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Effect of Irrigation Interval and Nitrogen and Phosphorus Fertilizers on Forage Yield and Water Productivity of Fodder Barley (*Hordium vulgare* L.) in Gezira

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Abstract: An experiment was conducted during three consecutive seasons viz 2003/04, 2004/05 and 2005/06, at Gezira Research Station Farm (latitude 14°24'N, longitude 33°31'E, and altitude 405 m asl) to determine the optimum irrigation interval and nitrogen and phosphorus fertilization of barley (*Hordium vulgare* L.) for forage. Experimental design was split-split plot design with three replications. Three irrigation intervals, viz every 10 days (W1), 15 days (W2) and 20 days (W3) were assigned to the main plots, two phosphorus levels, (0P) and 96 kg P_2O_5/ ha (1P) were assigned to the subplots and three nitrogen levels (0N), 96 (1N) and 192 kg urea/ ha (2N) were assigned to the sub subplots. The experiment was run during the 3rd week of November, with a local variety of barley (Baladi). Quantity of the applied water, dry matter yield at milk stage and of dry forage water productivity (kg dry matter / $m^3$of applied water) were determined. The three years mean quantity of water applied to the treatments W1, W2 and W3 were 4525, 4320 and 4290 m^3/ ha, respectively. The dry matter yields of barley in the three seasons decreased with increase of the irrigation interval. The comparatively higher dry matter yield in 2004/05 was attributed to lower day/ night temperatures during tillering - milk stage (30 - 75 days after sowing). The three years dry forage water productivities were 1.07 kg/m^3 (W1), 0.82 kg/m^3 (W2) and 0.71 kg/m^3 (W3). The forage yield increased with increase in level of N fertilization. The effect of P fertilization on dry matter yield was not significant. The highest dry matter yield was associated with the combination of irrigation every 10 days and 192 kg urea /ha.

Key words: Barley; forage production; irrigation intervals, N and P fertilization

INTRODUCTION

Prophet Mohammed *peace and prayers being upon him* have urged Muslims in a Hadeeth to economize the water of ablution even in the neighborhood of rivers. Fresh water was estimated at 0.01% to 0.002% of the earth water (Bohn *et al*. 1979). Irrigation water in the Sudan is a limiting factor for crop production since the easily irrigable areas are about 4.6 million hectares, while the annual share of irrigation water can irrigate only 2.5 million hectares. Hence, the concept of water productivity rather than land productivity should be used for crop choice. The planned area allotted for wheat in the Gezira scheme is about 167 000 ha; but due to the high cost of production, low yields and uncertainty of price, only about 62 500 ha are annually grown by wheat in the Gezira. To widen crop choices, barley, which produced high yield and good quality forage in the Gezira (Khair *et al*. 2001), can be considered as a winter fodder crop.

The research on barley as a forage crop in Sudan was started in the Gezira Research Station Farm in the year 2000 (Khair *et al*. 2001). Since then, however, quite a few number of studies were conducted in various parts of the Sudan. Those comprised studies on seed rate and sowing date in the Gezira (Salih *et al.* 2006). Seed rate and nitrogen fertilization were attempted in Dongola (Solomon Kumodan, personal communication). Cutting systems and time of nitrogen application were studied in Hudeiba (Mohammed 2006). Comparative performance with other winter sown forage cereals was carried out at a single sowing date in Gezira (Khair *et al.* 2007).

Water and nitrogen are the two most common limitations for crop production in arid and semi-arid regions, including Sudan. Favourable soil water conditions are required for high grain yield and for positive response to nitrogen fertilization (Frederick and Camberato 1995).

In Sudan, the yield of barley forage increased in response to the application of NP in the Gezira Research Farm (Khair *et al*. 2001). The objective of this study, therefore, was to determine the optimum irrigation interval and nitrogen and phosphorus fertilization for the production of forage barley in Gezira.

MATERIALS AND METHODS

An experiment was conducted for three winter seasons 2003/04, 2004/05 and 2005/06 at the Gezira Research Station Farm, Wad Medani, Sudan, (latitude14°24'N, longitude 33°31'E and altitude 405 m, asl). The objective was to study the response of fodder barley (*H. vulgare* L.) to three irrigation intervals; namely, every 10 days (W1), every 15 days (W2) and every 20 days (W3) in combination with three nitrogen levels in the form of urea at the rate of zero kg /ha (0N), 96 kg /ha (1N) and 192 kg /ha (2N) and phosphorous levels of zero kg /ha (0P) and 96 kg /ha (1P). The soil was montnorillonitic with high clay content and low organic matter. Land preparation involved disc plough, disc harrow, leveling and ridging to 60 cm wide ridges. The experiment was sown during the 3rd week of November every year. A local variety of barley referred to as “Baladi” was sown at the rate of 96 kg/ha, and the plots were kept weed free by two hand weedings. The plots were irrigated three times for establishment, before the treatments were applied. Super phosphate was applied simultaneously with sowing, and urea was applied before the second irrigation.

The quantity of irrigation water applied for each irrigation was measured by using ARC water flow metre, calibrated with the V-notch in the Hydraulic Research Station (HRS) Wad Medani. The trend of the quantity of water (m^3) measured by the ARC flow metre against the V-notch was plotted. It was evident from the trend line ($R^2 = 0.9923$) that quantity of water discharged could be obtained by dividing the flow metre reading by 6 as follows:

$$Q\ (m^3) = FR/6$$

where

Q: Water discharge (applied in m^3)

FR: Flow metre reading (final reading – start reading)

For forage yield, the plants were harvested 75 days after sowing (soft dough stage) and cut manually 10 cm above the ground from two central ridges. Fresh matter was immediately weighed in the field and was air-dried to determine the air dry matter. Data of the dry matter yields were statistically analyzed for the split-split plot design by Cropstat 7.2 software.

RESULTS AND DISCUSSION

Meteorological data

The meteorological data of the experimental site, during the three growing seasons, are shown in Table 1. During the mid stage (30–75 days after sowing), both maximum and minimum mean temperatures of 2004/05 were considerably lower than those of the other two seasons. During this period the maximum temperatures were closely comparable, but the min temperatures in 2003/04 were lower than those of 2005/06. The values of relative humidity of 2005/06 were considerably higher than those of the other two seasons (Table 1).

Irrigation water

In the three seasons (2003/04, 2004/05 and 2005/06), the number of irrigations were 7, 6 and 5 for W1, W2 and W3, respectively. Table 2 shows the total quantity of irrigation water applied for each irrigation level. Except for season 2004/05, the quantity of water for each of W2 and W3 were considerably lower than those of W1. In the three years, the quantity of irrigation water was in a descending order of W1, W2 and W3. The mean quantity of the irrigation water in 2004/05 was considerably higher than those of the other two seasons. The three years average amount of the applied water for barley on 10 days interval was only 4525 m^3/ha. In contrast, that of *Sorghum bicolor* cv. Wad Ahmed was 7880 m^3/ ha when irrigated on weekly basis during the rainy season in the Gezira (Elhadi 2007). That of wheat in the Gezira was 8181-8951 m^3/ ha when applied at 50% moisture depletion (Zakia 2000). To compare this with barley, the 50% soil moisture depletion often coincided closely with irrigation every 10 days in this study. For maize, however the best yields were obtained at rainfall of 1200 - 1500 mm (Skerman and Riveros 1990). This is equivalent to 12000 - 15000 m^3/ ha. The study, therefore presents barley as a water saving crop. In fact, the average amount of the applied water for barley constituted about 57% and 50% of those of Wad Ahmed and wheat, respectively.

Dry matter yield (DMY)

Considerable differences in the DMY were found between the three years. The mean DMY in 2003/04, 2004/05 and 2005/06 were 2.2, 5.4 and 3.6 t/ha, respectively. DMY ranged from as low as 0.5 t/ha in 2003/04 to as high as eight t/ha in 2004/05 (Table 3). In general and with few exceptions, the DMY in each year decreased with the order of W1, W2 and W3 and 2N, 1N and 0N. In each year, the lowest dry matter was associated with W3 and 0N, while the highest yield was associated withW1 and 2N (Table 3). The response of the crops to varying irrigation regimes seems to be climate-dependent. For instance, the dry matter yield of barley in response to W1 was significantly higher than those of either W2 or W3. The same trend was reported for five forage crops grown during March – June in the Gezira. The common factor between this study and that of Gezira is the low RH%. In contrast to the present findings, however, the irrigation regimes did not significantly affect the forage yield of 4 summer forage crops during July–September in the Gezira (Taha 2010), probably due to high RH% resulting from the rains which prevailed during this latter study.

Plant height

The shortest plant heights of barley in the milk stage were in 2003/04 while the tallest were in 2004/05 (Table 3). The irrigation regimes and nitrogen fertilization significantly affected plant height. The effect of the irrigation regimes was significant in a descending order of W1, W2 and W3. Those of nitrogen were in a descending order of 2N, 1N and 0N. The tallest plants heights were associated with W1 and 2N while the shortest were associated with W3 and 0N. The effect of phosphorus or the interaction of phosphorus with the irrigation regimes on plant height was not significant (Table 3).

Table 1. Mean maximum (max.), minimum (min.) temperature (°C) and relative humidity (%) during the three developmental stages of barley in the three seasons

	Sowing – pre tillering			Stage	Start tillering-milk stage				Stage
Month	Nov.	Dec.		mean	Dec.	Jan.			mean
days	3	1	2		3	1	2	3	
Season				**Temperature**					
2003/04	34	33	37	35	37	33	37	36	36
Max.									
2003/04	16	13	14	14	13	18	14	15	15
2004/05	40	39	40	40	32	32	31	34	32
2005/06	38	38	38	38	35	38	32	36	35
Min.									
2004/05	17	19	16	17	15	15	12	15	14
2005/06	22	19	20	20	18	19	16	15	17
				Relative humidity (%)					
2003/04	35	36	37	36	37	37	36	35	36
2004/05	30	41	41	37	41	32	31	31	34
2005/06	35	39	39	38	39	45	38	47	42

1, 2 and 3 refer to dekad during the growing month

Table 2. Total quantity of water (M^3/ha) in each irrigation regime

Nitrogen Level	Irrigation					
	W1	W2	W3	W1	W2	W3
	Plant height (cm)			DM (t/ha)		
			2003/04			
0N	46	33	32	1.7	0.6	0.5
1N	54	51	47	3.1	2.4	2.0
2N	55	48	44	4.4	2.8	2.4
LSD 0.05		2.47			0.26	
			2004/05			
0N	72	65	53	5.3	4.4	3.5
1N	80	67	61	6.1	5.0	4.7
2N	83	72	63	8.0	6.0	5.5
LSD 0.05		4.07			0.84	
			2005/06			
0N	68	54	45	4.4	3.2	2.2
1N	77	57	47	4.5	3.9	2.6
2N	85	85	50	5.3	4.1	2.7
LSD 0.05		3.06			0.26	

W1, W2 and W3: Irrigation every 10, 15 and 20 days, respectively

Table 3. Effect of watering regimes x nitrogen levels on plant height and dry matter (DM) yield

Season	Irrigation treatment			
	W1	W2	W3	Mean
2003/04	446	4056	3791	4097
2004/05	4663	4737	4246	4549
2005/06	4466	4166	4043	4225
Mean	4525	4320	4290	

W1, W2 and W3: Irrigation every 10, 15 and 20 days, respectively

Water productivity (WP)

The WP of forage barley was considerably affected by the growing season, irrigation regime and nitrogen application (Table 4). Season - wise, the WPs were 0.54, 1.21 and 0.85 kg/m^3 for season 2003/04, 2004/05 and 2005/06, respectively. The higher water productivity of barley in 2004/05 is a reflection to higher dry matter yields than reduction in irrigation water. In fact, the mean quantity of irrigation water of 2004/2005 was even higher than those of the other two seasons. Regarding the water regimes, the WP of W1 in the three seasons was higher than those of either W2 or W3. Overall treatments and seasons, the WPs of W1, W2 and W3 were 1.08, 0.82 and 0.70 kg/m^3 respectively. In each season, the WP over all the irrigation regimes tended to increase with increase in nitrogen fertilization. Over the 3 seasons, the WP of 0N, 1N and 2N were 0.66, 0.89 and 1.06 kg/m^3, respectively. In each season, the highest WP of forage barley was associated with W1 and 2N (Table 4).

Table 4. Water productivity of barley forage (kg/m^3) as affected by season, irrigation regime and nitrogen fertilization in the Gezira

Nitrogen level	**Irrigation regime**		
	W1	W2	W3
		2003/04	
0	0.38	0.16	0.14
1	0.70	0.59	0.53
2	0.98	0.69	0.46
		2004/05	
0	1.22	0.92	0.82
1	1.46	1.05	1.11
2	1.83	1.28	1.28
		2005/06	
0	0.97	0.76	0.54
1	1.0	0.92	0.65
2	1.18	0.98	0.67
Mean	1.08	0.28	0.70

Mean water productively is 0.54, 1= 21 and 0.85 and Kg/m3 for 2003/04, 2004/05 and 2005/06, respectively
W1, W2 and W3: Irrigation every 10, 15 and 20 days, respectively
0N= zero kg/ha; 1N = 96 kg/ha; 2N= 192kg/ha

In conclusion, compared to other field crops, the average applied irrigation water for barley is low and water productivity is high even if irrigated every 10 days. Barley is characterized by high dry matter yields especially in cool seasons. The highest dry matter yield of barley was associated with the application of 192 kg urea / ha and irrigation every 10 days.

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