Effect of Watering Regimes at Two Stage of Growth on Faba Bean Grain Yield at Selaim Basin

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Abstract

The study was carried out in farmer's field in Selaim basin for two consecutive seasons (2000-01 and 2001-02) to study the response of faba bean to differential irrigation in relation to two stages of growth on grain yield and the incidence of insect pests on the crop. Three watering regimes (14, 21and 28-day intervals) were interchanged in all possible combinations during the two phases of plant growth (vegetative and reproductive). The resultant nine treatment combinations were replicated four times in a randomized complete block design (RCBD). Variety SM-L was sown and sprayed with Folimat E.C (1ml L^{-1} of water) against insect pests. In both seasons treatment C1 (28 days-vegetative and 14 days-reproductive) gave the highest grain yield (3545 kg ha^{-1} and 2631 kg ha^{-1}) in the first and the second seasons, respectively. Treatment (C1) received only six irrigations with a total quantity of irrigation water of about 4464 m^3 ha^{-1} compared to irrigating 14 days throughout the growing season, which consumed about 7429 m^3 ha^{-1} in eight irrigations. Two irrigations were saved with a total quantity of water equal to 2965 m^3. Consumptive water use was less at the early vegetative and late growth stages and greater at middle stages.

Introduction

Faba bean is the most important food legume in the Sudan. It is grown as an irrigated winter crop in the Northern part of the Sudan where environmental conditions are suitable for its production than in any other part of the country. However, the growing season is restricted to a short period by high temperatures prevailing at the beginning and end of the winter season.

The Selaim basin is considered as the most important area for faba bean production in the Sudan. Yield per unit area is usually highest and the best quality throughout the country (Ibrahim, 1987).

Farmers in the Northern state of the Sudan generally apply lower number of irrigations. Faki (1991) reported that irrigation water is the most important single constraint to agricultural production in the Northern Sudan. He further stated that expensive water pumping from the Nile coupled with limited pump sizes, and energy and spare parts availability problems render irrigation water a costly resource that justifies optimal allocation among the different crops grown. For these reasons, frequent irrigation is generally the least adopted component of packages in on-farm trials.

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Thus, timing the length of irrigation interval with the stages of crop growth might bring about a reduction in the number of irrigations and results in an economic crop yield. Our current situation emphasizes the need for the use of scientifically sound methods for deciding when and how much to irrigate crops. According to Talyor (1965), irrigation should take place while the soil water potential is still high enough that the soil can and does supply water fast enough to meet the local atmospheric demands without placing the plants under stress that would reduce yield or quality of the harvested crop. Although, a high water status throughout the growing season is necessary to maintain unimpaired crop growth and high economic yield, the imposition of some stress by longer irrigation intervals, higher moisture depletion or skipping irrigation during the early vegetative or during maturation could still attain similar economic yields as well as saving irrigation water and improving water- use efficiency. Saxena and Stewart (1983) reviewed studies on water relations of faba bean during the first phase of ICARDA/IFAD Nile Valley Project in the Sudan. Therefore, the objective of this study was to determine the extent to which intervals between irrigations could be increased or widen without sacrificing yield, saving irrigation water and thus increase water use efficiency. In addition, determine the impact of soil moisture status on the incidence of insects' pests.

Materials and Methods

The experiment was carried out at a farmer's field in Selaim basin for two consecutive seasons (2000-01 and 2001-02). The design was a randomized complete block design. Treatments were factorial combinations, replicated four times. Plot size was 30 m^2 (5x6 m), and the net harvested area was 19.2 m^2 (4.8x4 m). Faba bean variety SM-L was grown. Rows were spaced 0.6 m apart and intra-row spacing of 0.2 m with two seeds per hole. Sowing dates were the 7 November for the first season and 14 November for the second season. The experiments were hand weeded twice and sprayed with Folimat E.C (1ml L^{-1} of water) against Aphids.

Soil moisture content was determined by standard gravimetric method. Soil samples were collected by an auger from each plot at an increment depth of 0.2 m from the surface to the depth of one meter. Sampling was made a few hours before irrigation and about three days after irrigation. The soil samples were put in an oven set at 110°C for 48 hours or until constant weight in order to determine their moisture content. The soil water loss during the first three days prior to soil sampling for soil moisture determination was assumed to be equal to crop water requirement during these three days, 3 x CWR (mm/day).

Plant height was taken as an index of plant growth. Data for plant height determination were collected every two weeks.

Physical water flow into each plot was measured by parshall flume in liters per second, which was later converted to cubic meters per hectare (m^3ha^{-1}).

Water- application efficiency (WAE), which is defined as the ratio of the volume of water that is stored by the irrigator in the soil root zone and ultimately consumed (transpired or evaporated or both) to the volume of water delivered at the farm was determined by the following equation:-

$$WAE = \frac{\text{Water stored}}{\text{Water applied}} \quad \ldots\ldots (1)$$

Reference evapotranspiration was calculated by Penman-Monteith method (Smith, 1990 and Allen et al., 1998).

$$ETo = \frac{\Delta x Rn}{\Delta+\gamma^*} + \frac{\gamma}{\Delta+\gamma^*} x \frac{900u_2}{t+275} (ea-ed) \quad \ldots\ldots\ldots\ldots (2)$$

Where:

Δ = slope of saturation vapor pressure curve at mean temperature

γ^*= (1+0.33U_2), U_2 (wind speed) in meters per second

γ = psychometric chart constant mb°C

Rn = net radiation in the units of evaporating water (mm/day)

t = temperature ˚C

ea and ed are aerodynamic terms in kilo Pascal

Crop coefficients (kc) were calculated as follows:

$$Kc = \frac{ETcrop}{ETo} \quad \ldots\ldots\ldots\ldots (3)$$

Crop coefficient incorporates the effects of crop growth stages, crop density and cultural factors affecting potential evapotranspiration.

For each time stage, crop water requirement (CWR) was determined from reference evapotranspiration and crop coefficients obtained as suggested by crop growth stages.

$$CWR = k_c \text{ x PET (mm/day)} \quad \ldots\ldots\ldots\ldots (4)$$

$$\text{Water use efficiency (kg/m}^3\text{)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total water used (m}^3\text{/ha)}} \quad \ldots\ldots\ldots\ldots (5)$$

$$\text{Harvest Index (HI)} = \frac{\text{Grain Yield (kg/ha) x 100}}{\text{Total Biological Yield (kg/ha)}} \quad \ldots\ldots\ldots\ldots (6)$$

Results and Discussion

Table 1 shows soil properties of some selected sites at Selaim basin and Table 2 shows factorial arrangement of the different treatments at the vegetative and the reproductive phases.

Irrigation interval had a highly significant ($P \leq 0.01$) effect on plant growth as measured by plant height. Prolonged irrigation interval (21 and 28 days) during the reproductive phase resulted in shorter plants (Table 4). Treatment C1 (28- days vegetative and 14- days reproductive) and treatment B1 (21-days vegetative and 14-days reproductive) gave comparatively taller plants in the first season and the second seasons, respectively (Tables 4 and Figure 1).

The effects of various irrigation regimes on the yield and its components are presented in Table 4. Highly significant ($P \leq 0.01$) effects were found on 100-seed weight and number of pods/plant due to differential irrigation regimes. Prolonged irrigation interval (28 days) during reproductive phase resulted in fewer number of pods/plant (22.7), while during the reproductive phase; the 28-days interval gave significantly lower seed weight (48 g) as compared with the two other intervals (Table 5), in the first season. In the second season, irrigating every 28 day during the vegetative phase gave the highest number of pods/plant, but some of the pods got affected during the reproductive phase. Grain yield was highly significantly ($P \leq 0.01$) affected by irrigation regime (Table 5 and 6). The highest grain yield was achieved by treatment C1 (3545 and 2631 kg ha^{-1}) in the first and second season respectively (irrigating every 28 and 14 days during vegetative and reproductive phases, respectively). The lowest yield was that of B3 (irrigating every 21 and 28 days during vegetative and reproductive phases, respectively); and C3 (irrigating every 28 days throughout the season, Table 4). However, yields of the rest of the treatments were not statistically different from each other on one hand and from C1 on the other hand, except B3 and C3, which were significantly lower than treatment C1.

Water stress reduced dry matter accumulation at all stages of development, particularly irrigating 28 days throughout the growing season. More drastic reduction was observed during flowering stage. Frequent watering i.e. every fourteen days during the reproductive phase increased dry matter accumulation, which was positively, and significantly correlated with yield of dry pods/plant, indicating that increase in dry matter per plant increased the yield of dry pods/plant, this confirms the results of (Shelke and Khuspe, 1980; and Pandey at el. 1984). Ageeb (1976, 1977b) and Mohamed (1981), reported by Ahmed (1996) found that the reproductive phase was sensitive to water stress than the vegetative phase. Ahmed (1996) indicated that crop response to irrigation treatments is site-specific and subject to seasonal weather fluctuations.

Treatment A1 (irrigating every 14 days) resulted in higher consumptive water use, i.e. actual evapotranspiration (ET), then it declined as the interval was extended (Table 3). The higher amounts of water received was associated with the increase of actual evapotranspiration rate. Ahmed (1996) reported that a crop water requirement for faba bean at Hudeiba was about 430 mm as measured by neutron probe. Stewart et al. (1983) reported that a significant relationship exists between applied irrigation water and evapotranspiration, increasing the amount of irrigation water increased evapotranspiration, but at lower rate. The middle growth period had a higher evapotranspiration than earlier or late growth periods. This is mainly because during the mid growth period, plants use more water to satisfy the demand for peak growth rate. Ford (1987) reported that daily sunflower water use averaged 0.35 to 0.38 cm over a season, starting at near zero at emergence and peaking at about 0.75 cm day^{-1} in the middle of the growing season.

Crop coefficients were calculated as ratios of actual evapotranspiration to reference evapotranspiration under the different watering regimes. Treatments A1 (watering every 14 days) and treatment C1 (watering 28 days during vegetative and 14 days during reproductive) resulted in crop coefficients greater than one in the mid growth period. They started by about 0.64 at emergence, peaked to 1.18 and declined to 0.52 at harvest time. Crop coefficients decreased as days between irrigations were extended. Treatments A3, B3 and C3 had comparatively lower crop coefficients than A1 and C1.

Higher water use efficiencies were associated with extended irrigation intervals, indicating that unnecessary application of irrigation water leads to low values of water use efficiency. Thus, irrigating every fourteen days gave the poorest values of water use efficiencies in both seasons, 0.45 and 0.30 in the first and the second seasons respectively (Table 3).

Water application efficiency, which is defined as the ratio of the volume of water that is stored by the irrigator in the soil root zone and ultimately consumed by the plant to the volume of water delivered at the farm was high for treatment C1 in the first season (79%) and high for treatment C2 (62%) in the second season (Table 3).

The importance of these results lies in the fact that the crop could tolerate prolonged irrigation intervals up to 28 days during the vegetative phase and up to 21 days during the reproductive phase without affecting economic yield Results of the first count one month after sowing (Table 8) indicated that all treatments had a non-significant effect on the number of percentage-damaged leaflets or the number of *Spodoptera exigua* larva per stem. The percentage damaged leaflets ranged from 34.5 to 42.9.

Figure 1 shows time course of plant height measurement and Figure 2 shows the relationships between water applied and the quantity of grain legume produced as a result. Treatment A1 consumed more water and treatment C1 gave the highest grain yield with minimum quantity of irrigation water applied.

Conclusions

1. At early vegetative growth stage faba bean water requirement is less due to small plant size, low growth rate and limited root proliferation. During this stage, it is not necessary to irrigate frequently except for serious drought. Proper tillage is a prerequisite to ensure deep root extension.
2. Water requirement of faba bean is greater at middle growth stages, and less at early and late growth stages.
3. Irrigation intervals of 28 days during the vegetative phase and 14 days during the reproductive phase gave the highest grain yields (3545 kg ha^{-1}) and (2631 kg ha^{-1}) in seasons, 2000-01 and 2001-02 respectively.
4. Shorter irrigation intervals must always be practiced during reproductive phase and longer intervals during vegetative phase. Longer intervals of up to 28 days during the productive phase resulted into 18% reduction in grain yield.
5. According to weather conditions up to 21 days irrigation interval during the reproductive phase can be reached, saving three irrigations with volume of irrigation water of about 4060 m^3. However, if not properly exercised 3-3.5% yield reduction can be incurred.
6. Two to three irrigations can be saved, with a volume of irrigation water ranging from 2965-4060 m^3.
7. Higher water use efficiencies were associated with extended irrigation intervals, indicating that unnecessary application of irrigation water results into low values of water use efficiency.
8. Crop coefficients decreased as days between irrigations were extended.

Recommendations

1. In Selaim, it is recommended to practice longer irrigation intervals (28 days) during the vegetative phase and shorter intervals (14 days) during the reproductive phase.
2. According to weather conditions and the quantity of available water supply, coupled with the need to raise water productivity, an interval of up to 21 days during the reproductive phase can be practiced.

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Table 1. Soil properties of some selected sites in Selaim Basin.

Property	A	B	C
pH	7.9	7.8	8.0
EC mmho/cm	2.7	0.7	1.2
SAR	10.0	10.0	3.0
Total -N ppm	1029	590	980
% Sand	30	20	22
% silt	21	35	48
% Clay	49	45	30
Bulk density	1.2	1.36	1.23
% F. c	36	37	36
% PWP	20.3	21.0	20.6

Table 2 . Length of irrigation intervals (days) for each treatment.

Treatments	Pre-flowering	Post-flowering
A1	14	14
A2	14	21
A3	14	28
B1	21	14
B2	21	21
B3	21	28
C1	28	14
C2	28	21
C3	28	28

Table 3. Effect of Number of Irrigations on Consumptive water use (CWU-mm), Water-application efficiency (WAE-%) and Water productivity efficiency (kgm^{-3}).

Cod	Season 2000-01				Season 2001-02			
	Irrig. No.	CWU	WAE	WUE	Irrig. No.	CWU	WAE	WUE
A1	8	350	47	0.45	7	369	50	0.30
A2	6	285	51	0.62	5	270	48	0.43
A3	5	326	61	0.60	5	217	40	0.42
B1	7	361	57	0.50	6	316	50	0.39
B2	5	301	56	0.57	5	221	41	0.45
B3	4	248	55	0.59	4	209	46	0.44
C1	6	351	79	0.79	5	228	51	0.59
C2	5	244	72	0.94	4	210	62	0.69
C3	4	199	59	0.77	3	126	37	0.69

Table 4. Effects of differential irrigation regimes on the yield and yield components, seasons 2000-01 and 2001-02.

Treat. code	Plant height (cm)	Pods/plant	100 Seed weight (g)	Yield (kg/ha)	Biomass (kg/ha)	Harvest Index (%)
Season 2000-01						
A1	139 cd	29 ab	50 ab	3375 bc	6742 ab	52
A2	135 bc	29 ab	50 ab	3255 bc	7130 ab	50
A3	130 abc	27 ab	53 b	3229 bc	6375 ab	52
B1	139 cd	29 ab	51ab	3164 b	6284 ab	52
B2	129 abc	34 b	47 a	3060 b	6196 ab	51
B3	124 a	27 ab	51ab	2673 a	5045 a	58
C1	147 d	24 a	51 ab	3545 c	7579 b	47
C2	132 abc	23 a	49 ab	31776 b	6288 ab	52
C3	125 ab	21 a	53 b	2619 a	5784 ab	47
SE±	1.6	1.7	0.9	70.1	388	3.5
CV%	4.1	21.8	6.1	7.8	21.1	23.8
Season 2001-02						
A1	116 ab	18 ab	49 bcd	2261 abc	4418 ab	52
A2	114 ab	16 ab	50 bcd	2437 c	5332 ab	47
A3	119 ab	17 ab	51d	2225 abc	4430 ab	52
B1	124 b	15 ab	50 cd	2469 c	4841 ab	52
B2	119 ab	15 ab	47 abc	2411 bc	4862 ab	51
B3	110 a	16 ab	46 ab	2017 ab	3810 a	47
C1	118 ab	20 b	48 bcd	2630 c	5649 b	51
C2	116 ab	16 ab	45 a	2326 abc	4692 ab	51
C3	114 ab	15 ab	47 abc	1984 a	4873 ab	47
SE+	1.9	0.8	0.7	77.6	309.2	2.8
CV%	5.5	15.8	4.7	11.7	22.4	19.7

† Means followed by common letters are not significantly different from each other according to Duncan's Multiple Range Test (DMRT).

Table 5. Effect of differential irrigation at vegetative and reproductive stages on growth, yield and yield components of faba bean 2000-01.

Treatment	Yield kg/ha	100seed wt (g)	Pods/ plant	Seeds /pod	TBY kg/ha	HI %	Plant Ht. (cm)
Veg. Stage							
14	3361^{A†}	51	28.4^{A}	2.6	6749	51	135
21	2965^{B}	50	28.9^{A}	2.6	5841	54	131
28	3113^{B}	51	22.7^{B}	2.7	6550	48	135
SE±	86	0.9	1.6	0.08	388	3.5	1.6
Sig. Level	**	NS	*	NS	NS	Ns	NS
Reprod.							
14	3361^{A}	51^{A}	27.4	2.7	6868	50	142^{A}
21	3238^{A}	48^{B}	28.6	2.6	6538	51	132^{B}
28	2840^{B}	52^{A}	23.9	2.7	5735	52	126^{C}
SE±	86	0.9	1.6	0.08	388	3.5	1.6
Sig. Level	**	*	NS	NS	NS	NS	**
C.V.%	9.5	6.1	21.1	10.3	21.1	23.7	4.1
AxB	*	NS	NS	NS	NS	NS	*

* Significant at P=5%, ** Significant at 1% *** significant at P=0.1%, NS = Not significant.

† Means followed by common letters are not significantly different from each other according to Duncan's Multiple Range Test (DMRT)

Table 6. Effect of differential irrigation at vegetative and reproductive stages on growth and yield components of faba bean 2001-02.

Treatment	Yield kg/ha	100seed wt (g)	Pods/ plant	Seeds /pod	TBY kg/ha	HI %	Plant ht (cm)
Veg. Stage							
14	2307^{A†}	49.9	16.9^{A}	2.6	4734	51	116
21	2299^{B}	47.7	15.7^{A}	2.6	4504	50	118
28	2313^{B}	46.5	19.9^{B}	2.7	5075	50	116
SE±	77.6	0.7	0.8	0.08	308.2	2.8	1.9
Sig. Level	NS	*	NS	NS	NS	NS	NS
Reprod.							
14	2453^{A}	49.2^{A}	17.5	2.7	4974	52	119^{A}
21	2391^{A}	46.9^{B}	16.0	2.6	4968	50	116^{B}
28	2075^{B}	48.0^{A}	16.1	2.7	4371	48	114^{C}
SE±	77.6	0.7	0.8	0.08	308.2	2.8	1.9
Sig. Level	**	**	NS	NS	NS	NS	NS
C.V.%	11.7	4.7	15.8	10.3	22.4	19.7	5.5
AxB	NS	NS	NS	NS	NS	NS	NS

Table 7. Effect of differential irrigation regimes and growth stages on grain yield ($kgha^{-1}$) of faba bean in Selaim, season 2000-01 and 2001-02.

Vegetative (days)	14	21	28	Mean
		Season 2000-01		
Reproductive				
14	3375 ab	3164 ab	3545 a	3361 a*
21	3480 ab	3060 b	3176 ab	3239 a
28	3229 ab	2673 c	2619 c	2840 b
Mean	3361 a	2966 b	3113 b	
SE±	86.4			
		Season 2001-02		
Reproductive				
14	2261 ab	2391 ab	2631 a	2428 a*
21	2437 ab	2411 b	2326 ab	2391 a
28	2224 ab	2017 c	1945 c	2062 b
Mean	2307 b	2273 a	2301 b	
SE±	77.6			

*Within each growth phase, means followed by the same letter are not statistically different from each other according to (DMRT).

Table 8. Effect of watering regimes at vegetative and reproductive stages on the incidence of some insect pests of faba bean at Selaim basin.

Growth stages	No. of S. exigua Larva/stem√x+1	% leaflet damaged by S. exigua	Aphids/stem √x+1
Vegetative phase			
14	1.08	36.2	2.7
21	1.08	37.4	2.6
28	1.00	40.1	1.6
SE±	0.2	2.3	0.9
Reproductive phase		42.8	2.5
14	1.04	34.5	1.9
21	1.08	36.3	1.5
28	1.04		
SE±	0.22	2.3	0.8
CV%	16.25	56.5	77.1

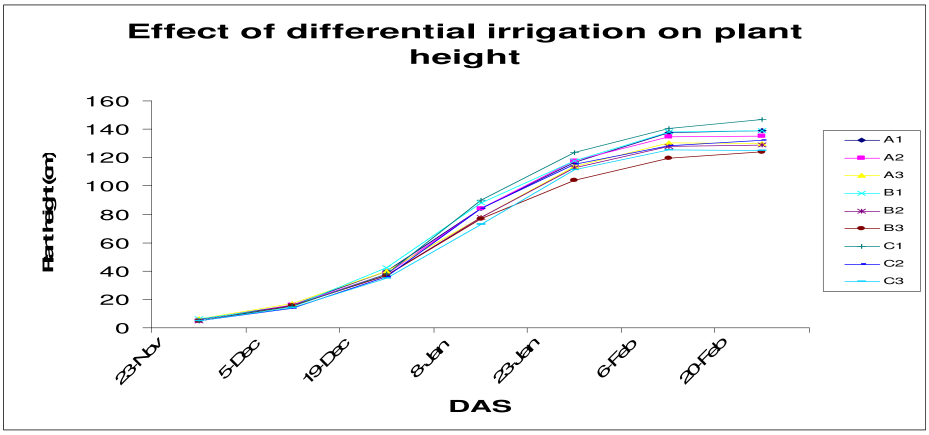

Figure1. Time course of plant height measurement for different treatments

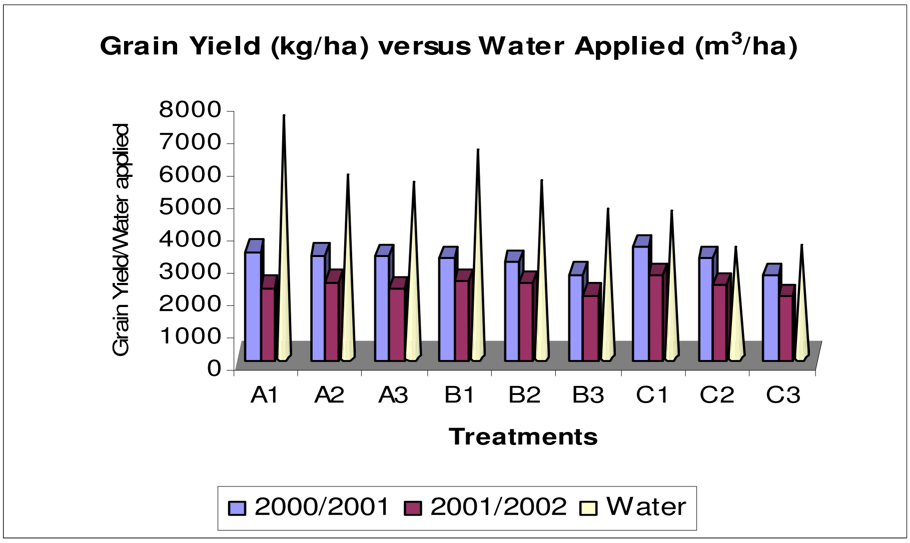

Figure 2. Relationship between water used and grain produced