Article

Forage yield and nutritional value of alfalfa at different cutting intervals

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Abstract

The objective was to determine the effect in cut-off intervals on dry matter yield, leaf-stem ratio, protein and digestibility *in situ* in the leaf and stem of alfalfa cv ‘San Miguelito’, in the Mexican Altiplano. Four cut intervals (3, 4, 5 and 6 weeks for spring-summer and 4, 5, 6 and 7 weeks for autumn-winter) were randomly distributed under a completely randomized experimental design, with 4 repetitions. The intervals of 6 and 7 weeks ($p< 0.05$), produced the highest yield of dry matter per cut with 4 393 kg DM ha^{-1}; however, they also obtained the lowest values of leaf-stem ratio (0.74), leaf and stem protein (26.9 and 11.7%) and leaf and stem digestibility (79.8 and 64.3%). In order to obtain an appropriate balance between yield and forage quality, it is concluded that alfalfa must be harvested, at cut-off intervals of six weeks in autumn and winter, four weeks in spring and five weeks in summer.

Keywords: *Medicago sativa*, digestibility, protein, yield.

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Introduction

Alfalfa (*Medicago sativa* L.) is the most used forage legume to feed dairy cattle in arid, semi-arid and temperate regions of Mexico. It is cut at medium intervals to harvest the highest forage yield per year per unit area, as well as its good content of crude protein, digestibility and degree of acceptance by cattle (Avice *et al*., 1997; McMahon *et al*., 1999; Chocarro *et al*., 2001). This forage can be used in fresh, hay and silage in mixture with one or several grasses and be transported to the pens where the cattle are confined (Amendola *et al*., 2005; Hernández *et al*., 2012).

The persistence and yield of an alfalfa meadow depend on the interval and severity of cut, since both influence the growth dynamics (Mendoza *et al*., 2010; Rojas *et al*., 2016; Álvarez-Vázquez *et al*., 2018). The changes that occur are at the level of forage yield components, population density, weight of stems and leaf-stem ratio (Matthew *et al*., 1996; Rojas *et al*., 2017). The average persistence of an alfalfa is three years, due to the interest of making a high frequency of cutting, 9 to 11 cuts per year (Amendola *et al*., 2005).

Mendoza *et al*. (2010), mention that 3-week cut-off intervals are not convenient because they reduce carbohydrate reserves and persistence of alfalfa. Based on research conducted by Hernández *et al*. (1992); Pérez *et al*. (2002) it is convenient to know the rate of regrowth of alfalfa at different intervals and severities of cut, to determine the optimum time of harvest and obtain a high yield. The cutoff interval for the optimum harvest time can be determined based on the seasonal growth rate of the alfalfa (Hernández *et al*., 1993; Hernández *et al*., 2012).

Some studies on foliar growth in grasses and legumes of temperate climate have shown that the rate of regrowth between successive defoliation is a productive parameter affected by the interval and severity of harvest (Pérez *et al*., 2002; Meuriot *et al*., 2005; Ventroni *et al*., 2010). Hernández *et al*. (1992) showed that, to achieve maximum forage yield per year and greater persistence of alfalfa, the cut interval should be established based on the stage of development of the plant. Because it is influenced by environmental conditions, the optimum cutoff interval should be estimated for each season and for different climatic conditions (Hernández *et al*., 1993).

The challenge is to find the best cutting interval (currently 9 to 11 cuts per year) that maximizes the persistence of an alfalfa (Amendola *et al*., 2005; Hernández *et al*., 2012), to propose successive defoliations according to the seasons of the year (Chen *et al*., 2012). The objective of this study was to determine the best cut-off intervals on dry matter yield, leaf-stem ratio, protein and *in situ* leaf and stem digestibility of the San Miguelito alfalfa cv in the Mexican Plateau.

Materials and methods

The trial was conducted from August 2006 to August 2007, in the Experimental Field of the Postgraduate College, Montecillo, Texcoco, State of Mexico, located at 19º 29’ north latitude and 98º 53’ west longitude, at a height of 2 240 meters above sea level. The climate of the place is temperate subhumid, the driest of the subhumid, with average annual rainfall of 636 mm, rain regime in summer, from June to October and average annual temperature of 15.2 °C (García, 2004). The soil of the area is sandy loam and slightly alkaline with pH 7 to 8.4 and 3.5 of organic matter (Ortiz, 1997; Rojas *et al*., 2017).

General management of the meadow

We worked with an alfalfa meadow, variety San Miguelito, planted in October 2004. The sowing was broadcast, and the study area was divided into 32 plots of 30 m^2 (6x5 m), comprising four cut-off intervals: 3, 4, 5 and 6 weeks for spring-summer and 4, 5, 6 and 7 weeks for autumn-winter, with four repetitions. The sowing density was 30 kg of viable pure seed per ha; was adjusted with the percentage of purity and germination. At the beginning of the study, a uniformity cut was made at 5 cm height, with a pruning tractor (New Holland Model 6610, USA). It was not fertilized in all the research and irrigation was provided every 15 days at field capacity.

Dry matter yield

The dry matter yield of alfalfa was estimated with two fixed tables of 0.25 m^2, previously located randomly in each treatment and repeated at the beginning of the experiment. The forage present within each frame was harvested one day before the cut was washed and deposited in labeled paper bags and dried in a forced air oven at 55 °C to constant weight. Subsequently, the dry weight was recorded, to determine the yield per unit area (kg of DM ha^{-1}) for each season of the year.

Leaf-stem relationship

From the samples collected in the field, to record the fresh weight, 100 g of forage was separated approximately. From this sample, leaf and stem were separated to calculate the leaf-stem ratio (RHT), which was obtained with the following formula.

RHT= H/T

Where: H= leaf dry weight (g); T= stem dry weight (g).

Protein in leaves and stems

From the samples for dry matter yield, a subsample of approximately 100 g was taken in each season and cut interval and dried in a forced air oven at 55 °C to constant weight, later the total protein content of leaves was determined and stems by the micro Kjeldahl method (AOAC, 1990).

***In situ* digestibility of leaves and stems**

With a digestion time of 72 h, *in situ* digestibility of the dry matter (DISMS) of the stem and leaf of the forage harvested in each season and interval between cut was determined (Meherez and Orskov, 1977).

Climatic data

The maximum monthly temperature ranged between 25 and 32 °C, while the minimum monthly temperature ranged between -3 and 8 °C. The maximum temperatures were recorded from February to June 2007 exceeding 26 °C, while the minimum temperatures were recorded from November 2006 to February 2007 with temperatures below 0 °C. The highest precipitation was recorded from August to November 2006 and from May to August 2007 with an accumulated rainfall of 479 mm. The months with the lowest precipitation were recorded from December 2006 to April 2007 with 74 mm. Obtaining a cumulative annual rainfall of 553 mm (Figure 1).

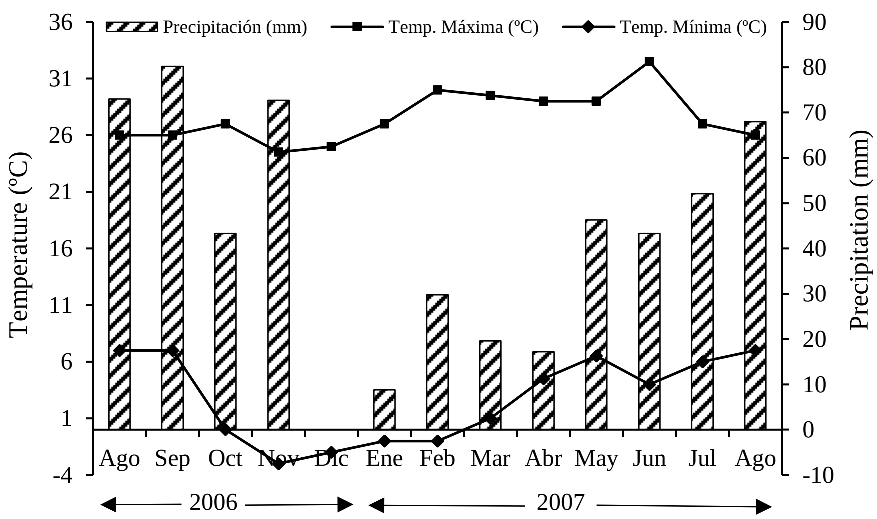

Figure 1. Maximum and minimum monthly average temperatures and monthly accumulated precipitation during the study period (2006-2007).

Statistical analysis

To compare the effect of the cut-off intervals, an analysis of variance was performed with the Mixed Model procedure (SAS, 2011). The treatments consisted of four cut-off intervals, randomly distributed under a completely random design with four repetitions. The comparison of means was performed using the adjusted Tukey test (α= 0.05).

Results and discussion

Dry matter yield

The lowest seasonal average yield of alfalfa was obtained in the winter season regardless of the interval between cut with 2 438 kg DM ha^{-1} and the highest value in summer and spring with an average of 3 357 kg DM ha^{-1} (p> 0.05; Table 1). As the interval between cuts increased, the average seasonal yield increased regardless of the seasons of the year, taking the lower and higher yield in the cutoff range of 4-3 and 7-6 with 1 501 and 4 393 kg DM ha^{-1}, respectively (p> 0.05).

Table 1. Average yield per cut of alfalfa (kg DM ha^{-1}), harvested at different cutting intervals.

Interval (weeks)	Autumn	Winter	Spring	Summer	Average	EEM
4-3	2 343 Ca	1 138 Cb	1 653 Cab	869 Dc	1 501 D	151.79
5-4	2 678 BCa	2 114 Bca	3 169 Ba	2 997 Ca	2 736 C	112.09
6-5	3 503 ABb	3 063 ABb	3 792 ABab	4 227 Ba	3 646 B	131.74
7-6	3 988 Abc	3 436 Ac	4 676 Aab	5 475 Aa	4 393 A	210.78
Average	3 128 ab	2 438 b	3 322 a	3 392 a		139.79
EEM	176.09	234.31	293.08	244.91	243.21	

4-3, 5-4, 6-5 and 7-6= cut-off intervals of 4, 5, 6 and 7 weeks for autumn-winter and 3, 4, 5 and 6 weeks for spring-summer, respectively; EEM= standard error of the mean; abcd= means with the same lowercase literal in the same row, they are not different ($p > 0.05$); ABCD= means with the same capital letter in the same column, they are not different ($p > 0.05$).

The tendency of reduction in the yield to lower cut-off intervals, evidences a possible depletion of the reserves located in the roots of the plants, since it has been demonstrated that, at short intervals, there is a depletion of the reserve substances and a rapid disappearance of forage species (Matthew *et al*., 1996; Valentine and Matthew, 1999; Villegas *et al*., 2006; Teixeira *et al*., 2008).

However, cut-off intervals similar to those studied may mean lower or higher yields depending on environmental conditions, the variety of alfalfa and agronomic management (Rivas *et al*., 2005; Villegas *et al*., 2004). The results obtained by these researchers indicate a distribution of performance, similar to that observed in the present study.

The differences in the average yield of forage (Table 1) for each cut interval and season ($p < 0.05$) show a frank combined effect of the cut interval and season, probably due to the effect of the minimum temperatures in autumn and winter. Although, this assertion requires considering a specific harvest interval, for each season of the year; definitely the lowest forage yields are obtained with the combination of cut-off intervals of 4-3 and 5-4 weeks in any season of the year ($p < 0.05$). Therefore, it is suggested to cut at intervals of 6-5 and 7-6 weeks regardless of the season of the year.

For the variety Jupiter of alfalfa Rojas *et al*. (2017) recorded the highest accumulation of dry forage in spring, with harvest intervals of four weeks. On the other hand, Rojas *et al*. (2016) when evaluating different varieties of alfalfa in the Valley of Mexico, they reported the highest forage yield in the stations with higher temperature and vice versa, managing a cut interval of 6, 5 and 4 weeks for winter, autumn and spring-summer.

Leaf-stem relationship

The index calculated for the leaf-stem relationship reveals that more alfalfa leaf was harvested in intervals of 4 to 3 weeks, in autumn-winter and spring-summer, than in intervals of 7 to 6 weeks, in autumn-winter and spring-summer ($p < 0.05$, Table 2). That is, a high proportion of leaves is associated with a low yield of dry matter, at short intervals and in autumn and winter ($p < 0.05$).

Table 2. Seasonal average of the leaf-stem ratio of alfalfa, harvested at different cut-off intervals.

Interval (weeks)	Autumn	Winter	Spring	Summer	Average	EEM
4-3	1.51 Ab	1.86 Aa	1.33 Ac	1.2 Ac	1.47 A	0.06
5-4	1.23 Bb	1.4 Ba	1 Bc	0.91 Bc	1.13 B	0.05
6-5	0.89 Cb	1.16 Ca	0.78 Cbc	0.71 Cc	0.88 C	0.04
7-6	0.77 Cab	0.9 Da	0.68 Cbc	0.6 Cc	0.74 D	0.02
Average	1.1 b	1.33 a	0.95 bc	0.85 c		0.04
EEM	0.07	0.09	0.06	0.05	0.07	

4-3, 5-4, 6-5 and 7-6= cut-off intervals of 4, 5, 6 and 7 weeks for autumn-winter and 3, 4, 5 and 6 weeks for spring-summer, respectively; EEM= standard error of the mean; abcd= means with the same lowercase literal in the same row, they are not different ($p > 0.05$). ABCD= means with the same capital letter in the same column, they are not different ($p > 0.05$).

With the increase in the cut interval, leaf/stem ratio decreased ($p < 0.05$) from 1.86 (4 to 6 weeks in winter) to 0.60 (7 to 6 weeks in summer). This has been previously reported (Mendoza *et al*., 2010), as demonstrated by the results of Villegas *et al*. (2006) for Valencian variety alfalfa, with leaf-stem ratio with the highest and lowest value of 1.29 and 0.72 in autumn and spring at cut-off intervals of 5 and 7 weeks, respectively ($p < 0.05$).

On average, leaf/stem ratio was 50% higher (1.47 *vs* 0.74), at cutoff intervals 4-3 than at 7-6. A value lower than unity, similar to that obtained in this work, was reported by different researchers in alfalfa in monoculture (Morales *et al*., 2006) and associated with different grasses (Camacho and García, 2003; Zaragoza *et al*., 2009). Rivas *et al*. (2005) obtained in five varieties of alfalfa an average leaf/stem ratio of 0.79, with the highest and lowest values of 1.05 and 0.62 in January and November ($p < 0.05$). On the other hand, Montes *et al*. (2016) reported a leaf-stem relationship in Alfalfa cv Oaxaca creole similar to that indicated in this research, obtaining the highest value when the interval between cuts is smaller and vice versa.

Protein in leaf and stem

The protein content, expressed as a percentage of dry matter, in leaves and stems, was influenced by the cut-off intervals and by the season ($p < 0.05$; Table 3). The alfalfa leaves harvested every 4 weeks, in the winter, had the highest protein content with 38% and less every 6 weeks with 23.4% in summer ($p < 0.05$). The cut interval that produced the lowest protein content of leaves was 7-6 weeks with an average of 34.1, 32.4, 31.6 and 28.4%, for the winter, autumn, spring and summer seasons, respectively.

The leaves with high protein content were harvested with cut intervals of 4-3 weeks, while leaves with low protein content were harvested by cutting the alfalfa for 7-6 weeks. This was probably due to the state of maturity of the leaves, which with cuts of 4-3 weeks were younger (Valentine and Matthew, 1999; Brock and Tilbrook, 2000).

Table 3. Average protein content of alfalfa leaves and stems (%) harvested at four cutting intervals.

Interval (weeks)	Autumn	Winter	Spring	Summer	Average	EEM
			Leaves			
4-3	34.2 Ac	38 Aa	35.8 Ab	33.2 Ad	35.3 A	0.43
5-4	32.9 Bc	36.1 Ba	34.4 Bb	31.5 Bd	33.7 B	0.5
6-5	31.2 Cc	33.4 Ca	32.3 Cb	25.4 Cd	30.6 C	0.88
7-6	28.3 Db	29 Da	27 Dc	23.4 Dd	26.9 D	0.59
Average	31.6 b	34.1 a	32.4 b	28.4 c		0.89
EEM	0.61	0.86	0.85	1.07	1.12	
			Stems			
4-3	16.4 Ab	18.1 Aa	16.8 Ab	14.7 Ac	16.5 A	0.38
5-4	15.8 Bc	17.4 Ba	16.3 Bb	13.8 Bd	15.8 AB	0.38
6-5	13.1 Cc	15.7 Ca	14.5 Cb	12.1 Cd	13.8 B	0.33
7-6	12.1 Db	13.5 Da	11.2 Dc	10.3 Dd	11.7 C	0.36
Average	14.3 b	16.1 a	14.7 b	12.7 c		0.43
EEM	0.45	0.47	0.58	0.44	0.56	

4-3, 5-4, 6-5 and 7-6= cut-off intervals of 4, 5, 6 and 7 weeks for autumn-winter and 3, 4, 5 and 6 weeks for spring-summer, respectively; EEM= standard error of the mean; abcd= means with the same lowercase literal in the same row, they are not different ($p > 0.05$). ABCD= means with the same capital letter in the same column, they are not different ($p > 0.05$).

In the case of stems, in all cut intervals, the highest protein content was recorded when alfalfa was harvested in winter with 16.1% and lower in summer with 12.7% ($p < 0.05$, Table 3). As in the leaves, in all the seasons, at a shorter cutting interval, higher protein concentration of stems ($p < 0.05$). The shorter cut intervals (4 to 3 weeks) produced higher protein content in stems, with respect to the other intervals ($p < 0.05$). In descending order, the protein content of stems was 18.1, 16.4, 16.8 and 14.7%, for short intervals (4-3 weeks) and 13.5, 12.1, 11.2 and 10.3% for longer intervals (7-6 weeks), in winter, autumn, spring and summer, respectively.

The highest protein content in alfalfa stems is attributed to the lower age of the harvested plants at short intervals (Valentine and Matthew, 1999). The results reveal that increasing the age of the plants decreases the protein content of leaves and stems (Avice *et al*., 1997). Similar results reported by Chocarro *et al*. (2001) as the interval between cuts decreased the same as the yield of dry matter, however, increased the amount of protein in alfalfa.

Digestibility of leaf and stem

The amounts of digestible dry matter contained in leaves and stems of alfalfa plants are presented in Table 4. In both cases, an increase in digestibility is clearly observed with the reduction of the cut interval ($p < 0.05$), in all seasons. In winter, the numerical values were higher, digestible dry matter of leaves and stems with an average of 86 and 74.4%, while in summer the lowest values were 80.8 and 65.1%, respectively ($p < 0.05$). These results may be due to the low temperatures registered in winter that stop the physiological maturity of the forage species (Brock and Tilbrook, 2000, Sage and Kubein, 2007), making them more digestible (Avice *et al*., 1997).

Table 4. Digestible dry matter contained in leaves and stems of alfalfa harvested at four cutting intervals.

Interval (weeks)	Autumn	Winter	Spring	Summer	Average	EEM
Leaves						
4-3	87.6 Aab	89.4 Aa	87.4 Aab	85.3 Ab	87.4 A	0.42
5-4	86.3 ABa	86.6 ABa	84.1 ABa	82.9 ABa	84.9 AB	0.51
6-5	83.4 BCab	84.6 Ba	82.5 BCab	79.8 Bb	82.5 BC	0.57
7-6	80.6 Ca	83.5 Ba	79.9 Ca	75.3 Cb	79.8 C	0.82
Average	84.5 ab	86 a	83.5 ab	80.8 b		0.67
EEM	0.72	0.64	0.77	0.94	0.89	
Stems						
4-3	74.6 Ab	78.6 Aa	76.2 Aab	73.4 Ab	75.7 A	0.54
5-4	66.9 Bbc	77.3 Aa	70.1 Bb	65.4 Bc	69.9 B	0.94
6-5	65.3 Bbc	72.2 Ba	68.7 Bab	62.8 Bc	67.2 BC	0.96
7-6	63.3 Bb	69.5 Ba	65.8 Bb	58.7 Cc	64.3 C	0.73
Average	67.5 ab	74.4 a	70.2 ab	65.1 b		0.78
EEM	0.84	0.99	1.02	0.86	0.87	

4-3, 5-4, 6-5 and 7-6= cut-off intervals of 4, 5, 6 and 7 weeks for autumn-winter and 3, 4, 5 and 6 weeks for spring-summer, respectively; EEM= standard error of the mean; abcd= means with the same lowercase literal in the same row, they are not different ($p > 0.05$). ABCD= means with the same capital letter in the same column, they are not different ($p > 0.05$).

The digestibility differences between winter-summer were 4.1, 3.7, 4.8 and 8.2% for leaves and 5.2, 11.9, 9.4 and 10.8% and for stems, with the intervals of 4-3, 5-4, 6-5 and 7- 6 respectively. In general, the greater interval between cuts affects more the stems and leaves digestibility than the seasons of the year (Table 4). Similar results reported by McMahon *et al*. (1999) in alfalfa digestibility with the highest and lowest value from 89.8 to 69%.

Conclusions

When the cutting interval was increased, a higher dry matter yield was obtained; however, the leaf-stem ratio, the lower protein content and the lower digestibility of the dry matter contained in the morphological components of the plants were lower. Therefore, the best harvest frequency for alfalfa cultivation is six weeks in the fall and winter and five and four weeks in the spring and summer, which achieves a balance between yield and quality of alfalfa.

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