EFFECT OF SEEDING RATE ON GROWTH AND YIELD OF TWO ALFALFA (MEDICAGO SATIVA L.) CULTIVARS

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Abstract

Purpose: A field experiment was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat during the period November 2001 to June 2002 to investigate the effect of seeding rates on growth and forage fresh and dry matter yields of two alfalfa (*Medicago sativa* L.) cultivars.

Design/methodology/approach: The treatments comprised four seeding rates viz; 10, 15, 20 and 25 kg ha-1 and two alfalfa cultivars (the local cultivar Hegazi and the introduced cultivar Siriver). The treatments were randomly assigned in a split plot design with four replicates. Parameters measured: plant density, plant height, leaf-to-stem ratio, leaf area index (LAI) and forage fresh and dry matter yields.

Findings: The results illustrated that a seeding rate of 25 kg ha-1 increased plant density, leaf area index and forage dry matter yield. A seeding rate of 15 kg ha-1 increased plant height and was superior over other seeding rates in forage fresh yield, whereas 20 kg ha-1 increased leaf-to-stem ratio. The local cultivar Hegazi tended to be superior over the introduced cultivar Siriver in plant height and forage fresh anddry matter yields. In contrast, the introduced cultivar was superior over the local one in plant density, number of leaves per plant, leaf area index and leaf-to-stem ratio.

Keywords: Seeding rates, Cultivars, Alfalfa, Growth, Yield

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INTRODUCTION

Livestock products serve to satisfy demands for food in developing and developed countries. Livestock production accounts for about 40 per cent of the gross volume of the world's agriculture production and its share is rising (FAO, 2002). It is the world's largest user of agricultural land, directly as pasture and indirectly through the production of fodder crops (FAO, 2002). In Sudan, the area of rangelands and irrigated forages is 96 million and 30 thousand hectares, respectively (Africover, 2005 cited in Abusuwar and Yahia, 2010). The estimated dry matter production for animal feed is 104.80 million tons (Abu-Suwar and Drrag, 2002).

Alfalfa (*Medicago sativa* L.) or lucerne, is probably the oldest fodder legume in the world. The crop, which belongs to the family Paplionaceae, is considered the queen of forages. Alfalfa is a better source of protein to livestock and adds high levels of nitrogen to the soil, reducing its erosion. The crop therefore has an important place in sustainable agriculture and environmental conservation. In Sudan, alfalfa is thought to be the chief fodder crop. The area under alfalfa production is estimated at 52521 hectare; however, the yield of the crop is relatively low (Ca 19.5 ton ha^{-1} fresh matter) (Abu-Suwar, 2004).

The question of how much seed to sow brings up many points of practical interest, especially in times when seeds are relatively expensive and frequently in short supply. When clean alfalfa seeds with a purity of 99 per cent are available, seeding rates of 25 to 30 kg ha^{-1} are recommended under flood irrigation, broadcast or drill conditions (Suttie, 2000). Seeding rates of 15 to 20 kg ha^{-1} are recommended on seedbeds that are extremely well prepared and when sprinkler irrigation is available (Suttie, 2000). Lichner and Khazim (1987) reported an increase in alfalfa plant density with increasing seeding rate. Hoveland *et al.* (1987) found no yield increase with increasing alfalfa seeding rate. However, during the establishment year, alfalfa forage yield was positively associated with seeding rate and yield was less consistent in subsequent years because of stand losses (Volence *et al.*, 1987; Boulton *et al.*, 1990). Furthermore, Sarraj (1987) pointed out that the alfalfa plant population was slightly affected by seeding rate.

In Sudan, common farmers' practice is to broadcast 53 to 106 kg ha^{-1} alfalfa seeds on flat plots; however researchers have made various alfalfa seeding rate recommendations. Khair (1999) recommended a

seeding rate of 8 to 10 kg ha^{-1} at Gezira (central Sudan), Shambat (towards the north) and Hudiba (northern Sudan). Notwithstanding, Nayel and Khidir (1995) showed that the optimum alfalfa seeding rate at Shambat (Khartoum) was 40 kg ha^{-1}. Hussein (1999) came up with a recommendation of 47.6 kg ha^{-1} at Khartoum. Other authors concluded that the alfalfa seeding rate could be reduced to about 50 per cent of normal recommendations without affecting the crop establishment in the first year (Rodrigues *et al.*, 1992). Similarly, Khair (1997) confirmed that the alfalfa seeding rate should be reduced to 12 kg ha^{-1} or even lower without considerable effect on forage yield. Obviously, in Sudan, the alfalfa seeding rate recommendations are controversial. The objective of this study was therefore to investigate the effect of seeding rate on alfalfa growth and forage fresh and dry yields of two alfalfa cultivars.

MATERIALS AND METHODS

The study site

A field experiment was carried out at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat, Sudan, from November 2001 to June 2002. The farm is located in a semi-desert zone (latitude 15º 40' N and longitude 32º 32' E). The rainy season is from July to September with annual rainfall of about 67.8 mm. The soil of the experimental site is alkaline (pH 7.8 to 8) and cracking with about 50 per cent clay content.

THE TREATMENTS AND EXPERIMENTAL SETUP

The experiment comprised eight treatments which were the combination of four seeding rates *viz*; 10, 15, 20 and 25 kg ha^{-1} (designated by S_1, S_2, S_3 and S_4, respectively) and two cultivars: the local cultivar Hegazi and the introduced cultivar Siriver (designated by C_1 and C_2, respectively). The cultivar Siriver was obtained from the Arab Authority for Agricultural Investment and Development (AAAD). The treatments were arranged in a split-plot design with four replicates. The main plots were allotted to the cultivars and the sub plots were allotted to four seeding rates.

The alfalfa crop was sown on 5th November 2001 by broadcasting seeds on flat plots (4 x 3 metres each). Surface irrigation was the only

irrigation system used. Irrigation water was applied at intervals of 7 to 14 days depending on weather conditions. Hand weeding was done twice in December (before the first cutting). Two sprays with Primor were applied against aphid (*Aphids spp.*) insects.

PARAMETERS MEASURED

An area of one square metre was marked in the middle of each plot (treatment) at the beginning of the experiment. Plant counts (densities) were performed on the above-mentioned marked areas ten and thirty days from sowing and before each cutting thereafter.

Data were also collected on the following parameters at each cutting for each treatment:

1. Plant height (cm): five plants were randomly selected from each plot and plant height was measured from ground level to the tip of the plants and average plant height recorded.
2. Leaf-to-stem ratio: ten plants (shoots) were randomly taken from each plot. The plants were partitioned into leaves (include petioles) and stems. Air-dried weights for the two parts were obtained and leaf-to-stem ratios were calculated based on the dry weights.
3. Leaf area index (LAI): the ten plants that were randomly taken from each plot for leaf-to-stem ratios were used for leaf area index calculation. Twenty leaflets were randomly taken, and then leaf area was estimated using the punch method according to the procedure described by Watson and Watson (1953). LAI was then calculated using the following formula:

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area} \times \text{No. of leaves plant}^{-1} \times \text{plant density}}{\text{Area of land occupied by leaves}}$$

4. Forage fresh yield (ton ha^{-1}): this parameter was obtained by clipping the entire forage of each plot which was then immediately weighted using a spring scale. Transformation was then made to ascertain forage fresh yield in ton ha^{-1}.
5. Forage dry matter yield (ton ha^{-1}): green forage of one square metre from each plot was air-dried and dry matter yield was calculated in ton ha^{-1}.

STATISTICAL ANALYSIS

Data collected on each sampling occasion were subjected to analysis of variance (ANOVA) appropriate for a split-plot design. Means of each parameter were compared using Duncan multiple range test (DMRT).

RESULTS AND DISCUSSION

Plant counts

The number of shoots per unit area showed a great variability according to seeding rates. Plant counts were significantly ($P \leq 0.05$) affected by seeding rate in five out of eight sampling dates (Table 1). However, there was an increasing trend in plant density with increasing seeding rate in almost all counting occasions (except count number 8). High shoot numbers were produced at high seeding rates. This finding is in accordance with Kephart *et al.* (1992) who reported that plant density in the sowing year increased linearly with seeding rate. However, in counts number 3, 5 and 6 there were no significant differences observed. Significant differences between the different seeding rates were manifested early in the growing season but as the season advanced (count 5 and 6) differences disappeared. This is expected, since early in the season, numbers of shoots truly reflect the seeding rates, while as the season advances, mortality due to competition in higher seeding rates and tillering in lower seeding rates offset the differences in seeding rates.

The introduced cultivar Siriver (C_2) outnumbered the local cultivar Hegazi (C_1) with respect to plant counts in four out of six counting occasions during harvest. However, the significant differences were only observed during the first count (Table 1). The introduced cultivar Siriver exceeded the local cultivar Hegazi in plant density by 15 per cent. This may be attributed to the high tillering capacity of the Siriver cultivar. In contrast, Gross *et al.* (1958) found that alfalfa stands did not differ greatly in their population counts (cited by Fadul, 2001).

PLANT HEIGHT (CM)

Plant height was not significantly affected by seeding rates except in the 1st and 4th samplings. Treatments S_2 (15 kg ha $^{-1}$) increased plant height compared to S_1, S_3, and S_4 in almost all sampling dates except in the 2nd

cutting (Table 2). This unanticipated result is difficult to explain, since this trait is usually taken as an index of intensity of plant competition under conditions of varying plant density. This result indicted that the highest seeding rate (S_4) was not imposing high plant competition to force plants to grow taller in the search for light.

The local cultivar Hegazi (C_1) was taller than the introduced cultivar Siriver (C_2) by 18 per cent in almost all sampling occasions. The significant differences between them were observed in five out of six sampling occasions (Table 2). The local cultivar Hegazi showed a quick recovery after cutting, while the introduced cultivar typically takes a relatively longer time to recover. This may be due to an inherited character in the local cultivar, which enabled it to manifest a wide adaptability to the prevailing conditions.

This confirmed the finding of Fadul (2001), who demonstrated that the re-growth of local cultivar Hegazi was quicker than the introduced cultivar Pioneer 5929.

Treatments	Sampling numbers							
	Before harvest		1st	2nd	3rd	4th	5th	6th
Seeding rates								
S_1	038.50^{b}	049.25^{b}	0637.00^{c}	0256.88^{b}	325.63^{a}	302.13^{b}	253.00^{a}	280.63^{a}
S_2	042.25^{b}	061.25^{b}	0717.50^{c}	0336.13^{b}	389.13^{a}	371.38^{ab}	300.00^{a}	275.37^{a}
S_3	127.13^{a}	143.13^{a}	1584.00^{b}	0926.75^{a}	311.63^{a}	428.13^{a}	269.50^{a}	281.50^{a}
S_4	150.25^{a}	174.75^{a}	3115.88^{a}	1021.13^{a}	375.50^{a}	444.75^{a}	283.17^{a}	276.00^{a}
SE±	034.74	033.29	0366.08	0129.77	101.59	046.49	050.59	040.01
Cultivars								
C_1	099.50^{a}	109.19^{a}	1808.00^{a}	436.63^{a}	451.94^{a}	324.00^{a}	261.08^{a}	276.31^{a}
C_2	079.56^{a}	105.00^{a}	1219.19^{b}	475.31^{a}	449.00^{a}	449.19^{a}	292.00^{a}	280.40^{a}
SE±	007.85	010.33	0027.30	107.17	079.90	040.45	038.50	022.76

S_1, S_2, S_3, and S_4 = 10, 15, 20 and 25 kg ha^{-1}, respectively
C_1 = Hegazi cultivar
C_2 = Siriver cultivar
SE = Standard error
Means followed by the same superscript(s) in the same column for each treatment are not significantly different ($P \leq 0.05$) due to Duncan's Multiple Range Test (DMRT)

Table 1. Alfalfa mean plant count (plant density) m^{-2} as affected by seeding rates and cultivars

LEAF-TO-STEM RATIO

As shown in Table (2) the significant differences among seeding rates with respect to leaf-to-stem ratio were only observed in one out of six harvests. Seeding rate had little influence on leafiness of alfalfa (McGuire, 1983). Treatment S_3 (20 kg ha^{-1}) possessed a higher leaf-to-stem ratio in three out of six samplings. This may be due to relatively high numbers of branches associated with treatments S_1 and S_2 and higher competition in S_4, which was reflected in low leaflets weight. Accordingly, leaf-to-stem ratio is expected to be high for S_3.

With respect to cultivars, the introduced cultivar Siriver scored higher (27 per cent) in leaf-to-stem ratio compared with the local cultivar Hegazi in four out of six sampling occasions. However, the significant differences between the two cultivars were observed on the 3rd, 4th and 5th cutting occasions (Table 2). This may be attributed to a high leaf area and number of leaves per plant associated with the Siriver cultivar. There were significant interactions between seeding rates and alfalfa cultivars with respect to leaf-to-stem ratio during the 1st cutting (Figure 1).

LEAF AREA INDEX (LAI)

Leaf area index increased with increasing seeding rate in four out of six sampling dates. However, the significant differences were detected in two sampling occasions only (Table 3). Treatment S_4 (25 kg ha^{-1}) increased leaf area index by 106 per cent, 41 per cent and 20 per cent over S_1, S_2 and S_3, respectively.

Treatments	Sampling numbers (cutting numbers)											
	Plant height						Leaf to stem ratio					
Seeding rates	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th
S_1	61.20^{ab}	70.30^{a}	48.60^{a}	48.60^{b}	50.04^{a}	42.84^{a}	0.89^{a}	0.96^{a}	1.03^{a}	1.76^{a}	0.45^{a}	0.65^{a}
S_2	63.20^{a}	66.60^{a}	50.93^{a}	51.75^{a}	51.60^{a}	43.04^{a}	0.89^{a}	0.89^{a}	0.95^{a}	1.39^{a}	0.84^{a}	0.71^{a}
S_3	56.40^{b}	69.30^{a}	48.98^{a}	46.88^{b}	47.67^{a}	41.93^{a}	0.99^{a}	0.99^{a}	1.16^{a}	1.40^{a}	0.78^{a}	0.70^{a}
S_4	57.80^{b}	69.90^{a}	48.25^{a}	45.88^{b}	46.29^{a}	41.19^{a}	0.72^{b}	0.89^{a}	1.14^{a}	1.58^{a}	0.72^{a}	0.71^{a}
SE±	02.40	01.66	01.64	01.85	02.64	01.68	0.08	0.07	0.10	0.27	0.12	0.10
Cultivars												
C_1	64.30^{a}	73.90^{a}	48.75^{a}	54.29^{a}	53.70^{a}	46.34^{a}	0.87^{a}	0.92^{a}	0.93^{b}	1.95^{a}	0.58^{b}	0.57^{a}
C_2	55.00^{b}	64.14^{a}	45.29^{a}	42.26^{b}	44.09^{b}	38.16^{b}	0.87^{a}	0.94^{a}	1.21^{a}	1.11^{b}	0.86^{a}	0.81^{a}
SE±	02.26	03.10	01.59	01.86	00.19	02.39	0.09	0.11	0.06	0.24	0.08	0.11

Table 2. Alfalfa mean plant height (cm) and leaf-to-stem ratio as affected by seeding rates and cultivars

S1, S2, S3, and S4 = 10, 15, 20 and 25 kg ha-1, respectively
C1 = Hegazi cultivar
C2 = Siriver cultivar
SE = Standard error
Means followed by the same superscript(s) in the same column for each treatment are not significantly different ($P \leq 0.05$) due to Duncan's Multiple Range Test (DMRT)

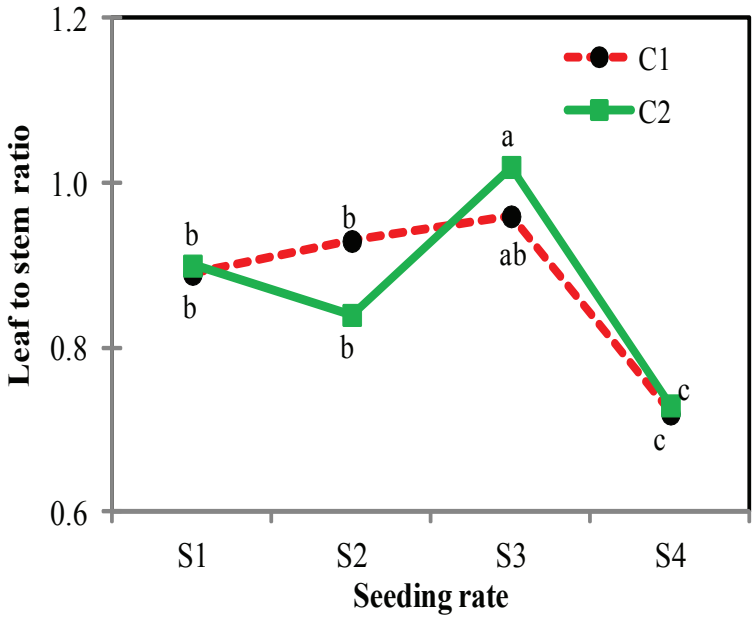

Figure 1. Interaction between seeding rates and cultivars with respect to alfalfa leaf-to-stem ratio at 1st cutting. Points with the same letter(s) are not significantly different from each other ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT).

The high number of shoots per unit area associated with this treatment (S4) is expected to be reflected in high leaf area index. The present result is similar to that of Nayel (1984), who reported that seeding rate did not affect leaf area index.

The introduced cultivar Siriver produced a higher leaf area index than the local cultivar Hegazi. It increased leaf area index by 23 per cent over the Hegazi cultivar. Differences, however, were significant in four out of six cuttings as shown in Table (3). This could be attributed to a high number of leaves per plant and shoots per unit area exhibited by this cultivar, and much larger leaflets in the Siriver cultivar than those in the Hegazi. This would be reflected in a high leaf area index.

FORAGE FRESH YIELD (TON HA^{-1})

The seeding rates significantly affected fodder fresh yield in almost all cuttings as demonstrated in Table 4. Treatment S_4 (25 kg ha^{-1}) gave

more fodder fresh yield in four out of six counts. However, there were no significant differences among treatment S_2, S_3 and S_4 in all cuttings (except the first cutting) (Table 4). Whereas in the remaining two cuttings (3 and 6), treatment S_3 (20 kg ha^{-1}) gave more fodder fresh yield than treatment S_1, S_2 and S_4. Differences between S_1 and S_2 on the one hand and S_2 and S_3 on the other hand were not significant. Maximum forage fresh yield of 11.4 ton ha^{-1} was recorded in the second cutting. The non-significant differences between the intermediate seeding rate (S_2) and the highest seeding rates (S_3 and S_4) might be due to competition associated with high seeding rates and the ability of stand provided by S_2 to produce relatively high numbers of shoots per unit area, which compensated for the low seeding rate. This is in conformity with results obtained by Breazeal *et al.* (2000) who found that high population densities of alfalfa did not improve herbage yield. Increasing the number of plants per unit area reduces the volume of air and soil that the individual plant can exploit, and therefore increases competition between plants for soil nutrients, carbon dioxide and light. Contradicting results were reported by Elkarouri (1977) who found that the high plant density provided by a seeding rate of 43.2 kg ha^{-1} is optimum for alfalfa fodder production.

Although there were no significant differences between the two cultivars in almost all accounts in terms of forage fresh yield, the local

Treatments	Sampling numbers (cutting numbers)					
	1st	2nd	3rd	4th	5th	6th
Seeding rates						
S_1	05.00c	05.21c	6.53a	2.82a	2.18a	2.44a
S_2	09.21b	08.76bc	6.30a	4.12a	4.67a	2.34a
S_3	10.70ab	09.89b	7.85a	4.53a	3.77a	2.04a
S_4	12.05a	14.95a	9.35a	5.07a	3.45a	1.84a
SE±	02.76	02.12	1.81	0.87	0.96	0.50
Cultivars						
C_1	09.00a	09.37a	7.65a	3.30b	3.00b	2.25a
C_2	10.61a	10.08a	8.36a	4.97a	4.61a	2.10a
SE±	02.05	01.43	1.01	0.18	0.24	0.17

Table 3. Alfalfa mean leaf area index (LAI) as affected by seeding rates and cultivars

S_1, S_2, S_3, and S_4 = 10, 15, 20 and 25 kg ha^{-1}, respectively
C_1 = Hegazi cultivar
C_2 = Siriver cultivar
SE = Standard error
Means followed by the same superscript(s) in the same column for each treatment are not significantly different ($P \leq 0.05$) due to Duncan's Multiple Range Test (DMRT)

cultivar Hegazi out-yielded the introduced cultivar Siriver in five out of six harvesting dates (Table 4). It increased forage fresh yield by 13 per cent over the introduced cultivar. The local cultivar Hegazi is well-adapted to the local environment that allowed the crop to absorb more nutrients and water, resulting in high root reserve and herbage yield. In addition, Christian (1977) reported that varieties of local origin posses advantages that result in the production of higher yields than those of exotic varieties.

FORAGE DRY MATTER YIELD (TON HA^{-1})

As shown in Table 4, there were no significant differences observed among seeding rates with respect to forage dry matter yield in almost all counting occasions. However, forage dry matter yield increased with increasing seeding rate in five out of six harvesting dates. A maximum forage dry matter yield of 2.85 ton ha^{-1} was obtained.

Any increase in dry matter yield per unit area due to additional number of plants is offset by an equal loss due to the decrease in weight per plant (Arnon, 1972). This finding is in accordance with that of Khair (1997) who found that dry matter production of alfalfa was not affected by seeding rate.

The local cultivar Hegazi out-yielded the introduced cultivar Siriver in forage dry matter yield, with significant differences in the last cutting (6th cutting) (Table 4). It increased total forage dry matter yield by 7 per cent over the introduced cultivar. This might be due to taller plants and more fodder fresh yield associated with the Hegazi Cultivar. Significant differences were observed among mean forage dry matter yields as a result of interaction between seeding rates and cultivars in the 2nd cutting (Figure 2).

CONCLUSIONS

From the results of this study it can be concluded that:

1. Although the highest forage yield was produced by the highest seeding rate (25 kg ha^{-1}), since there are no significant differences between S_2, S_3 and S_4, from an economical point of view it is logical to recommend S_2 (15 kg ha^{-1}) to be the optimal seeding rate for alfalfa production under similar conditions at Shambat Demonstration Farm.

Table 4. Alfalfa mean forage fresh and dry matter yields (ton ha-1) as affected by seeding rates and cultivars

Treatments	Sampling numbers (cutting numbers)											
	Fresh yield						Dry matter yield					
Seeding rates	1st	2nd	3rd	4th	5th	6th	1st	2nd	3rd	4th	5th	6th
S_1	6.30^{c}	08.47^{b}	7.14^{b}	6.21^{b}	6.19^{a}	4.84^{b}	2.00^{a}	2.00^{a}	1.81^{a}	1.58^{a}	2.00^{a}	1.42^{a}
S_2	7.60^{bc}	09.83^{ab}	8.05^{ab}	7.69^{a}	7.08^{ab}	5.78^{ab}	2.07^{a}	2.25^{a}	1.97^{a}	2.14^{a}	2.12^{a}	1.52^{a}
S_3	9.25^{ab}	11.32^{a}	9.34^{a}	8.33^{a}	7.94^{a}	6.28^{a}	2.46^{a}	2.32^{a}	2.15^{a}	2.08^{a}	2.02^{a}	1.58^{a}
S_4	9.95^{a}	11.43^{a}	9.31^{a}	8.49^{a}	7.95^{a}	5.88^{ab}	2.85^{a}	2.58^{a}	2.25^{a}	2.35^{a}	2.37^{a}	1.49^{a}
SE±	0.97	00.74	0.63	0.56	0.60	0.48	0.36	0.21	0.25	0.29	0.34	0.16^{a}
Cultivars												
C_1	8.18^{a}	10.41^{a}	9.16^{a}	8.51^{a}	7.68^{a}	6.60^{a}	2.32^{a}	2.30^{a}	2.12^{a}	2.18^{a}	2.15^{a}	1.71^{a}
C_2	8.36^{a}	10.10^{a}	7.73^{a}	6.85^{a}	6.89^{a}	4.79^{a}	2.37^{a}	2.27^{a}	1.97^{a}	1.89^{a}	2.11^{a}	1.29^{a}
SE±	1.44	01.05	0.81	0.73	0.40	0.62	0.23	0.17	0.25	0.11	0.11	0.12

S_1, S_2, S_3, and S_4 = 10, 15, 20 and 25 kg ha^{-1}, respectively
C_1 = Hegazi cultivar
C_2 = Siriver cultivar
SE = Standard error
Means followed by the same superscript(s) in the same column for each treatment are not significantly different ($P \leq 0.05$) due to Duncan's Multiple Range Test (DMRT)

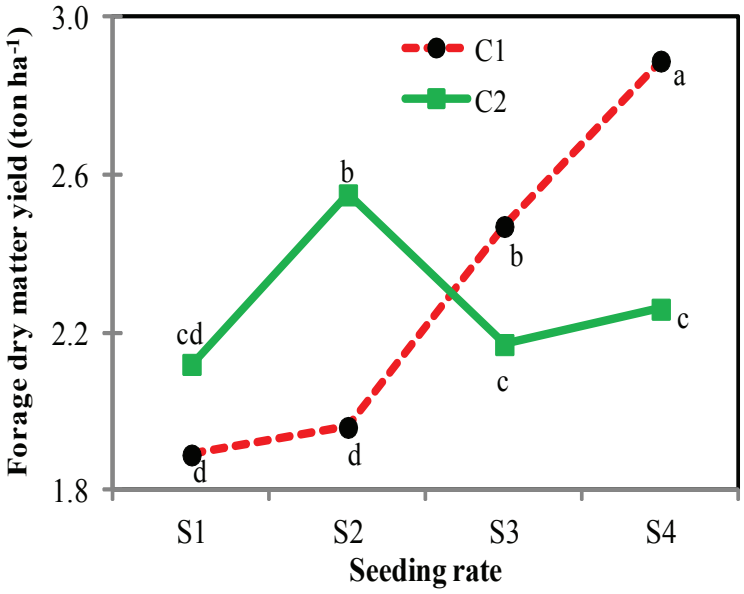

Figure 2. Interaction between seeding rates and cultivars with respect to alfalfa forage dry matter yield (ton ha^{-1}) at 2nd cutting. Points with the same letter(s) are not significantly different from each other ($P \leq 0.05$) according to Duncan's Multiple Range Test (DMRT).

1. The local cultivar Hegazi was superior over the introduced cultivar Siriver in plant height and fodder fresh yield, whereas the introduced cultivar Siriver was superior over the local one in plant density, leaf-to-stem ratio and leaf area index. This might mean that the exotic cultivar Siriver is much leafier than the local cultivar Hegazi, and consequently more nutritious than Hegazi.

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