U. of K J. Agric. Sci. 24(1), 60-74, 2016

Effects of Irrigation System and Interval on Fodder Productivity of Lucerne (*Medicago sativa* L.) Under Semi-arid Environment

El Nadi[1], A.H. and Idris[2], A.Y.

[1]**Faculty of Agriculture, University of Khartoum, Sudan**
[2]**Faculty of Agriculture, University of Zalingi, Sudan**

Abstract: A field experiment was conducted in the Faculty of Agriculture, University of Khartoum,(Lat. 15°40′ N. Long. $32^0$32′ E). and 380 metres above sea level. The investigation was for three years, during January to August of 2007, 2008 and 2009. The objectives of the experiment were to study the effects of the irrigation intervals of 8 days (W_1) and of 12 days (W_2) on the yield of lucerne fodder, using drip and sprinkler irrigation systems, each of which received 8mm day^{-1} The amount per irrigation of W_1 was therefore 8x8=64mm and that of W_2 was 8x12=96mm .The experimental design was radomized complete block because the geographical site could not allow other designs. The results showed that the production of lucerne irrigated at W_1 was higher than that obtained at W_2 by about 70 % from the total yield of 2007, 2008 and 2009 by (42 % in drip irrigation and 38 % in sprinkler irrigation). During the relatively cool weather (January to March), the yield was more than during the hot weather (April to June). Fodder production during the rainy season (July and August) was higher than during the hot season. This was probably a result of cloudy and rainy condition. Water use efficiency (WUE) under the W_1 irrigation interval was more than at the irrigation interval W_2 in each of 2007, 2008 and 2009. The high productivity was associated with high leaf /stem ratio.

Key words: Lucerne; irrigation systems; irrigation intervals

INTRODUCTION

Lucerne (*Medicago sativa* L.) is the main irrigated leguminous fodder in northern Sudan. The demand for fodder is increasing with increasing animals brought from rain-fed pastures to temporary settlements to prepare them for export. Furthermore, dairy farms are also increasing with continuous growth in urban population (Zaroug *et al.* 1997).

According to the Nile Waters Agreement of 1959 the annual share of the Sudan is about $20x10^9$ m^3, while the irrigable area is about 20×10^6 ha. (Farrah 1998). The share for agriculture shall, no doubt, be reduced when allowance is made for increasing needs for hydro-electric power, industry, domestic and recreational uses. The arid and semi-arid zones of the Sudan represent about 70% of the total area (Ayoub 1998). Hence, sound water management and high water use efficiency must always be targeted.

Adequate attention was given to determine the water requirements of lucerne grown under arid and semi-arid conditions. Examples for this are the contributions of Carter and Sheaffer (1983), Grimese *et al*. (1993), Saeed and El Nadi (1997), Ahmed and Sid Ahmed (2009), Al Lawati *et al.* (2010), Hansen (2011), and the comprehensive FAO review (FAO 2011). Nevertheless, there is scanty work to give reasons for the differences in the yield of lucerne fodder in response to the combined effects of irrigation inputs, irrigation systems, soil moisture and seasonal changes in weather. Therefore, the present undertaking was made to bridge some gaps in the information needed for proper irrigation scheduling of lucerne.

MATERIALS AND METHODS

Duration and location of the experiment:

This work was carried out in the Faculty of Agriculture, Shambat, University of Khartoum, (Lat. $15^0 40'$ N. Long. $32^0 32'$ E) and 380 metres above sea level. Lucerne (*M. sativa* L.) was sown in December, 2006. After the crop was established, data collection was during January to August 2007, 2008 and 2009.

The irrigation system

Two irrigation systems were used:-

(1) Drip irrigation with 70 cm lateral spacing, 50 cm between emitters and with a pressure regulator to stabilize the discharge rate during operation time.

(2) Overhead sprinkler system, 1.5 m above ground level, the sprinklers were 15 m apart and rotated to deliver water to the intended experimental plots and guard area.

Crop establishment

The irrigation systems were installed 15 m apart so that no water of irrigation was allowed to be received by other experimental plots when the amount or interval was different from the other system.

Under drip irrigation seeds were sown on rows 70 cm apart and 50 cm within the row to meet the delivery of the emitters. For the sprinkler system, the seeds were sown on the flat and the seed rate was the equivalent of 10 kg ha^{-1} for each irrigation system. A basal dose of urea (46%N) was applied to enhance crop growth before the rhyzobium nodules were effective to fix atmospheric nitrogen. Aphids were controlled with primore (48%), when necessary. The treatments were introduced after the first cut to help initiation of basal buds to produce tillers for good crop cover.

Treatments and experimental design

The experimental plot was16 m^2. The irrigation intervals were once every 8 days (W_1) and every 12 days (W_2), both of which received 8 mm day^{-1}. Thus the amounts per irrigation for W_1 and for W_2 were 64 and 96 mm, respectively.

The experimental design was randomized complete block with four replicates for each of the two irrigation systems. Other designs were not possible because of limitation in land area. Soil moisture was determined gravimetrically, and the sampling depths were 0-15, 15-30, 30- 45, 45-60 and 60-90cm from the soil surface. Depleted moisture between any two successive irrigations was calculated by the difference in moisture content soon after water applied infiltrated from the soil surface and the moisture content just before the next irrigation.

Samples and measurements

The amount of water used to produce the weight of monthly cuts of fodder was calculated. Fresh fodder was cut every 30 to 32 days and weight was based on a sample area of one m^2 within each of the experimental plots .The dry weight was based on a sub-sample of 100g and was expressed in tons ha^{-1} and ranged between 20 % to 22 % of the fresh weight.

Crop water use efficiency (CWUE)

This parameter was calculated by dividing the weight of dry matter (DM) (tons ha^{-1}) by evapotranspiration (mm) during the period of producing the crop (Michael 1978).

Effect of seasonal weather on fodder production

The monthly average DM, was based on the average of the four plots of W_1 and of W_2 under sprinkler and under drip irrigation during the period January to August of 2007, 2008 and 2009.

RESULTS

Table 1 shows that the difference in amount of irrigation per year was only 64mm, and Table 2 show's that drip irrigation W_1 produced higher yield (kg ha^{-1}) than W_2 in 2007, 2008 and in 2009. The relatively lower yield of W_1 and W_2 in 2008 was probably due to the low rainfall in 2008, being only 87mm.

Table 1. Irrigation number and amount per irrigation and year for intervals W_1 and W_2

Irrigation interval (days)	Number	Irrigation Amount Per irrigation (mm)	Irrigation amount per year(mm)
8 (W_1)	28	64	1792
12 (W_2)	18	96	1728

Table 2. Fodder yield of lucerne (kg ha^{-1}) as affected by rain amount and irrigation interval for 2007, 2008 and 2009

Years	Rain (mm)	Yield (kg ha^{-1})	
		W_1	W_2
2007	127	1919	1855
2008	87	1879	1815
2009	140	1932	1868

Drip irrigation applied every eight days produced significantly higher yield than that produced by sprinkler irrigation in most of the eight cuts in 2007 (Table 3). This is probably due to the higher moisture content below the soil surface as a result of using drip irrigation.

Table 3. Effects of irrigation intervals and type on the dry weight (t/ha) of eight cuts of lucerne fodder in 2007.

Treatments:	Cut No.								
	1	2	3	4	5	6	7	8	Means
a)Sprinkler irrigation									
W_1	3.08	2.86	2.86	2.73	2.69	2.68	2.57	2.16	2.70
W_2	2.83	2.37	2.42	2.46	2.60	2.19	2.20	2.01	2.39
S.E±	0.18	0.11	0.16	0.12	0.18	0.19	0.06	0.16	0.15
LSD(0.05)	ns	0.35*	ns	ns	ns	ns	0.19*	ns	0.46
C.V %	8.62	11.00	5.77	6.61	10.00	11.31	3.72	11.00	8.50
b)Drip irrigation									
W_1	3.12	3.06	2.96	2.89	2.84	2.79	2.57	2.44	2.83
W_2	2.28	2.79	2.85	2.58	2.37	2.27	2.43	2.22	2.47
S.E±	0.11	0.05	0.08	0.08	0.09	0.09	0.15	0.06	0.09
LSD(0.05)	0.35*	0.16*	ns	0.25*	0.29*	0.29*	ns	0.19*	0.28
C.V%	5.79	2.52	3.93	4.32	4.99	4.93	8.60	3.72	4.85

ns. = not statistically significant; * = significant at 0.05;

The dry weight of lucerne per cut in 2008 under the drip system was only significantly higher than that of the sprinkler system in three of the eight cuts (Table 4) but with a higher mean for the eight cuts. This exceptional result was probably due to error in sampling or possibly the fact that the difference between treatments did reach 100 % as will be seen in the discussion in which the superiority of the drip over sprinkler irrigation was 70.4 %.

Table 4. Effect of irrigation intervals and type on the dry weight (t/ha) of eight cuts of lucerne in 2008.

Treatments.	Cut No.								
	1	2	3	4	5	6	7	8	Mean
a)Sprinkler irrigation									
W_1	2.76	2.71	2.67	2.67	2.66	2.65	2.44	2.11	2.58
W_2	2.42	2.33	2.31	2.35	2.18	2.45	2.06	1.96	2.26
S.E±	0.18	0.11	0.17	0.18	1.16	0.28	0.26	0.17	0.31
LSD(0.05)	ns	0.35*	ns	ns	ns	ns	ns	ns	1.00
C.V%	6.55	4.45	4.38	7.66	4.63	3.91	4.73	5.71	5.25
b)Drip irrigation									
W_1	2.75	2.70	2.69	2.64	2.62	2.58	2.55	2.47	2.63
W_2	2.34	2.36	2.33	2.16	2.26	2.24	2.26	2.22	2.27
S.E±	0.14	0.15	0.19	0.11	0.12	0.16	0.28	0.11	0.16
LSD(0.05)	ns	ns	ns	0.35*	ns	ns	ns	ns	0.50
C.V%	7.62	6.22	3.21	6.56	5.34	6.71	4.01	7.77	5.93

ns. = not statistically significant; * = significant at 0.05; .

The yield per cut using the drip irrigation was higher than the sprinkler irrigation in six of the eight cuts and also was higher in the mean of the eight cuts (Table 5).

Table 5. Effect of irrigation intervals and irrigation type on the dry weight (t/ha) of eight cuts of lucerne in 2009.

	Cut No.								
Treatment	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Mean**
a) Sprinkler irrigation									
W_1	2.66	2.61	2.61	2.55	2.46	2.41	2.33	2.16	2.47
W_2	2.25	2.36	2.31	2.31	2.21	2.26	2.05	2.01	2.22
S.E±	0.12	0.38	0.19	1.08	0.19	0.66	0.29	0.12	0.38
LSD(0.05)	0.38*	1.21	0.60	3.44	0.60	2.10	0.92	0.38	1.20
	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	
C.V%	6.47	3.73	4.34	5.65	4.27	7.82	5.33	9.47	5.89
b) Drip irrigation									
W_1	2.69	2.59	2.59	2.59	2.54	2.47	2.44	2.44	2.54
W_2	2.31	2.33	2.32	2.31	2.29	2.26	2.22	2.22	2.28
S.E±	1.08	0.16	1.15	0.25	0.08	0.19	0.12	0.11	0.39
LSD(0.05)	3.44	0.51	3.66	0.80	0.25*	0.60	0.38	0.35	1.25
	n.s	n.s	n.s	n.s		n.s	n.s	n.s	
C.V%	5.23	8.77	5.65	8.71	3.20	6.37	9.41	4.34	6.09

n.s. = not statistically significant; * = significant at 0.05;.

Fodder production under drip irrigation was higher than that of sprinkler irrigation, and irrigation interval W_1 was higher than W_2 in the three years.

Table 6. Effect of irrigation intervals and type on total DM yield (t / ha^{-1}) of the eight cuts of lucerne fodder under drip and sprinkler irrigation in 2007, 2008 and 2009

Years	W_1	W_2	Increase in DM	%
		Drip irrigation		
2007	22.64a	19.76 a	2.88a	15
2008	21.04b	18.16 b	2.88a	16
2009	20.32b	18.24 b	2.09b	11
Means	21.33A	18.72B	2.61	14
		Sprinkler irrigation		
2007	21.60a	19.12a	2.48a	13
2008	20.56b	18.08b	2.48a	14
2009	19.76c	17.76c	2.00b	11
Means	20.64A	18.46B	2.18	12

Means in columns and /or rows followed by the same letter(s) are not significantly different at $P< 0.05$ according to Duncan Multiple Range Test.

Water use efficiency (WUE)

Fig 1a. shows that the irrigation interval W_1 had higher WUE than that of W_2 for eight monthly cuts under sprinkler irrigation. However, there was decline in WUE at cut 4 harvested in March (end of the cool season). Thereafter, WUE declined for both W_1 and W_2 for cuts number 4, 5 and 6 (the hot season) and declined further in cuts No. 7 and 8 (the humid monsoon season).

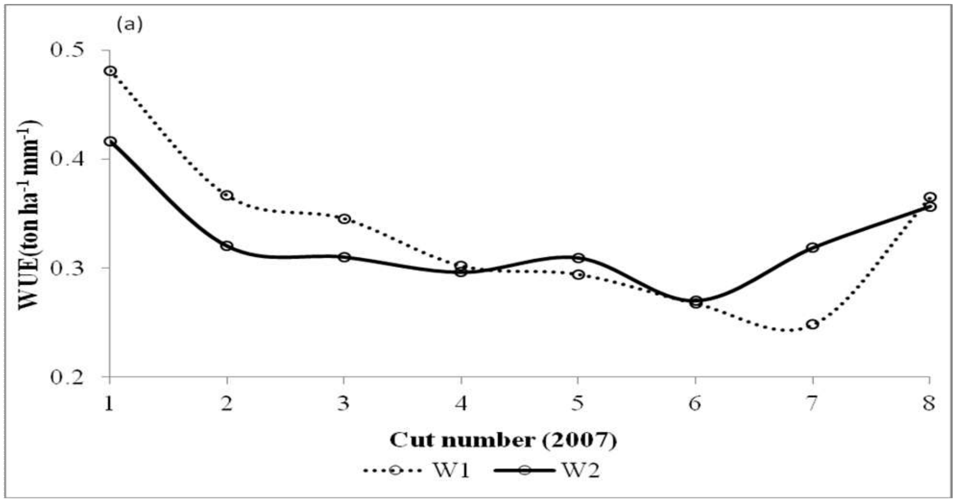

Fig 1a. Water use efficiency for sprinkler irrigation at two irrigation intervals W_1 and W_2 in 2007

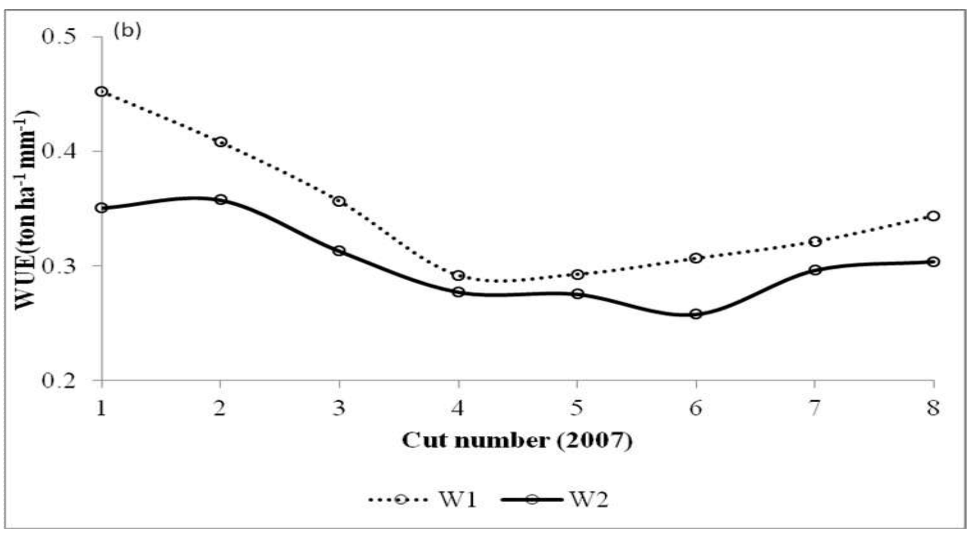

Fig 1b. Water use efficency for drip irrigation at two irrigation intervals $W_1$and W_2 in 2007

WUE was similar for cut 1 then declined to cut 4 during the hot season for both sprinkler irrigation and drip irrigation yet, WUE increased up slightly to cut 8 (the cool season).

The difference between Fig 1a and Fig 1b in 2007 is due to the higher effect of sprinkler irrigation on WUE during the cool season (January – March), but effect declined during the hot season (April – August). Moreover, in 2007 the drip irrigation at W_1 maintained a higher level of WUE and that the more frequent irrigation W_1 was higher than W_2 .

In 2008 (Figs 2a. and 2b) and 2009 (Figs 3a and 3b) the difference in WUE due to the irrigation intervals W_1 and W_2 was maintained but with differences in magnitude due to the environmental changes between the three season (Idris and El Nadi 20014).

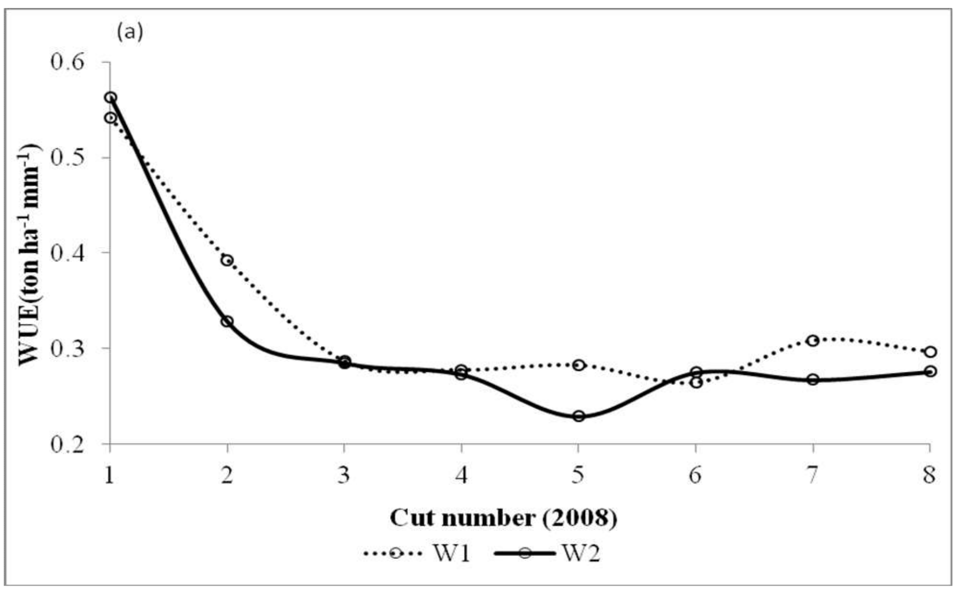

Fig 2a. Water use efficiency for sprinkler irrigation at two irrigation intervals W_1 and W_2 in 2008

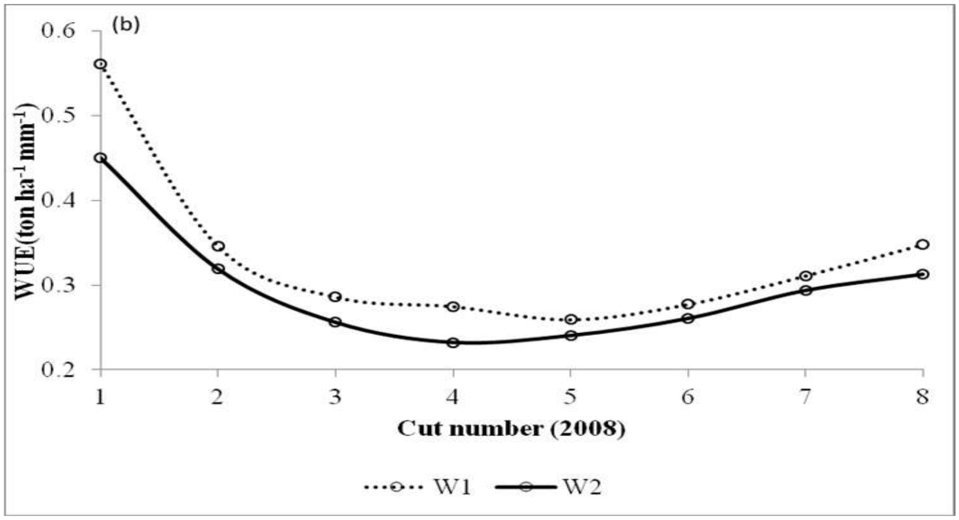

Fig 2b. Water use efficincy for drip irrigation intervals W_1 and W_2 in 2008

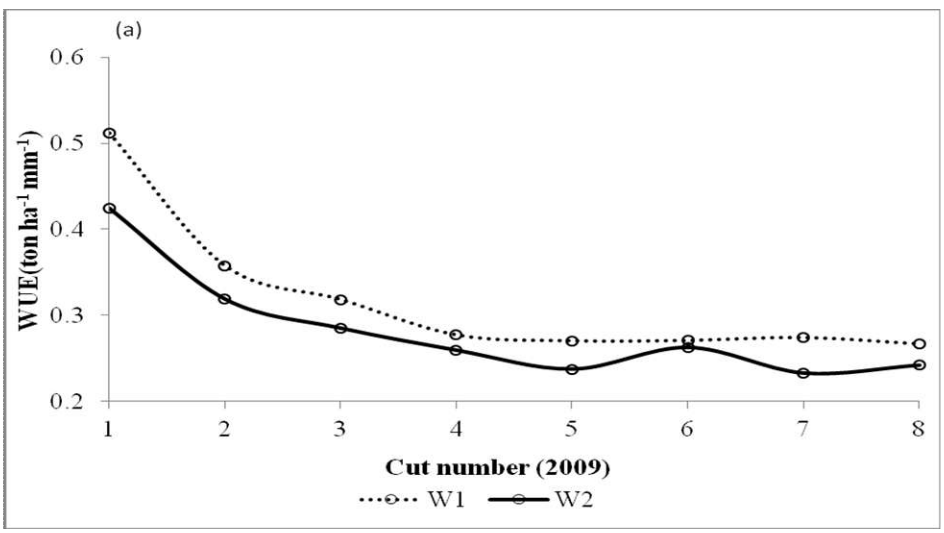

Fig. 3a. Water use efficiency for sprinkler irrigation at the two irrigation intervals in 2009

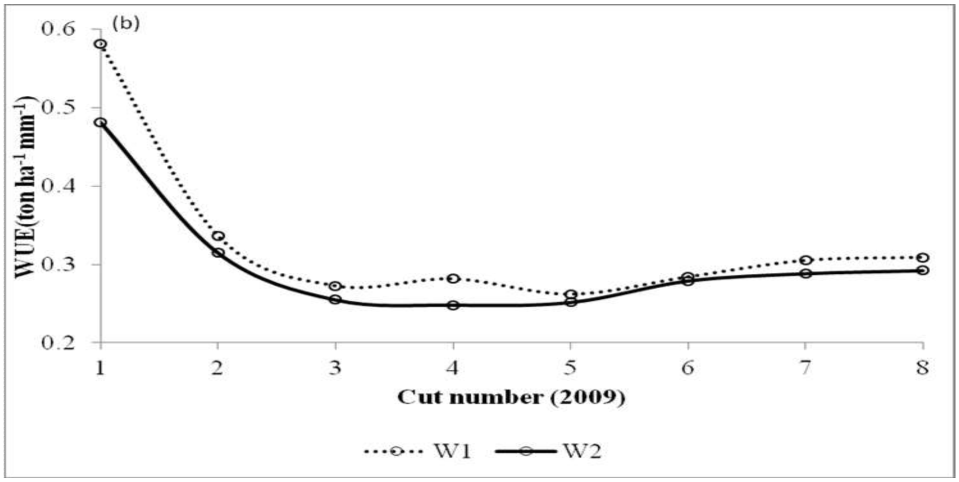

Fig 3b. Water use efficiency for drip irrigation at the two irrigation intervals in 2009

DISCUSSION

The samples taken from the experiment included the comparison of the dry weight of eight cuts taken every month of the three years. The result showed that the dry yield of the drip irrigation was significantly higher (P=0.05) than that obtained from the sprinkler system in 17 cuts out of the total of 24 cuts taken in the three years *ie* 70.4 %.

The fresh and dry weights of leaves and stems and the calculated values of WUE were higher at the irrigation mterval of 8 days than that applied every 12 days.

The productivity of lucerne declined in the hot season of the year and increased during the cool season. The irrigation interval of 8 days produced higher yield than the irrigation mterval of 12 days. The reason for this is possibly due to the higher moisture content below the soil surface, as measured at the depths of 0–30, 30 – 45, 45–60 and 60–90 cm. This finding is similar to that found by Saeed and El Nadi (1991) and Carter and Sheaffer, (1983). Moreover, in a comprehensive review, it was reported that frequent irrigation of about 8 to 10 days produced higher yields of lucerne than longer irrigation periods (FAO 2011). Drover (1966) found that heavy irrigation in the order of about 90 to 100 mm, as applied to his experiment, resulted in temporary water logging in heavy clay soils at a site near the location of this experiment. Carter and Sheaffer (1993) found that anaerobic conditions, reduced water availability even for short periods. WUE as shown in Figs 1, 2 and 3 shows that in the eight cuts irrigation interval W_1 resulted in higher values than that of W_2.

CONCLUSION

Irrigation every 8 days produces better yield of lucerne fodder than irrigation every 12 days. Drip irrigation excelles sprinkler irrigation irrespective of the irrigation interval.

Higher crop productivity is coupled with higher leaf/stem ratio, more than with higher WUE.

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تأثير نظام الري وفتراته علي إنتاجية علف البرسيم

عبدالمحسن حسن النادى[1] وعبداللطيف يوسف ادريس[2]

1- كلية الزراعه - جامعة الخرطوم
2- كلية الزراعه - جامعة زالنجي - السودان

المستخلص: أجريت تجربة لدراسة تأثير معاملات فترات الري (8 أيام و 12 يوم) ونظام الرى بالتنقيط و بالرش علي إنتاجية علف البرسيم خلال الفترة من يناير الى اغسطس في كل من عام 2007 و 2008 و 2009 في مزرعة كلية الزراعه بجامعة الخرطوم, بإستخدام تصميم القطاعات العشوائية الكاملة.
كانت زيادة المحصول نتيجة للري بالتنقيط حوالي 70 % من مجموع المحصول الناتج في السنوات 2007 و2008 و2009. كما اتضح أيضاً أن كفاءة الري (Water use efficiency) نتيجة للري كل 8 ايام كانت أعلى من تلك الناتجة من الري كل 12 يوماً في كل من السنوات 2007، 2008 و2009.
كانت إنتاجية العلف المحصود في الفصل المعتدل من السنه (يناير – مارس) افضل من الانتاجيه في الفصل الحار (ابريل – يونيو) وقد تدنت الانتاجية اكثر من ذلك في الفصل الممطر من السنه مع ارتفاع الرطوبه النسبيه . وقد كانت الانتاجية العاليه من العلف مصحوبة بمعدل اكبر في نسبة وزن الاوراق الجافه الى الوزن الجاف لسوق النبات (Leaf/stem ratio).