% soil moisture depletion, was identical to that of irrigation at field capacity soil moisture level. This further indicated considerable saving in irrigation water to obtain higher water use efficiency and increased crop production. Overall, the WUE of faba bean was slightly higher in the second year (2002-03) than the first year (2001-02) of cropping but the difference was not significant. This could be attributed to the difference in the irrigation water application which was less in the second year than the first year of cropping thus giving higher values of WUE.

Overall, the results indicated that irrigation to barley and faba bean crops at 15% soil moisture depletion than irrigation at field capacity is practical to obtain higher WUE and efficient water management for optimal crop production in arid climatic conditions.

CONCLUSIONS

Plant growth parameters of barley and faba bean crops were significantly affected by different irrigation treatments. Mean barley grain yield ranged from 4.52-6.72 Mg ha^{-1} and the faba bean seed yield from 0.86-1.45 Mg ha^{-1} in different irrigation treatments. There was no significant difference in WUE for barley and faba bean crop between T_1 and T_2 treatments. The WUE was slightly higher in T_2 (irrigation at 15% soil moisture depletion) than T_1 (irrigation at field capacity soil moisture level). In conclusion, appreciable grain yield of barley and faba bean seed can be achieved if irrigated at 15% soil moisture depletion. The study provided useful information on the effect of water stress on plant growth characteristics for scheduling irrigation of barley and faba bean crops in an arid environmental conditions for efficient water management.

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