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Comparing the yield of alfalfa cultivars in different harvests under limited irrigation condition

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Abstract

This experiment was conducted in 2011 at the research field of Seed and Plant Improvement Institute, Karaj, Iran, to compare alfalfa cultivars in different harvests. The experiment was conducted in the form of a randomized complete block design with three replications and two factors: (1) eleven alfalfa cultivars obtained from the Seed and Plant Improvement Institute, Karaj, Iran, and (2) four harvests which were conducted when the field was at 20-30% flowering on June 13, July 10, August 7 and September 17. Analysis of variance indicated the significant variation of dry leaf weight and leaf area index among the cultivars. Harvest had significant effect on all measured traits including fresh and dry leaf weight, LAI, and fresh and dry forage yield. The interaction of the two factors had also a significant effect on fresh leaf weight, fresh forage yield and dry forage yield. Mean comparison showed that the highest dry forage yield (0.33 kg/m^2) was achieved in KFA6 × the second harvest. However, KFA12 had the highest LAI. Among the harvests, the second and the third harvests had the highest forage yield.

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Introduction

Alfalfa, from Fabaceae family, has 60 species which 20 of them are perennial and 40 of them are annual. *Medicago sativa* is a highly palatable forage crop containing high protein, calcium and vitamins and low cellulose (Heidari Sharifabad and Dari, 2001; Karimi, 2007). Alfalfa is not only an important forage crop playing role in livestock feeding, but it is effective on the improvement of soil quality. The origin of this plant is the north west of Iran, Anatoly in Turkey and Caucasian area (Karimi, 2007; Michaud *et al.*, 1988).

Improvement of dry forage yield is one of the main objectives in breeding programs of forage crops. On the other hand, stem dry matter is the main index in determining the adaptation of alfalfa cultivars to the environmental conditions (Annicchiarico *et al.*, 2006; Torricelli, 2006). Veronesi *et al.* (2010) reported that improvement of dry matter yield is still the major objective in alfalfa breeding programs. Alfalfa dry matter yield in experimental conditions is 20 t/ha in the United States (Sheaffer *et al.*, 1988), 9.4 to 17.6 t/ha in the United Kingdom (Aldrich, 1984) and 14.5 to 19 t/ha in France (Guy, 1993).

Leaf area index (LAI) represents the ratio of overall leaf area to the ground area that those leaves cover. LAI is an important physiological index which represents the photosynthesis capacity of the plant. LAI depends on the number and size of the leaves (Koochaki and Sarmadnia, 1989). Leaf area is the major parameter used in the studies on plant growth and modeling and ecophysiology such as photosynthesis, transpiration, weed competition, and energy use efficiency (Jonckheere *et al.*, 2004). Evans and wardlow (1976) reported that the main factor that causes variation in the dry matter yield of various cultivars is their leaf area which is related to the number and size of their leaves. Leaf area index had different trend during the growth season. Darvishi *et al.* (2005) studied LAI of four Iranian alfalfa cultivars and reported that in the second and the third harvests, the LAI of Hamedani and Shirazi cultivars was significantly higher than the other cultivars. They also found a significant correlation between the LAI and shoot dry matter. In different experiments it was found that the effect of leaf area on dry matter yield is more important than the effect of photosynthesis rate on dry matter yield (Duncan and Hesketh, 1968; Hanson, 1971; Khan and Tsunoda, 1970).

The objective of this experiment was to compare the LAI, leaf yield and forage yield of different alfalfa cultivars in several harvests, in order to select the highest yield cultivar under limited irrigation conditions.

Materials and methods

This experiment was conducted in 2011 at the research field of Seed and Plant Improvement Institute, Karaj, Iran (35°45' E, 50°55' N, and 1254 m above the sea level), to compare alfalfa cultivars in different harvests. Mean annual precipitation was 263 mm in the year of the experiment, mean daily temperature was 27°C and mean relative humidity was 35%. The soil at the test site was sandy clay.
The experiment was conducted in the form of a randomized complete block design with three replications and two factors:

Cultivar

Eleven alfalfa cultivars which were tested in the Seed and Plant Improvement Institute, Karaj, Iran, were used in this experiment. The code and origin of cultivars are listed in Table 1.

Harvest

Four harvests were conducted when the field was at 20-30% flowering on June 13, July 10, August 7 and September 17. Samples were harvested 5 cm above the soil surface.

Plots were 2 × 7 m and planting rows were 50 cm apart. Irrigation was conducted in furrow method every 14 days to test the cultivars under limited irrigation condition. After each harvest, leaf area index (LAI) was measured by LI-3100 (LI-COR,

Lincoln, NE) instrument. To measure dry leaf weight, samples were weighted after drying in a 70°C oven for 72 h. To obtain the dry forage yield, samples were weighted after drying the samples in a 75°C oven for 72 h.

Data were subjected to analysis of variance using SPSS (ver. II). Means were compared according to the SNK method at α≤0.05.

Results and discussion

Fresh leaf weight

Analysis of variance indicated that cultivar had no significant effect on fresh leaf weight. However, harvest had significant effect on this trait at P≤0.01 and the effect of cultivar × interaction was significant at P≤0.05 (Table 2).

Table 1. The code and the origin of the tested cultivars.

No.	Code	Origin
1	KFA1	Ghareh Yonjeh
2	KFA3	Ghareh Yonjeh
3	KFA5	Hamedani
4	KFA6	Ghareh Yonjeh
5	KFA9	Chahar Mahal o Bakhtiari
6	KFA11	Ghareh Yonjeh
7	KFA12	Ghareh Yonjeh
8	KFA13	Ghareh Yonjeh
9	KFA16	Hamedani
10	KFA17	Hamedani
11	MFA	Hamedani

Mean comparison showed that there were no significant differences between cultivars (Table 3). Mean comparison of fresh leaf weight in different harvests indicated that this trait was the highest in the second harvest (531.21 g/m²) and the lowest in the fourth harvest (270.91 g/m²). Study of the interaction on cultivar × harvest showed that fresh leaf weight varied significantly between different cultivars in the first and the third harvest (Table 3). In the first harvest, the highest fresh leaf weight was achieved in KFA11 (593.33 g/m²) and the lowest was achieved in KFA9 (370.0 g/m²). However, in the third harvest, KFA1 had the highest and KFA13 had the lowest leaf fresh weight (540.0 and 360.0 g/m², respectively).

Table 2. Analysis of variance of the effect of the treatments on the measured traits.

SOV	df	Mean Squares (MS)				
		Fresh leaf weight	Dry leaf weight	Leaf area index	Fresh forage yield	Dry forage yield
Block	2	6339.394	36.423	0.053	0.044	0.004
Cultivar (A)	10	ns	*	*	ns	ns
Harvest (B)	3	**	*	**	**	**
A × B	30	*	ns	ns	**	*
Error	60	4661.742	399.134	0.079	0.014	0.001
CV (%)	-	16.06	18.64	18.77	14.5	15.42

Ns, non significant; *, significant at P≤0.05; **, significant at P≤0.01.

Dry leaf weight

Analysis of variance showed that cultivar and harvest significantly affected dry leaf weight at P≤0.05; however, the effect of their interaction was not significant (Table 2).

Mean comparison of the cultivars indicated that different cultivars were in different categories; the highest dry leaf weight (122.2 g/m²) was achieved in KFA12 and the lowest dry leaf weight (92.6 g/m²) was achieved in KFA17 (Table 4). Mean comparison of harvests showed that the highest leaf dry weight (129.96 g/m²) was achieved in the second harvest without significant differences from the first harvest (121.47 g/m²). Among the harvests, the lowest dry leaf weight (76.73 g/m²) was achieved in the fourth harvest (Table 4). Studying the interaction of cultivars × harvests indicated the interaction cultivars × the

third harvest created different categories and the highest dry leaf weight (127.33 g/m²) in this interaction was achieved in KFA12 and the lowest dry leaf weight (86.13 g/m²) was achieved in KFA9 (Table 4).

Leaf area index (LAI)

Results indicated that cultivar significantly affected LAI at P≤0.05. The effect of harvest on LAI was significant at P≤0.01, and the effect of the interaction of cultivar × harvest was not significant on this trait (Table 2).

Table 3. The effect of cultivar, harvest and their interaction on fresh leaf weight.

Cultivars code	Mean comparison of cultivars (g/m²)	Mean comparison of cultivar × harvest (g/m²)			
		Harvest 1	Harvest 2	Harvest 3	Harvest 4
KFA1	455.00a	450.0ab	520.00a	540.0a	310.0a
KFA11	475.83a	593.33a	566.67a	446.66ab	296.67a
KFA12	476.67a	513.33ab	643.33a	486.66ab	263.33a
KFA13	420.83a	506.66ab	523.33a	360.0b	293.33a
KFA16	428.33a	456.66ab	496.67a	440.0ab	320.00a
KFA17	381.66a	446.66ab	430.00a	413.33ab	236.67a
KFA3	432.50a	440.0ab	670.00a	380.0b	240.0a
KFA5	394.16a	436.66ab	426.67a	433.33ab	280.0a
KFA6	405.83a	440.0ab	506.67a	416.66ab	260.0a
KFA9	400.83a	370.0b	580.00a	406.66ab	246.67a
MFA	420.00a	536.66ab	480.00a	430.0ab	233.33a
Mean comparison of harvests (g/m²)		471.82b	531.21a	432.12c	270.91d

For mean comparison of cultivars and cultivar × harvest, means in a column followed by the same letter are not significantly different at P≤0.05.
For mean comparison of harvests, means in a row followed by the same letter are not significant at P≤0.05.

Table 4. The effect of cultivar, harvest and their interaction on dry leaf weight.

Cultivars code	Mean comparison of cultivars (g/m²)	Mean comparison of cultivar × harvest (g/m²)			
		Harvest 1	Harvest 2	Harvest 3	Harvest 4
KFA1	109.80ab	118.13a	120.40a	116.13ab	84.53a
KFA11	115.87ab	138.53a	145.20a	99.73ab	80.00a
KFA12	122.23a	130.27a	156.27a	127.33a	75.07a
KFA13	105.23ab	130.27a	127.60a	88.53b	74.53a
KFA16	109.86ab	126.67a	115.47a	108.13ab	89.20a
KFA17	92.60b	102.93a	104.13a	90.26b	73.07a
KFA3	115.26ab	137.07a	156.67a	94.26b	73.07a
KFA5	102.26ab	113.47a	116.27a	100.13ab	79.20a
KFA6	100.00ab	110.00a	116.13a	95.2b	78.67a
KFA9	101.43ab	99.20a	149.07a	86.13b	71.33a
MFA	103.8ab	129.60a	122.40a	97.86ab	65.33a
Mean comparison of harvests (g/m²)		121.47a	129.96a	100.34b	76.73c

For mean comparison of cultivars and cultivar × harvest, means in a column followed by the same letter are not significantly different at P≤0.05.
For mean comparison of harvests, means in a row followed by the same letter are not significant at P≤0.05.

Mean comparison of cultivars showed that the highest LAI (1.71) was achieved in KFA11 and KFA12 and the lowest LAI (1.3) was achieved in KFA17. Mean comparison of harvests represented that the second harvest had the highest LAI (2.13) and the fourth harvest had the lowest LAI (0.95). Results of mean comparison for the interaction of the two factors also indicated that there were significant differences only in the interaction of cultivars × the second harvest. Among this interaction, the highest LAI was achieved in KFA1 and KFA12 (1.87 and 1.83, respectively) and the lowest LAI (1.30) was achieved in KFA13 (Table 5).

Fresh forage yield

Analysis of variance showed that cultivar had no significant effect on fresh forage yield; however, harvest and the interaction of cultivar × harvest had significant on this trait at P≤0.01 (Table 2).

Results indicated that all cultivars were in a same statistical category (Table 6). Among the harvests, the second one had the highest (1.08 kg/m²) fresh forage yield and the fourth harvest had the lowest (0.51 kg/m²) fresh forage yield (Table 6). Mean comparison

of the interaction of cultivar × harvest showed that there were significant differences only among cultivar × the first and cultivar × the second harvest. In cultivar × the first harvest, the highest (1.15 kg/m²) and the lowest (0.81 kg/m²) fresh forage yield were obtained in KFA3 and KFA17, respectively. In the interaction of cultivar × the second harvest, the highest (1.44 kg/m²) and the lowest (0.66 kg/m²) fresh forage yield were obtained in KFA6 and KFA5, respectively (Table 6).

Table 5. The effect of cultivar, harvest and their interaction on leaf area index.

Cultivars code	Mean comparison of cultivars	Mean comparison of cultivar × harvest			
		Harvest 1	Harvest 2	Harvest 3	Harvest 4
KFA1	1.64ab	1.42a	2.15a	1.87a	1.14a
KFA11	1.71a	1.76a	2.40a	1.53b	1.15a
KFA12	1.71a	1.45a	2.69a	1.83a	0.89a
KFA13	1.48ab	1.60a	2.00a	1.30c	1.01a
KFA16	1.51ab	1.38a	2.12a	1.51b	1.03a
KFA17	1.30b	1.24a	1.74a	1.41bc	0.79a
KFA3	1.49ab	1.23a	2.56a	1.32bc	0.88a
KFA5	1.37ab	1.33a	1.67a	1.51b	0.96a
KFA6	1.35ab	1.21a	2.00a	1.35bc	0.85a
KFA9	1.40ab	1.09a	2.25a	1.38bc	0.90a
MFA	1.49ab	1.61a	1.91a	1.57b	0.87a
Mean comparison of harvests		1.39b	2.13a	1.51b	0.95c

For mean comparison of cultivars and cultivar × harvest, means in a column followed by the same letter are not significantly different at P≤0.05.
For mean comparison of harvests, means in a row followed by the same letter are not significant at P≤0.05.

Dry forage yield

Analysis of variance represented that although cultivar had no significant effect on dry forage yield; however, the effects of harvest and the interaction of cultivar × harvest were significant on this trait at P≤0.01 and P≤0.05, respectively (Table 2).

Mean comparison indicated that there were no significant differences among the cultivars (Table 7). Among the harvests, the highest dry forage yield (0.26 kg/m²) was achieved in the first and the second harvest and the lowest dry forage yield (0.14 kg/m²) was related to the fourth harvest (Table 7). Studying the interaction of the two factors showed that there were significant differences only in the interaction of cultivar × the second harvest; the highest dry forage yield (0.33 kg/m²) was achieved in KFA6 × the second harvest and the lowest dry forage yield (0.19 kg/m²) was achieved in KFA5 (Table 7).

Table 6. The effect of cultivar, harvest and their interaction on fresh forage yield.

Cultivars code	Mean comparison of cultivars (kg/m²)	Mean comparison of cultivar × harvest (kg/m²)			
		Harvest 1	Harvest 2	Harvest 3	Harvest 4
KFA1	0.88a	1.08ab	1.05ab	0.76a	0.63a
KFA11	0.91a	1.11ab	1.02ab	0.75a	0.57a
KFA12	0.88a	1.00ab	1.24a	0.77a	0.53a
KFA13	0.81a	0.96ab	1.07ab	0.70a	0.52a
KFA16	0.85a	0.96ab	1.16ab	0.76a	0.51a
KFA17	0.73a	0.81b	0.94ab	0.70a	0.45a
KFA3	0.79a	1.15a	1.09ab	0.49a	0.43a
KFA5	0.69a	0.89ab	0.66b	0.70a	0.50a
KFA6	0.88a	0.82b	1.44a	0.73a	0.55a
KFA9	0.78a	1.06ab	0.95ab	0.70a	0.41a
MFA	0.81a	1.03ab	1.07ab	0.65a	0.51a
Mean comparison of harvests (kg/m²)		0.99b	1.08a	0.70c	0.51d

For mean comparison of cultivars and cultivar × harvest, means in a column followed by the same letter are not significantly different at P≤0.05. For mean comparison of harvests, means in a row followed by the same letter are not significant at P≤0.05.

In alfalfa, dry forage yield is the main trait which isevaluated in experiments and researchers try to improve it. Of course the quality of the forage isanother major feature which is the objective of

experiments. In our experiment, studying the mean comparison of dry forage yield different cultivars showed that all cultivars were significantly the same;

so, other traits and the quality of the cultivars must be taken into consideration when selecting a cultivar.

Study of the different harvests showed that the highest dry forage yield was obtained in the first and the second harvests. High yield in these harvests may be attributed to longer growth period, suitable climatic conditions such as air temperature, longer daylight hours, presence of sufficient nutrients in soil, plant juvenility, and many other factors. Low dry forage yield in the third and fourth harvests may also be attributed to the reduction of soil nutrients, short growth period and daylight hours, hot weather in the third harvest and cold weather in the fourth harvest, plant aging, and low root reservoirs to stimulate the following re-growths.

Table 7. The effect of cultivar, harvest and their interaction on dry forage yield.

Cultivars code	Mean comparison of cultivars (kg/m²)	Mean comparison of cultivar × harvest (kg/m²)			
		Harvest 1	Harvest 2	Harvest 3	Harvest 4
KFA1	0.20a	0.27a	0.23ab	0.16a	0.15a
KFA11	0.23a	0.32a	0.28ab	0.18a	0.16a
KFA12	0.21a	0.24a	0.29ab	0.17a	0.14a
KFA13	0.20a	0.26a	0.24ab	0.15a	0.13a
KFA16	0.20a	0.25a	0.25ab	0.17a	0.14a
KFA17	0.18a	0.22a	0.22ab	0.17a	0.12a
KFA3	0.21a	0.31a	0.29ab	0.13a	0.12a
KFA5	0.18a	0.25a	0.19b	0.15a	0.13a
KFA6	0.22a	0.23a	0.33a	0.17a	0.15a
KFA9	0.20a	0.29a	0.26ab	0.16a	0.11a
MFA	0.20a	0.27a	0.26ab	0.16a	0.13a
Mean comparison of harvests (kg/m²)		0.26a	0.26a	0.16b	0.14c

For mean comparison of cultivars and cultivar × harvest, means in a column followed by the same letter are not significantly different at P≤0.05.
For mean comparison of harvests, means in a row followed by the same letter are not significant at P≤0.05.

Forage yield is affected by the yield components such as leaf yield, stem yield and flower yield. Studies on the leaf yield in our experiment also showed that the variation of leaf yield had the same trends as those of forage yield. Other researchers such as Saeed and El-Nadi (1997) attributed this reduction of yield to the reduction of stems density, stem height and leaf area index.

In our experiment it seems that high forage yield in the second harvest may be the result of higher fresh and dry leaf yield and leaf area index. However, high forage yield in the first harvest was the result of enhancement in the number of internodes and stem height. This represents that the quality of the forage in the second harvest must be higher than the first harvest. Leaf area is an important physiological index for plant studies (Blanco and Folegatti, 2005). In our experiment it was proved that LAI is directly related to the dry matter yield. The close relation of leaf area with the dry matter yield was also observed in other experiments on alfalfa (Sharrat *et al.*, 1988) and barley (Romas *et al.*, 1983) and wheat (Aase, 1987).

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