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Effect of Different Irrigation Intervals on Wheat (*Triticum aestivum L)* in Semi-arid Regions of Sudan.

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ABSTRACT: A field experiment was conducted for two consecutive winter seasons (2008/09-2009/010) at the Demonstration Farm, College of Agricultural Studies, Sudan University of Science and Technology, to study the effect of different irrigation intervals on growth, yield, yield components and water use efficiency of wheat (*Triticum aestivum* L.).Wheat cultivar Condor was grown with different irrigation intervals namely every 7, 10, 14, 21 and 28 days. The experimental design was a randomized complete block design with four replications. The parameters studied were: plant height, dry matter accumulation, number of plants/m^2, number of tillers/plant, days to five leaf stages, days to 50% heading, days to maturity, number of spikes/m^2, spikelets/spike, number of grains/spike, 1000-grain weight, grain and straw yield , water use efficiency and protein%. The results showed that there were highly significant differences in the studied parameters due to irrigation intervals, except for days to fifth leaf stage and harvest index in the first season and number of plant/m^2 in second season, where the irrigation every 7days recorded higher values, slightly different from 10 days. The results showed highly significant differences in treatments effects on biomass, straw and grain yield, harvest index, water use efficiency and protein content. In general irrigation every 7 and 10 days gave the highest protein content, grain, straw yield and field water use efficiency. But for economics aspect irrigation every 10 days is recommended. Irrigation every 14 have no remarkable effect, on the other hand irrigation every 21, and 28 days must be avoided under this semi-arid condition.
KEY WORDS: *Irrigation, intervals, wheat, production*.

INTRODUCTION

Demand for wheat in the past was not very high because the nutritional habit of the majority of the Sudanese population was based mainly on sorghum. At present, wheat consumption has increased and the government is attempting to attain self-sufficiency in this commodity. In order to fulfill this objective, it is necessary to increase the cultivated area and obtain maximum output from each unit volume of water (m^3) consumed. Therefore, knowledge of the optimum time to apply the available water is necessary for the effective water use, labor and capital (Farah, 1994). Wheat production under semi-arid conditions of Sudan is now a success. Grain yield of over 5 tons/hectare were obtained with high technology use. However, lack of yield stability over seasons and location has remained a great challenge to both research and production management (Babiker and Faki, 1994). The crop is grown entirely under irrigation, either from river flows, as in

Gezira, New Halfa and the White Nile Agricultural Schemes, or lifted from the River Nile and wells using diesel pumps, as in the Northern State and River Nile state (Farah, 1994). Ageeb (1993) stated that, irrigation water and irrigation practices are factors which have always limited wheat productivity. The recommended number of irrigations at the vegetative and the reproductive stages need to be applied properly and timely for better yields. Furthermore, low soil moisture conditions reduce the number of reproductive tillers which limit their contribution to grain yield (McMaster, 1999). Detection of crop water stress is critical for efficient irrigation water management, especially in the semi-arid regions. On the other hand, irrigation water is becoming increasingly scares; this highlights the importance of the effective and efficient use of this resource. Therefore, the objectives of this study are to investigate the effects of different watering intervals on wheat yield, yield components, water use efficiency and protein%.

MATERIALS and METHODS

A field experiment was conducted for two consecutive winter seasons (2008/09-2009/010) at the Demonstration Farm, College of Agricultural Studies, Sudan University of Science and Technology, latitude 15° 40′ N, longitude 32° 32′ E and altitude 386m above sea level. The soil was montmorillonitic clay with a pH in the range of 7.8- 8.5 (Abdelhafiz, 2001). The climate of the locality was described by Adam (2002) as a semi-desert and tropical with low relative humidity. The mean annual rainfall is about 160 mm and the mean maximum temperature is more than 40 ◦C in summer and around 20 ◦C in cool season. Solar radiation is about 400 – 500 cal cm^{-2} day^{-1}. Wheat cultivar Condor was subjected to different irrigation intervals namely: W_1 = Irrigated every 7 days ,W_2 = Irrigated every 10 days, W_3 = Irrigated every 14 days, W_4 = Irrigated every 21 days, and W_5 = Irrigated every 28 days. The laid out of experiment was randomized complete block design, repeated four times.

Land preparation started on October by removal of stubble and pre-sowing irrigation was applied to help control weeds and to facilitate land preparation. Then a disc-plough was used followed by disc-harrow and leveling followed by ridging at a spacing of 70 cm. The size of the plot was 4x4 m consisting of 5 ridges. The crop was sown manually on top of the ridges at 3 cm depth. In each plot the two outer ridges were used for growth sampling and the middle three ridges were used for yield determinations. The crop was sown on the 25th of November, 2008 and 21th of November 2009 for the two seasons respectively. The seed rate was 120 kg/ha mixed by Iiroon-star 42 (3 g/kg seeds) to protect the seeds before and after seedling. Urea (46%N) was applied before the second irrigation at the rate of 86 kg/ha in both seasons, in addition to 43 kg/ha superphosphate (P_2O_5 =46%) applied at the side of the ridges and covered with soil just before sowing. The crop was free from weeds in the second season, but some broad leaved weeds occurred in the first season, and were removed manually. Insect infestation was very minor in the second season, while in the first season an infestation of aphids was observed. The infestation was limited to the border. Final yield was estimated from the effective area in the middle of each plot. Number of plants per square meter, by counting all shoots per sample (whole plants + tillers). Five samples were taken from each plot after 15 days from sowing (DAS) in two seasons, the number of tillers was counted from the main stem plant. Five readings were recorded throughout the crop development cycle viz. 15, 30, 45, 60 and 75 days after sowing (DAS). Five plants were randomly selected from each plot, labeled, and their heights were periodically determined. Average plant height measured in cm was then recorded. Five plants samples were oven dried at 75 – 80°C for 24 hours and weights then recorded to determine the dry matter accumulation in (g). Time to five leaf stage was determined from the day of sowing until the 5 Th leaf appearance. Like wise, the 50% spikes formation. For final harvest, one metre row was sampled from the three middle ridges, and spikes were randomly taken from each plot to study the following parameters: i) number of spikes / m^2 ii) number of spikelets / spike iii) number of grains / spike and iv) thousand-grains weight (g):

The 1000 grains were carefully counted from the same sampls of each plot. The weight of the sample was precisely determined. Final biological yield (kg/ha), from one meter row in each plot was carefully determined. The whole bunch of plants were carefully uprooted and taken to the crops laboratory, left to dry thoroughly for a week, before they were weighed. Final grain yield (kg/ha). Straw yield kg/ha = biomass - grain yield.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield} \times 100}{\text{Total biological yield}}$$

Water use efficiency (WUE) was calculated using the equation of Ali and Talukder, (2008) for grain yield as follow:

$$\text{WUE (kg/mm/ha)} = \frac{\text{Grain or seed yield(kg/ha)}}{\text{Water applied to the field (mm/ha)}}$$

Sample of grains from each plot in the second season were taken to the chemistry laboratory for protein analysis.

The data on plant parameters were analyzed year wise on individual basis and their means were computed. Statistical analyses for ANOVA were carried out by using "MSTAT-C" (Anonymous, 1986) whereas the means were compared through Duncan's Multiple Range Test at (p=0.05) and Excel program to illustrate and compare data on figures.

RESULTS and DISCUSSION

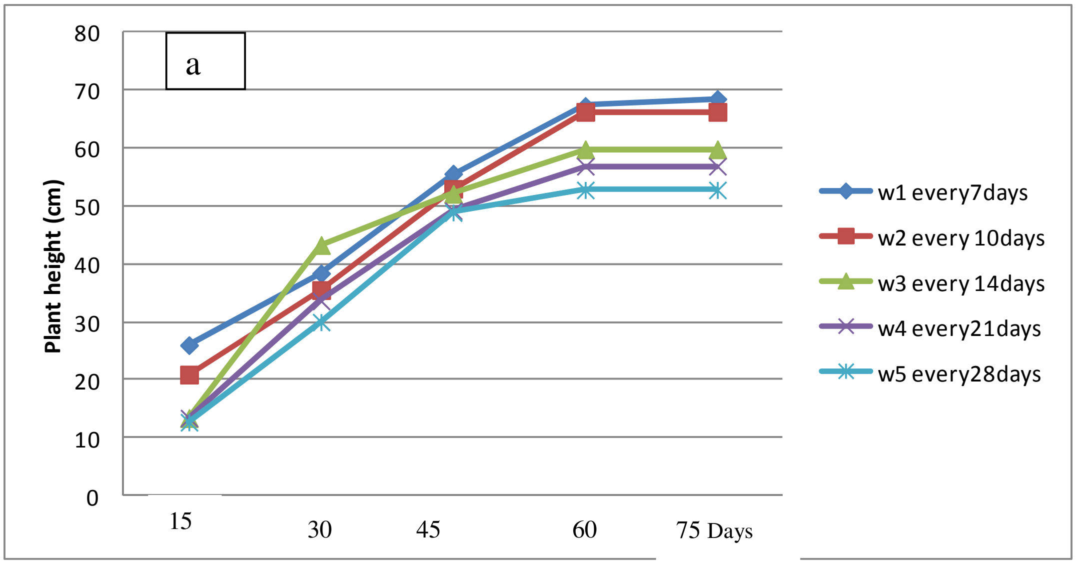
Generally, the results showed that growth and yield attributes of wheat under different irrigation intervals were highest when irrigation intervals were shortest. Also growth and yield attributes were relatively lower in the first season than in the second season at all sampling periods due to weather and Aphids effects.

Plant height (cm):

The shorter irrigation intervals (7, 10 and 14 days) resulted in taller plants compared to the longest irrigation intervals (21 and 28 days) (Figuer 1_a, 1_b). Several investigations from different parts of the world reported that plant height increased with more frequent irrigation and decreased with less frequent irrigation (Elmonyeri *et al*., 1982). Haikl and Melegy, (2005) reported that the positive effect of irrigation on plant height may be attributed to the effect of irrigation on the encouragement of cell elongation, cell division and consequently increased meristemic growth.

Dry matter accumulation (g):

High dry matter production is an important pre-requisite for high grain yield. In the present study (Figuer. 2_a, 2_b) dry matter accumulation was sensitive to water deficit, it was consistently reduced under water stress. Supporting evidence was reported by Squie *et al*., (1989) who observed that the simple linear relationship between dry matter production and radiation interception break down when water is in short supply. The present finding showed that in both seasons dry matter accumulation was consistently greater with shorter irrigation intervals (7, 10 and 14 days) than the longer ones (21 and 28days). The reduction in dry matter accumulation may be attributed to unbalanced soil water-air relations that led to reducing the photosynthetic activity and unbalanced relations between plant hormones and biological processes in the whole plant organs (Schneider and Howell, 1997).



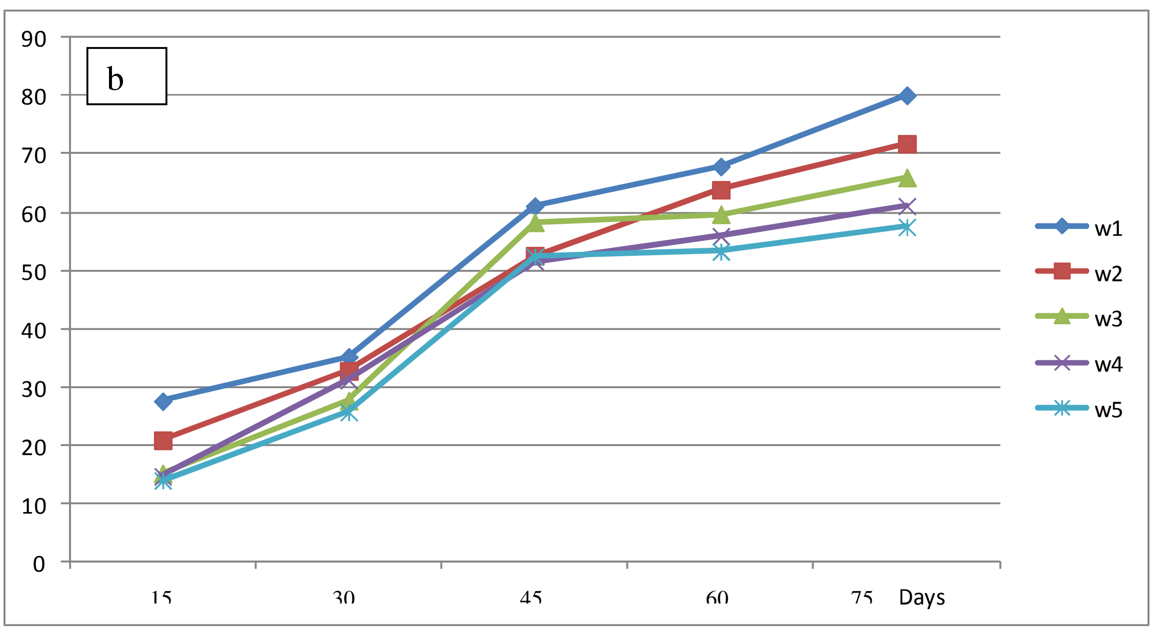
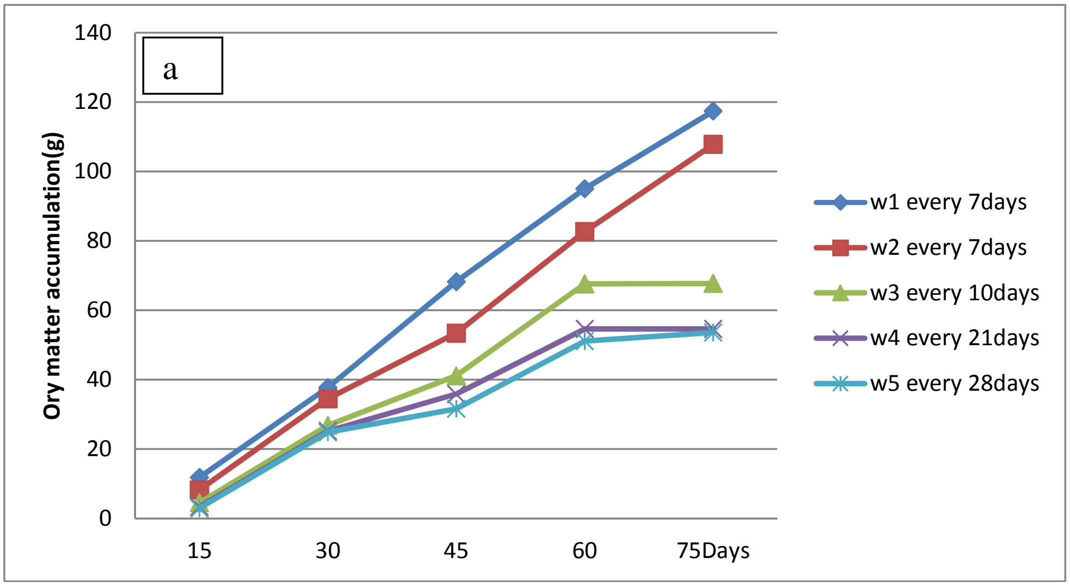


Figure 1. Effect of different irrigation intervals on plant height (cm) of wheat during (a) 2008/09 season and (b) 2009/010 season



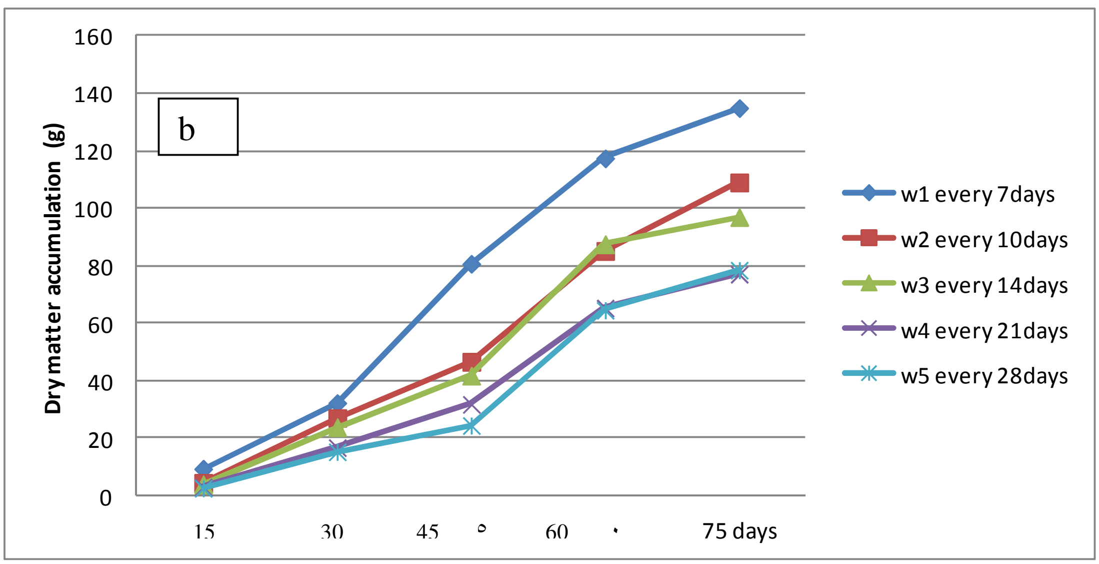


Figure 2. Effect of different irrigation intervals on dry matter accumulation (g) in wheat during (a) 2008/09 season, (b) 2009/010

Number of Plants /m^2 and Number of Tillers/plant:

The highest number of plants/m^2 and surviving tillers were associated with the shorter irrigation intervals 7, 10 and 14days (Table 1). Cooper (1980) and Awad *et al*., (2000) found greater tiller survival with frequent irrigation. The beneficial effect of frequent irrigation may be due to improved availability of nutrients in the upper surface of the soil where the nodal roots usually spread. Survival of productive tillers was reported to be positively correlated with grain yield (Shanahan *et al*., 1985). The higher number of tillers may be attributed to adequate moisture supply, particularly at tillering stage. Bajwa *et al*., (1993) observed significant effect on varying levels of irrigations on the number of tillers/m2.

The final yield of wheat is the product of the number of spikes/m^2 x spikelets/spike x grains/spike x weight of grains. However, the different irrigation treatments in this study showed different effects on the components of yield.

Table 1: Effect of different irrigation intervals on plants/m^2 and tillers/plant of wheat during 2008/09 and 2009/010 seasons:

Treatments	2008/09		2009/010	
	Plants/m^2	Tillers/plant	Plants/m^2	Tillers/plant
W_1	188.8a	4.6a	144.6a	4.1a
W_2	176.9a	4.1a	144.6a	4.1a
W_3	169.3ab	3.5bc	126.9a	3.8ab
W_4	151.1bc	3.1c	134.6a	3.4ab
W_5	154.6c	3.6b	128.7a	3.2b
LSD	21.33	0.48	25.9	0.72
SE±	6.92	0.16	5.4	12.9
CV%	8.33	8.34	3.8	0.24

Means followed by the same letter in each column are not significantly different at p=0.05 according to DMRT. $W_{1=}$irrigation every 7 days ,$W_{2=}$ irrigation every 10 days ,$W_{3=}$irrigation every 14 days ,$W_{4=}$irrigation every 21 days ,$W_{5=}$irrigation every 28 days

Yield and yield components:

Number of spikes/m^2:

Shorter irrigation intervals (7 and 10 days) produced greater number of spikes/m^2 in both seasons (Table 2). Bajwa *et al* (1993) observed significant effect of varying levels of irrigations on the number of spikes/m^2. From this study a greater percentage of dead tillers were associated with the most unfavorable treatments (intervals 21 and 28 days). Under favorable conditions, however, Shanahan *et al.*, (1985) reported greater number of spikes/m^2 with frequent irrigation. The most favorable treatments in this study (interval 7, 10 and 14 days) gave the highest number of spikes/m^2.

Number of Spikelet/spike:

The shorter irrigation intervals (7 and 10days) caused insignificant increase in the number of spikelets per spike in both seasons (Table 2). These results are in agreement with those obtained by Awad *et al*., (2000).

Number of grains/spike:

In the two seasons respectively, shorter irrigation intervals (7 and 10 days) produced greater number of grains/spike (Table 2). The maximum number of grains/spike obtained may be due to suitable moisture availability for those treatments (Hussain, 1996; Akram, 2000).

Thousand-grain weight (g):

The present results (Table 2) showed that 1000-grains weight increased with short irrigation intervals (7,10 and 14 days) than longer ones (21 and 28 days) in both seasons. These results are in agreement with Ibrahim (1995) and Martin and Drewitt (1982) who reported consistant increase in grain weight with frequent irrigation.

Table 2: Effect of different irrigation intervals on yield components of wheat during 2008/09 and 2009/010 seasons:

Treatments	2008/09				2009/010			
	Spikes/m^2	Spikelets /spike	Grains /spike	1000grain weight(g)	Spikes/m^2	Spikelets /spike	Grains /spike	1000grain weight(g)
W_1	260.8a	58.9a	51.5a	40.8a	278.6a	50.9a	47.2a	37.5a
W_2	243.8a	46.2b	40.5b	38.5b	227.9b	47.4a	44.1a	37.5a
W_3	175.7b	34.0c	27.2c	35.7c	220.5bc	36.3b	32.9b	34.9b
W_4	154.3bc	27.7cd	22.1cd	32.9d	218.8bc	30.9c	26.4b	33.7c
W_5	144.6c	26.1d	18.4d	32.1d	201.4c	25.8d	21.2d	33.3c
LSD	24.3	7.4	5.7	2.0	20.9	4.9	4.3	0.63
SE±	7.9	2.4	1.9	0.7	6.8	1.6	1.4	0.6
CV%	8.1	12.4	11.6	3.6	5.9	8.3	8.0	3.6

Grain yield (kg/ha):

The results of grain yield (kg/ha) are shown in Table 3. In both seasons, grain yield was significantly reduced under longer irrigation intervals due to lower number of tillers/plant, number of spikes/m^2, number of spikelets-/spike, number of grains/spike and 1000-grains weight. These results are in agreement with those obtained by Awad *et al*. (2000), El Hadi and Khadr (2003) and Singh *et al*., (2009).

Straw yield and Biomass (kg/ha):

The shorter irrigation intervals resulted in higher biomass and straw yield in the two seasons (Table 3). Increasing soil moisture depletion by decreasing the amount of irrigation progressively from ear-emergence to harvest, reduced straw and grain yields. This was in conformity with the findings of Omer and Aziai (1993).

Water use efficiency (WUE) kg/mm/ha: The water use efficiency is expressed as kg grain/m^3 water consumed by wheat plants. This criterion has been used to evaluate the crop production under different irrigation treatments. The present findings are in harmony with the scientific approaches that supposed the plant roots could extract more soil water from a greater depth under conditions of stress as compared to those irrigated at relatively wet situations. That means the stored water in soil at water stress can be used with more efficiency. These results are in agreement with those reported by El Hadi and Khadr (2003) who indicated that wheat responded to water stress conditions. Haikel and Melegy (2005) concluded that the maximum grain yield and lowest water use efficiency of wheat were recorded when irrigated with the recommended irrigation requirements under sandy soils and sprinkler irrigation system.

Harvest index:

The shorter irrigation intervals also increased the harvest index slightly in both seasons (Table 3). The lower harvest index in the first season was due to the taller plants with few spikes and grains which contributed to straw yield and hence resulted in low harvest index.

Table 3: Effect of different irrigation intervals on grain and straw yield, harvest index and water use efficiency of wheat during 2008/09 and 2009/010 seasons:

	2008/09					2009/010				
Treat ments	Grain yield (kg/ha)	Straw yield (kg/ha)	T B Y (kg/ha)	W U E kg/m /ha	H I %	Grain yield kg/ha	Straw yield kg/ha	T B Y kg /ha	W U E kg/m /ha	H I %
W1	2869a	6709a	9578a	3.48c	30.2a	4080a	6961a	11040a	4.13b	36.9a
W_2	2279a	6018a	8798b	4.o5b	29.9a	3071b	5830b	8900b	4.17b	34.5ab
W_3	1964b	3369c	5768c	4..09b	34.1a	2522c	5393bc	7915c	4.90b	31.9ab
W_4	1355c	3105c	4459d	4.44ab	30.6a	2362c	4432d	6293d	6.10a	37.7a
W_5	1197c	2971c	4167d	4.85a	30.8a	1979d	4589cd	6567d	6.48a	30.6b
LSD	209.5	674.8	487.4	0.516	4.70	326.7	897.4	795.6	0.835	5.97
SE±	68.0	219.0	158.2	0.17	1.53	106.0	291.2	258.2	0.27	1.9
CV%	6.7	9.9	4.8	8.0	9.8	7.6	10.7	6.3	10.6	11.3

T B Y=total biomass yield

Protein content%: The effect of watering intervals on protein % are presented in Table 4. The results revealed that protein contents are sensitive to water frequency and water stress especially irrigation interval every 28 days, and this may due to effect of water stress on physiology and growth of wheat.

Table 4: Effect of different irrigation intervals on protein content% of wheat during 2009 season:

Treatments	Protein content%
W_1	11.7a
W_2	11.7a
W_3	10.7a
W_4	10.8a
W_5	8.3.b
LSD	1.84
SE±	0.6
CV%	11.2

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