Tarım Bilimleri Dergisi
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Journal of Agricultural Sciences
Journal homepage:
www.agri.ankara.edu.tr/journal

TARIM BİLİMLERİ DERGİSİ — JOURNAL OF AGRICULTURAL SCIENCES 25 (2019) 384-390

Influence of Harvesting on Quality of Alfalfa Forage used for Haylage and Hay

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ARTICLE INFO
Research Article
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Received: 18 June 2018, Received in Revised Form: 16 August 2018, Accepted: 08 September 2019

ABSTRACT

The paper presents the three years efficiency results (2011-2013) of the work and ways of harvesting (three types of mowers, with or without spreading the forage) influencing the quality of the forage (the content of crude protein and crude fiber) during the three days drying process. These results indicate that the harvesting method can strongly affect the work efficiency, energy consumption, the forage drying intensity and the quality of forage used for hay and haylage preparation. The best quality of the forage was achieved when a drum rotating mower PÖTTINGER CAT 185 was used. Negative correlation was found between content of crude protein and the crude fibre content, depending on the type of mower, varying in the range between r= -0.978 and r= -0.882 (PÖTTINGER CAT 185 r= -0.882 P≤0.05 to JF STOLL SB 200 r= -0.978 P≤0.001).

Keywords: Mowers; Cutting; Drying; Crude protein; Crude fiber

1. Introduction

In many regions of the world, alfalfa (*Medicago sativa*) is an important fodder plant for the provision of high-quality animal feed for ruminant (Khadda et al 2015; Ahmad et al 2016). It is very adaptable to the environmental conditions, which enables a wide area of growing (in the northern hemisphere it is grown up to 69° N - in Scandinavian countries, and in the south up to 45° S (New Zealand), as well as on 55° S in Argentina and Chile (Ivanov 1988). Its preference lies in the fact that it is used in different ways: fresh, hay, silage, haylage and/or for pasturage. It has high nutritive values. All of this gives it the title of Queen of forage crops. High variability of yield and quality of alfalfa forage is defined in the world, be it influenced by genetics, cultivation technology, harvesting manner (Brummer 2004; Ahmad et al 2016; Karayilanli & Ayhan 2016), and seed yield (Stanisavljević et al 2012; Zhang et al 2017). Bagg (2004) recommends manipulation of the mowed alfalfa mass of humidity up to 50% using a rotary spreader. Subsequent treatment of the mass with a lower percentage of humidity results in a large loss of leaves. In the southeastern and southern Europe, alfalfa is mainly used for drying and haymaking, but in smaller areas it is used for storing haylage. Given that the process of hay storing and/or alfalfa haylage is done on the fields, it is largely dependent on climatic factors. Based on rainfall simulation, Coblentz & Muck (2012) reported consistent reductions in concentrations of WSC and starch. However, changes in WSC were relatively modest, and postwetting concentrations of WSC could be buoyed by hydrolysis of starch. In addition, they found much less desirable indicators of ensilability, when forages were subjected to natural rainfall events followed by prolonged exposure under field conditions. Therefore, the selection of the appropriate mowing apparatus and timely alfalfa mowing is essential for protein and fibre content, being the most important parameter of the forage quality. Mowers are agricultural machines that consume a lot of energy, and the special attention has to be paid to optimal energy consumption and quality of work (Hosseini & Shamsi 2012).

The aim of this study was to determine the impact on yield, quality of forage and energy consumption by examining the ways of alfalfa harvesting.

2. Material and Methods

Field experiment was established in Central Serbia, (43^0 33' 33''N; 21^0 12' 53''E) on alfalfa Cultivar Kruševacka-28 in the third to fifth year of use when in the phase ½ of flowering. Random block system with three repetitons over the plots of 30 m x 10 m= 300 m^2 was used. Cultivar is characterized by high genetic potential for yield of forage (over 80 t ha^{-1}) and dry matter (over 20 t ha^{-1}). It is suitable for intensive production, achieves 6 cuts per year with applied irrigation. This cultivar is tolerant to lodging, frequent cutting and possesses a high resistance to low temperatures and drought, providing excellent forage quality: crude protein content is 20-22 g kg^{-1} and crude fiber (CF) about 32 g kg^{-1} (Institute for Forage Crops 2011).

Alfalfa seeding have been performed following classical soil tillage system, after deep autumn plowing and secondary soil tillage, characterised with a seed norm of 20 kg h^{-1} during each experimental year, the mineral fertilizer consisting of 8% (N): 16% (P_2O_5): 24% (K_2O) 150 kg h^{-1} was deposited over the plot.

At the first alfalfa harvest during 2011 (A_1), 2012 (A_2), 2013 (A_3) - factor A, three mowers were studied: IMT 627 667 (B_1), whose cutting apparatus consists of fixed and mobile part. Fixed part consists of steel beam with fingers. Each finger has a counter knife attached it by clinch. The movable part is a rod with moving blades having a straight line and return movement, Pottinger CAT 185 (B_2), rotary mower with two drums that work in pairs. Each drum has three movable blades which cut the stem cut off with free and high velocity of the blades (60 to 80 m s^{-1}), and JF-STOLL SB 200 (B_3), rotary mower with five disks with two knives each - factor B. After cutting, forage was spread on one half of the plot during the first two days (C_2), whereas on the other half it was dried without spreading (C_1) (factor C). Samples of forage were analyzed immediately after cutting (D_0), on the cutting day after 8^h (18^h) (D_1), on the second day at 18^h (D_2) and on the third day at 18^h (D_3), factor D time after cutting. Speed is determined by the chronometer method based on distance travelled per unit of time. The quality of work is determined through the working width, the stems cutting height and losses while mowing, assuming that the optimum cutting height for alfalfa is 6 cm. Stem cutting height is determined by the on-site determination of loss, by measuring the height of stubble for each probe (probe within three replicates) on a suitable surface. The mean values are determined for each trial on the basis of obtained parameters. During mowing, losses were measured on the surface of one length meter of swath in working width, of tested mowers, on the same place where the height of cut was determined. Total losses (L_Σ [%]) represent the sum of the losses incurred due to the cut height (L_{Hcut} [%]) and losses incurred due to chopping (L_{Chop} [%]). After cutting, humidity of the mowed mass was measured on the first, second and third day at 18 h (after drying in a drier at 105 ^{0}C), and the forage quality parameters in the dry matter were measured: Crude protein (CP, g kg^{-1}), using the Kjeldahl method (AOAC 1990) and crude fibre (CF, g kg^{-1}), using the Weende method (AOAC 1990).

Statistical analysis of forage quality: analysis of variance (ANOVA F-test) was applied to determine the influence of the factors, whereas Tukey's Multiple Range test was used for assessing the influence of the middle of the treatment. The relationship between traits was established by the Pearson's Correlation Test (r). The program Minitab 16.1.0 was used for data processing.

3. Results and Discussion

Under the agroecological conditions in South East Europe, alfalfa is generally mowed four times, wherein the first cutting contributes to an overall forage yield with about 50% (Strbanović et al 2015). Therefore, this work depicted the results of the first cut. During experiment (2011-2013), there was no rainfall in the alfalfa drying period (D_1-D_3), and the temperature had not varied for more than 2%. Also, the relative humidity did not vary for more than 2% (Figure 1).

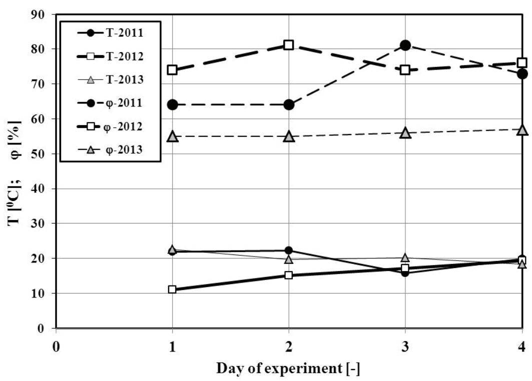

Figure 1- Atmospheric conditions during experimental mowing: the mean temperature T [^{0}C] and relative humidity ϕ [%]

3.1. Work efficiency of the mowers

In our tests, the maximum value of the utilization coefficient of working swath of 0.97 (1.55 m), was found at classical mower in the first year of research. The lowest value of 0.91 (1.81 m) was recorded at the rotational disc mower in the third year of research. The cutting height depends on the mower movement speed. The maximum value of the cutting height from 7.25 cm was recorded at the rotational disc mower in the third year of research, at speed of 12.4 km h^{-1}. The minimum value of the cutting height of 5.52 cm in the first year of research was recorded at rotary mower with drums at speed of 9.1 km h^{-1} (Figure 2). The obtained results are consistent with the results of other researchers (Wiersma & Wiederholt 2001).

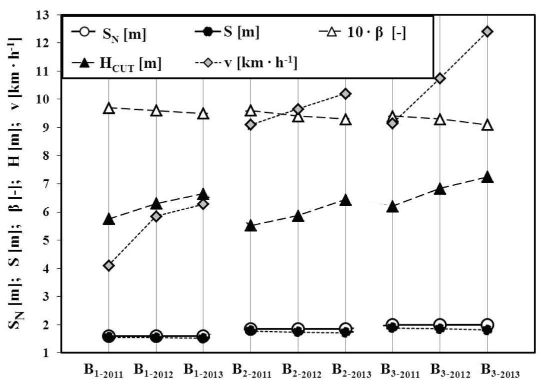

Figure 2- Operational parameters of the harvesters: nominal working swath S_N [m]; achieved working swath S [m]; coefficient of achieved working swath β [-]; cutting height H_{CUT} [m]; working speed v [km · h^{-1}]

Figure 3 shows the losses of the tested mowers. Minimum losses of 1.03% were recorded in conventional mowers in the first year, whereas maximum of 3.03% were recorded at rotary mowers with drums in the third year of research. The evidenced losses correspond with the results of other researchers (Bagg 2004; Barać et al 2012).

Using variance analysis (F test) we found that years (factor A) and interactions AxB, AxC, AxD did not seem significant for the moisture content,

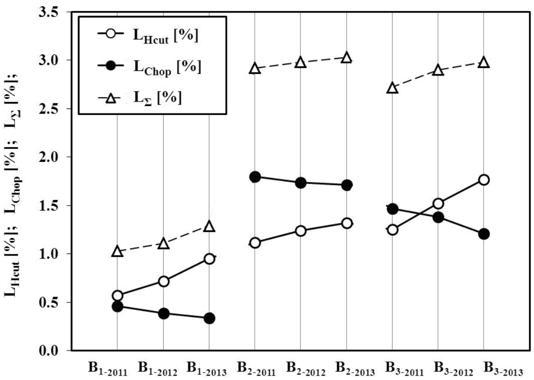

Figure 3- Harvesting losses due to: cutting height L_{HCut} [%], chopping L_{Chop} [%] and total L_{Σ}[%]

crude protein and crude fiber in alfalfa forage (hereinafter the average values for 2011-2013 are given). Influence of different mower (factor B), hay spreading (C) and drying time (D) had significant impact ($P\leq0.05$ to $P\leq0.001$), as well as their interaction on the moisture content, crude protein and crude fiber in the alfalfa forage (Table 1).

3.2. Forage moisture

Forage moisture should be up to 20% (Undersander et al 2004) for drying process and hay preparation without additives that can be stored. Optimum moisture content is 55%-60% for making haylage without additives (Dinić & Djordjević 2005). Due to possible rainfall, it is usefull to make green fodder into stored hay or silage. As expected, moisture ranged from 76% (B_1) to 71% (B_2 and B_3) immediately after mowing, so that due to high moisture, forage could have not been used even for silage. After eight hours, moisture from the treatments B_1 C_1 and C_2 (56.8% and 55.5%) B_2 C_1 (55.1%) was ideally suited for the preparation of haylage. Forage referred to in the treatment B_3 C_2 and B_2 C_2 (47.7% and 49.0%) had a significantly lower moisture ($P\leq0.05$) than forage from B_1 C_1 (56.8%). As expected, in all B_1-B_3 treatments of the forage spreading (C_2), moisture was lower compared to the forage not spread (C_1) (Table 2).

On the second day of forage drying, moisture between spread and non-spread feed was as follows: 7.6% for the treatment B_1; 6.5% for the treatment B_2 and 4.7% for B_3. However, after two days of drying, the moisture of the applied treatments was high for hay making, but low for haylage, so the different mowers (B_1-B_3) and forage spreading could not influence enough on forage moisture to make it sufficient for hay storing. After the third day (D_3) the forage treatment: B_3 C_1 and C_2 (moisture content 18.9% and 17.3%); B_2 C_2 (moisture content 18.6%), and B_1 C_2 (moisture content 18.7%) met conditions

Table 1- Results of analysis of variance (ANOVA) for forage moisture, crude proteins, crude fiber. Sources of variation: (A), year; (B), type of mower; (C), hay spreader; (D), time after cutting

Source of variation	*Forage moisture (%)*	*Crude proteins (CP, g kg^{-1})*	*Crude fibre (CP, g kg^{-1})*
Year (A)	ns	ns	ns
Type of mower (B)	*	*	*
Hay spreader (C)	**	*	*
Time after cutting (D)	***	***	***
AxB	ns	ns	ns
AxC	ns	ns	ns
AxD	ns	ns	ns
BxC	**	*	*
BxD	**	*	*
CxD	*	*	*

***, significant F tests at the $P\leq0.001$ level of significance; **, significant F tests at the $P\leq0.01$ level of significance; *, significant F tests at the $P\leq0.05$ level of significance; ns, not significant F tests at the $P\geq0.05$ level of significance

Table 2- Influence of way of alfalfa harvesting to forage moisture during three days of drying

Type of mowers-B treatmens B_1-B_3	*Forage moisture (%)*					
	Before cutting	*Immediately after cutting (10 h) D_0*	*C*	*Cutting day 18 h D_1*	*Second day 18 h D_2*	*Third day 18 h D_3*
B_1	78.0 ^{a}	76.0 ^{a}	C_1	56.8 $^{a\,A}$	35.0 $^{a\,B}$	25.4 $^{a\,C}$
			C_2	55.5 $^{ab\,A}$	27.4 $^{ab\,B}$	18.7 $^{ab\,C}$
B_2	76.0 ^{a}	71.5 ^{b}	C_1	55.1 $^{ab\,A}$	33.4 $^{a\,B}$	22.0 $^{a\,C}$
			C_2	49.0 $^{b\,A}$	26.9 $^{b\,B}$	18.6 $^{b\,C}$
B_3	75.0 ^{a}	71.5 ^{b}	C_1	50.6 $^{ab\,A}$	29.6 $^{ab\,B}$	18.9 $^{ab\,C}$
			C_2	47.7 $^{b\,A}$	24.9 $^{b\,B}$	17.3 $^{b\,C}$

a, b, (different small letters) significant effect (P≤0.05; Tukey's Multiple Range test) for the column; A, B, C (different capital letters) significant effect (P≤0.05; Tukey's Multiple Range test) for the row

for hay making, which can be stored for long time (Undersander et al 2004).

3.3. The content of crude protein and crude fiber

Strbanović et al (2017) found the maximum crude protein content of 212 g kg^{-1} dry matter for the researched sorts at the beginning of flowering process, whereas the lowest recorded content 174 g kg^{-1} of dry matter. Thus, depending on a sort, the content of CP in the forage varied for 41 g kg^{-1} dry matter. Our research has shown lower levels of crude protein, which can be explained by the fact that mowing was done at a stage when a ½ plant was in flowering process. In general, the quality of alfalfa forage got worse as the days of drying passed (the protein content in the alfalfa forage decreased, a crude fibre content increased), which was statistically significant between the first and third day (P≤0.05) (Table 3 and 4).

Following Fonnesbeck et al (1986) yield loss from soluble nutrients was 9.7% (losses of 18.8% available carbohydrate, 10.2% of crude protein, 19.8% of lipids and 14.0% of soluble minerals). Influence of rain damage on hay quality reducing was more expressed than the influence of advancement in maturity.

Table 3- Influence of alfalfa harvesting on crude protein content in dry matter alfalfa forage during the three days of drying

Type of mowers-B treatmens B_1-B_3	*C*	*CP, g kg^{-1}*		
		Cutting day 18 h D_1	*Second day 18 h D_2*	*Third day 18 h D_3*
B_1	C_1	163.0 $^{a\,A}$	138.4 $^{ab\,B}$	125.8 $^{ab\,B}$
	C_2	160.9 $^{ab\,A}$	124.4 $^{b\,B}$	112.2 $^{b\,B}$
B_2	C_1	164.8 $^{a\,A}$	147.9 $^{a\,AB}$	137.1 $^{a\,B}$
	C_2	160.5 $^{ab\,A}$	139.6 $^{a\,B}$	128.6 $^{a\,B}$
B_3	C_1	157.0 $^{b\,A}$	125.6 $^{b\,B}$	125.6 $^{ab\,B}$
	C_2	158.8 $^{b\,A}$	133.7 $^{ab\,AB}$	119.8 $^{b\,B}$

a, b, (different small letters) significant effect (P≤0.05; Tukey's Multiple Range test) for the column; A, B, (different capital letters) significant effect (P≤0.05; Tukey's Multiple Range test) for the row

Table 4- Influence of alfalfa harvesting on crude fibre content in dry matter of alfalfa forage during the three days of drying

Type of mowers-B treatmens B_1-B_3	*C*	*CF, g kg^{-1}*		
		Cutting day 18 h D_1	*Second day 18 h D_2*	*Third day 18 h D_3*
B_1	C_1	34.96 $_{a\,B}$	38.35 $_{a\,AB}$	39.85 $_{a\,A}$
	C_2	34.57 $_{a\,B}$	37.57 $_{a\,AB}$	40.41 $_{a\,A}$
B_2	C_1	35.24 $_{a\,B}$	36.99 $_{a\,AB}$	38.45 $_{a\,A}$
	C_2	34.59 $_{a\,B}$	36.02 $_{a\,AB}$	39.26 $_{a\,A}$
B_3	C_1	35.28 $_{a\,B}$	38.53 $_{a\,AB}$	39.55 $_{a\,A}$
	C_2	34.81 $_{a\,B}$	37.58 $_{a\,AB}$	40.39 $_{a\,A}$

a, b, (different small letters) significant effect ($P \leq 0.05$; Tukey's Multiple Range test) for the column; A, B, (different capital letters) significant effect ($P \leq 0.05$; Tukey's Multiple Range test) for the row

The highest contents of crude proteins was recorded 8^h after mowing (D_1), on the second (D_2), and on the third day (D_3) from the treatment of B_2 C_1. The crude protein content was lower from treatments with the spread forage, as a consequence of leaves loss (having the highest protein content) during the mass spreading. (Table 3).

Influence of mower had no statistically significant effect after any time (D_1-D_3) on the crude fibre content (Table 4). According to Strbanović et al (2017) the average value of the crude fibre content for fifteen alfalfa sorts is 275 g kg^{-1} with differences of 99 g kg^{-1} of dry matter, caused by impact of a sort, and the total variability expressed by the coefficient of variation 10.48%. It also indicates a high impact on the exploitation phase of the crude fiber content.

After application of various mowers for the collection of alfalfa forage, a negative correlation between the content of crude protein and crude fiber was found, but of different intensity ($P \leq 0.01$ B_1; B_2 $P \leq 0.05$; B_3 $P \leq 0.001$) (Table 5). The results of the negative interdependent correlation ($P \leq 0.001$) between content of protein and cellulose are consistent with the results of Heuze et al (2013), Strbanović et al (2017).

Table 5- Coefficient of simple correlation (r) between the content of crude protein and crude fiber content in the forage cut by different mowers (n= 6)

Type of mowers-B tretmani B_1-B_3	*r*
B_1	-0.929 **
B_2	-0.882 *
B_3	-0.978 ***

Statistical significance level; *, $P \leq 0.05$; **, $P \leq 0.01$; ***, $P \leq 0.001$

4. Conclusions

If the alfalfa forage is used to store haylage under the given conditions and in similar regions throughout the world, ten hours are sufficient if the collection is performed by a rotary mower with a drum PÖTTINGER CAT 185 (B_2) or less, using a rotary device with discs JF-STOLL SB 200 (B_3) with spreading. For hay storing (humidity under 20%), the application of a rotary device with discs STOLL JF-SB 200 (B_3) provides moisture, be the forage spread or not. That is also provided by the other two mowers (B_1 and B_2), with hay spreading (C_2). The best forage quality was achieved by mower PÖTTINGER CAT 185 (B_2), which is reflected in the highest crude protein content and the lowest dependence correlation with the crude fibre content (r= -0,882; $P \leq 0.05$).

Acknowledgements

The investigation published in this paper is a part of the project "Improvement of biotechnological procedures as a function of rational utilization of energy, agricultural products productivity and quality increase" financed by the Ministry of Education and Science of the Republic of Serbia, grant No TR-31051.

Abbreviations and Symbols	
r	Index of correlation
P	Signifficance level
L_{Σ}	Total losses, (%)
L_{Hcut}	Cut-height losses, (%)
L_{Chop}	Chopping losses, (%)
CP	Crude protein content, (g kg^{-1})
CF	Crude fibre content, (g kg^{-1})

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