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Effect of Water Stress and Cutting Frequency on Alfalfa (*Medicago sativa* L.) Seed Production*

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Abstract: A split-plot experiment was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, during the period January 1999 - June 2000 to study the effect of water stress and cutting frequency on seed production of alfalfa (*Medicago sativa* L.). Three irrigation intervals (7, 14 and 21 days) were assigned to the main plots and designated I_1, I_2 and I_3, respectively, and three cutting frequencies; namely, 21, 28 and 35 days were assigned to the subplots and given the symbols C_1, C_2 and C_3, respectively. Data were collected on number of racemes per plant, number of pods per raceme, number of seeds per pod, 1000-seed weight and final seed yield. Correlation analyses were carried out between yield and some of its components. The results revealed that shorter irrigation intervals (7 and 14 days) were significantly better than the longer interval (21 days), and the 35 days cutting frequency was the best for seed yield. Neither the number of seeds per pod nor the 1000-seed weight were affected by the cutting intervals. However, the former was significantly affected by irrigation intervals. Mean seed yield for the irrigation intervals was 77.9, 86.2 and 41,4 kg/ha for I_1, I_2 and I_3, respectively. On the other hand, cutting frequencies resulted in seed yields of 38.1, 78,2 and 89.2 kg/ha for C_1, C_2 and C_3, respectively. Correlation analyses showed that seed yield was highly correlated with 1000-seed weight and number of seeds per pod.

Key words: Alfalfa; water stress; cutting frequency; seed production

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INTRODUCTION

Alfalfa or lucerne (*Medicago satva* L.) is the most important forage crop in the world. Its worldwide distribution is attributed to its remarkable adaptation to wide variations in climatic and soil conditions. Furthermore, it has well-known characteristics of longevity, symbiotic nitrogen-fixation, high yield of good quality herbage, suitability for mechanical harvesting and good recovery after cutting or grazing. The crop contributes to the feeding of horses, farm animals and poultry. The crop is either grazed or used as green fodder or given *in situ* as hay. Alfalfa has high feeding value, compared to commonly grown fodder crops, due to its high protein and mineral contents and is an excellent source of vitamin A (Marble 1989).

The irrigated forages in the Sudan constitute about 4% of the total natural pasture and silvo-pastoral grazing. Irrigated fodders are mainly grown in the Northern (0.5 million tons), Khartoum and Eastern States (one million tons each). Khair (1999) stated that alfalfa constitutes 94%, Abu Sabeen (fodder sorghum) about 5% and the other leguminous forages about 1%.

In addition to its high nutritive value, alfalfa plays an important role in crop rotation through its positive effects on soil fertility, soil structure and soil erosion. It can be grazed alone or in mixtures with grasses and other legumes. However, in heavy clay soils (Vertisols) of the Sudan, soil compaction results from the stay of the crop before clearance.

Alfalfa makes its best growth in relatively dry climates where water is available for irrigation, and also withstands long periods of drought but with reduced productivity. In humid climates, however, it is grown successfully in central, eastern and southern United States. The best soils are deep loams with porous subsoil. Carpenter and Johnson (1996) showed that high yield of alfalfa and less susceptibility to root and crown diseases can be obtained by light and frequent irrigation with good drainage. El Hag (1988) reported that frequent irrigation is the best for economic production under the conditions of heavy clay soils, such as those of central Sudan.

The main objective of this work was to study the effect of different irrigation regimes and different cutting frequencies on seed production of alfalfa.

MATERIALS AND METHODS

This study was conducted in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, Shambat (lat. $15^o40^'$ N, long. 32 $^o32'$E,380 m asl). The climate of the locality is semi-arid, with low relative humidity. The temperature varies between 45^oC maximum and 21^oC minimum in summer, and 25^oC and 15^oC in winter (Adam 2002). The soil is alkaline, (pH 8.0), with about 50% cracking clay (Drover 1966; Saeed 1968). The soil contains about 0.07% nitrogen, 0.23meq/l potassium and 0.1935 meq/l available phosphorus (Mohamed 1999).

Seeds of the local variety "Hegazi" were obtained from Pioneer Seed Company, Khartoum, Sudan. The layout of the experiment was split-plot design with four replicates. The main plots comprised the three irrigation intervals of 7, 14 and 21 days and were designated I_1, I_2 and I_3, respectively, while the subplots were assigned for the three cutting frequencies: 21, 28 and 35 days, designated C_1, C_2 and C_3, respectively.

Since lucerne seeds are small and need well prepared fine seedbed, the experimental area was disc ploughed, disc harrowed and then leveled to facilitate even flow of irrigation water. The seeds were sown on ridges 0.7 m apart. The plot size was 16 m^2, and a guard area of 5 m width was reserved on the western and northern sides of the experimental plots to avoid animal attacks. The seeds were broadcast at the rate of 59.4 kg/ha, and the sowing date was 15^{th} of January 1999. Irrigation was delivered immediately after sowing, and the second was 7 days thereafter in order to facilitate seedling emergence. Weeds were effectively controlled manually.

Meteorological data; namely, daily mean temperature, hours of bright sunshine, wind speed, pan evaporation, rainfall and relative humidity, during the study period, were obtained from Shambat Meteorological Observatory, about 250 m away.

Seed Production

After the last cut in March 2000 (15 months after sowing), the crop was left without cutting to allow the development of pods for seed production during the sunny weather of March to June, 2000, at the time when the bees were abundant and active for pollination. Data on the following parameters were collected:

Number of racemes per plant: An area of 0.7 m^2 in the centre of one of the two middle ridges in each plot was reserved for counting the number of racemes, throughout the period from April 12 to May 10, 2000, at ten days interval, starting from the appearance of the first floral bud. Five plants were randomly chosen from the reserved area in each plot and tagged for counting the number of racemes and was expressed as average per plant.

Number of pods per raceme and number of seeds per pod: At harvest time (June 2000), the five tagged plants were harvested separately and the average number of pods per raceme and the average number of seeds per pod were recorded

Total seed yield : Seed yield was determined when the crop was 80%-90% mature, as indicated by the change of the colour of pods from yellow to brown and dark brown (Marble 1989). Mature pods were picked manually three times at an interval of ten days. The harvested pods for each plot were collected in paper bags and air-dried for 15 days. The pods were then threshed manually, and the seeds were cleaned using 1.6 mm sieve. The clean seeds were weighed, and the total seed yield for each plot was determined and expressed as kg/ha.

Thousand-seed weight: From the seed yield of each plot, one thousand seeds were counted at random, weighed and the average weight was expressed in grammes.

Statistical analysis

Correlation analysis was carried out between yield and some of its components, giving the regression equations and values of r^2. Means were separated and compared using Duncan's Multiple Range Test, as was stated by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Irrigation interval, time of cutting and their interaction significantly influenced the number of racemes/plant after the last cut. I_2 and I_3 were not significantly different from each other, but significantly increased the number of racemes per plant as compared with I_1 (Table 1). The interactions I_2xC_2, I_2xC_3 and I_3xC_3 resulted in a significantly higher number of racemes/plant than all other interactions, whereas I_2xC_1 interaction showed significantly lower means of the character than most interactions. This is in line with the findings of Ali (2000) who reported that both number of racemes per stem and number of pods per raceme are significantly increased by increasing the number of cuttings. He attributed this to the high nutrient reserves in the crown and root system. Similar results were also recorded by Messengle (1974) and Kharbeet and Al Shamma (1987) who found that number of racemes per stem and number of pods per raceme is increased by increasing the number of cuttings. In contrast to this finding, Taylor and Marble (1986) showed that number of pods per raceme is not affected by irrigation intervals.

The number of pods per raceme was significantly affected by irrigation interval, frequency of cutting and their interaction. I_2 treatment had a significantly higher mean number of pods per raceme than I_1 and I_3. Moreover, I_3 significantly increased this character as compared with I_1. Number of pods per raceme was significantly higher under C_3 treatment as compared with both C_1 and C2 which were not significantly different from each other.

On the other hand, the interaction I_2xC_3 significantly increased the number of pods/raceme, as compared with all other interactions, whereas I_1xC_1 and I_1xC_3 interactions gave significantly lower means of the same character (Table 1)

Irrigation interval significantly affected the number of seeds per pod, whereas time of cutting and the interaction did not affect this character. I_2 treatment significantly decreased the number of seeds per pod, compared to I_1 and I_3 which were not significantly different from each other (Table 2). Abu Shakra and Bray (1969) observed that 15 days irrigation interval increased the number of seeds per pod and total seed yield compared to shorter irrigation intervals, which might have resulted in water-logging.

Neither irrigation interval nor frequency of cutting or their interaction significantly affected 1000-seed weight, but they significantly increased seed yield per hectare. Both I_1 and I_2 treatments significantly increased seed yield as compared with I_3, but with no significant difference between them. Moreover, C3 had significantly higher seed yield than C_1 and C_2. Also, C_2 had a similar trend to C_3. The interaction I_2xC_3 gave significantly higher seed yield (Table 2).

Irrigation interval of 14 days significantly increased seed yield per unit area. This may be attributed to the effect of irrigation on some reproductive parameters, such as number of racemes per plant, number of flowers per raceme and number of pods per raceme. Taylor and Marble (1986) showed that seed yield is positively correlated with number of stems, number of racemes and number of pods per raceme. Pederson *et al.* (1972) mentioned that 1000-seed weight is significantly reduced with water stress, compared with excessive irrigation, whereas seed yield was reduced by about 13% at the water stress condition (21 days interval).

The longer cutting frequency increased seed yield significantly, and this may be due to the effect of one or more of the components of seed yield. Similar results were also reported by Ahmed (2000).

Table 3 shows the correlation coefficients between seed yield and some of the selected yield components. The highest correlation coefficient was between number of pods per raceme and number of seeds per pod (R^2 =0.99); followed by the correlation between number of pods and number of racemes per plant (R^2=0.63). This indicates that the number of racemes is not affected by cutting treatments. Nayel and Khidir (1995) found that there is no effect of cutting management on the number of racemes per unit area and number of seeds per pod. However, number of pods per unit area, number of pods per raceme and seed yield per hectare were positively affected by cutting management.

Table 1. Effect of irrigation intervals, cutting frequency and their interaction on the number of racemes per plant and number of pods per raceme of alfalfa during 1999/2000 season

	Number of racemes/plant				Number of pods/raceme			
Irrigation	C_1	C2	C_3	Mean	C_1	C_2	C_3	Mean
I_1	14.45^{ef}	16.50^{cd}	15.80^{dc}	15.58^{b}	41.75^{c}	50.05^{d}	41.05^{e}	44.28c
I_2	14.40^{f}	20.45^{a}	20.98^{a}	18.61^{a}	64.75^{bc}	68.15^{b}	76.50^{a}	69.80a
I3	17.80^{bc}	18.70^{b}	20.15^{a}	18.88^{a}	63.90^{bc}	55.85^{d}	62.85c	60.87b
Mean	15.55^{b}	18.55^{a}	18.98a		56.80^{b}	58.02^{ab}	60.13^{a}	
S.E.± for I				0.30				1.80
S.E.± for C				0.26				0.98
S.E.± for IxC				0.46				1.70

I_1, I_2 and I_3: Irrigation every 7, 14 and 21 days, respectively
C1, C2 and C3= cutting frequencies every 21, 28 and 35 days, respectively
Means followed by similar letter(s) are not significantly different at 0.05 level of probability, according to Duncan Multiple Range Test.

Table 2. Effect of irrigation intervals, cutting frequency and their interaction on number of seeds per pod, 1000-seed weight and seed yield of alfalfa during 1999/2000 season

	Number of seeds per pod				1000-seed weight (g)				seed yield (kg/ha)			
Irrigation	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C3	Mean
I_1	2.01[a]	1.91[a]	2.39[a]	2.10[b]	3.52[a]	3.35[a]	3.47[a]	3.45[a]	32.91[de]	112.74[a]	88.05[b]	77.90[a]
I_2	1.82[a]	1.55[a]	1.80[a]	1.72[a]	3.39[a]	3.19[a]	3.47[a]	3.35[a]	56.69[c]	83.27[b]	118.53[a]	86.16[a]
I_3	1.91[a]	2.17[a]	2.34[a]	2.14[b]	3.49[a]	2.96[a]	3.36[a]	3.27[a]	24.54[e]	38.60[d]	61.10[c]	41.41[b]
Mean	1.91[a]	1.88[a]	2.18[a]		3.47[a]	3.17a	3.43[a]		38.05[c]	78.20[b]	89.23[a]	
S.E.± for I		0.10				0.11				3.56		
S.E.± for C		0.23				0.11				2.12		
S.E.± for IxC		0.40				0.48				3.66		

I_1, I_2 and I_3: Irrigation every 7, 14 and 21 days, respectively
C_1, C_2 and C_3= Cutting frequencies every 21, 28 and 35 days, respectively
Means followed by similar letter(s) are not significantly different at 0.05 level of probability, according to Duncan Multiple Range Test

Table 3. Correlation coefficients (R^2) of yield and some yield components

	1000-seed wt	Number of seeds/pod	Number of pods/raceme	Number of racemes /plant	Seed yield
Seed yield	0.106	-0.577	-0.392	-0.329	
1000-seed wt		-0.06	-0.18	-21.84	0.106
Number of seeds/pod	-0.06		0.99	-1.41	-0.577
Number of pods/raceme	-0.18	0.99		0.633	-0.392
Number of racemes /plant	-21.84	-1.41	0.633		-0.329

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تأثير الاجهاد المائي وفترات قطع البرسيم علي انتاج البذور*

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موجز البحث: أجريت تجربة حقلية بالمزرعة التجريبية لكلية الزراعة جامعة الخرطوم، في الفترة من يناير 1999 وحتى يونيو 2000، لدراسة تأثير الإجهاد المائي و فترات القطع على إنتاج بذور البرسيم الحجازي. استخدم تصميم القطاعات المنشقة لتنفيذ التجربة والمكونة من ثلاث فترات للري (7 و 14 و 21 يوما) خصصت لها الأحواض الرئيسية و ثلاث فترات للقطع (21 و 28 و 35 يوما) خصصت لها الأحواض الفرعية. جمعت بيانات عن عدد العناقيد بالنبات، وعدد القرون بالعنقود الواحد، وعدد البذور بالقرن، ووزن الألف بذرة، والإنتاجية من البذور. كما أُجريت دراسة للعلاقة بين الإنتاجية من البذور وبعض مكونات الإنتاجية. أوضحت النتائج وجود فروق معنوية بين فترات الري القصيرة (7 و14 يوماً) و فترة الري الطويلة (21 يوماً)، وأن القطع كل 35 يوماً هو الأفضل لإنتاج البذور. لم يتأثر عدد البذور بالقرن ولا وزن الألف بذرة بفترات القطع، بينما ازداد عدد البذور بالقرن فى حالة الري كل 14 يوماً، وكان متوسط إنتاجية البذور 66.9 و 86.2 و 41.4 كجم/ هكتار لفترات الرى 7 و 14 و 21 يوماً على التوالي. ومن ناحية أخرى، كانت الإنتاجية 38.2 و 78.2 و 89.2 كجم/ هكتار لفترات القطع كل 21 و 28 و 35 يوماً، على التوالي. أوضحت النتائج أن إنتاجية البذور ذات ارتباط قوى مع وزن الألف بذرة وعدد البذور بالقرن.

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