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Effects of Row Spacing and Sowing Rate on Quality Performance of Alfalfa (*Medicago sativa* L.) Under Tokat Ecological Conditions

Mahir OZKURT[a]*, Yaşar KARADAG[a]

[a]*Department of Plant Production and Technologies, Faculty of Applied Sciences, Mus Alparslan University, Muş, TURKEY*

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Corresponding Author: Mahir OZKURT, E-mail: mahirozkurt@gmail.com
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ABSTRACT
This research was conducted to determine the effects of row spacing and sowing rate on the hay quality characteristics of alfalfa under Tokat-Kazova ecological conditions during the years of 2014-2016. Alfalfa cultivar Bilensoy-80 was sown at four different row spacings (15, 30, 45 and 60 cm) and six different sowing rates (5, 10, 15, 20, 25 and 30 kg ha^{-1}). The experimental design was randomized complete block design in split plots with four replications. Row spacings were main plots and sowing rates were sub-plots. The highest crude protein content (% 20.8) and relative feed value (147.8) were obtained from 5 kg ha^{-1} sowing rate and 15 cm row spacing. It was concluded based on present findings that Belinsoy-80 alfalfa cultivar should be sown at 15 cm row spacing and 25 kg ha^{-1}sowing rate for high hay quality under Tokat-Kazova ecological conditions.

Keywords: *Lucerne, Sowing rate, Crude protein rate, ADF, RFV, Anatolia*

1. Introduction

Alfalfa is the most common forage plant worldwide. So, called as the queen of forage crops, alfalfa has a higher forage yield than almost all the other forage crops. Hay and green herbage of alfalfa with quite a high protein yield per unit area are delicious and nutritious for all kinds of animals. Alfalfa herbage is rich in vitamins. Due to its deep roots, it can easily benefit from soil water and nutrients. Since alfalfa is a leguminous plant, it is able to fixate free atmospheric nitrogen into the soils through root nodules (Acıkgöz 2001). Relative feed value is generally used to assess quality of alfalfa hay and herbage (Yavuz 2005). The relative feed value is calculated with the use of acid detergent fiber (ADF) and neutral detergent fiber (NDF) values. In animal feeding, ADF has been used as an energy indicator especially in ruminant rations (Tekce & Gül 2014) and NDF has been used as an indicator of how much feed an animal will consume within 24 hours (Budak & Budak 2014). In other words, while ADF value gives an idea about the quality of the feed, NDF value gives an idea about the size-thickness of the feed (Kutlu 2008). In calculating the relative feed value, digestible dry matter and dry matter intake are determined and protein content is not included in the calculation (Güney et al. 2016). Protein ratio itself is a quality criterion.

Inter-row and intra-row spacing designate solar radiation and consequent biomass production of alfalfa plants. Row spacing alone influences the yield and quality of the plants and it is an easy-to-apply agronomic practice (Mattera et al. 2013). Plant losses in the year of establishment are generally higher in high sowing rate than in low sowing rate (Volenec et al. 1987).

Seed cost and seed supply constitute the most important problems in cultivation of forage crops. Alfalfa cultivated lands are renewed generally in every four years. In 2017, alfalfa seed need of Turkey was 3297.0 tons, but certificated alfalfa seed production was 887.4 tons. That means only 26.9% of alfalfa seed needs were met (Anonymous 2018). The remaining 75% was supplied from the seeds produced in alfalfa cultivated lands of farmers and growers. In Turkey, although varied with the regions, alfalfa sowing rate vary between 40 - 180 kg ha^{-1}. Following the first winter after sowing, it is desired to have a plant density of 130 plants/m^2 (Rashidi et al. 2009). With a simple calculation, approximately 9 kg ha^{-1} seed is sufficient to attain this plant density after the first winter. Thousand grain weight of alfalfa is approximately 2.4 g. It is known that approximately 50-60% of the seeds sown form the seedlings and 60-80% of these seedlings die after the first winter (Rashidi et al. 2009). In this case, the sowing rate per hectare is 9 kg. When it considered that half of the seeds planted will not emerge since the field conditions were not optimal, soil was not well prepared and problems were encountered in germination of the seeds, it will be sufficient to use 18 kg of seed per hectare to achieve optimum plant density. In this sense, sowing rate (amount of seed to be sown per unit area) has become an important issue in alfalfa cultivation.

Numerous researches have been completed on sowing rate and plant density in many parts of the world. Chocarro & Lloveras (2015) reported in their research that narrower row spacings provided higher dry matter yields. Yilmaz et al. (2015) conducted a study under ecological conditions of Kahramanmaras province and reported that narrow row spacing was more advantageous in terms of herbage and seed yields. Caddel et al. (2017) indicated “variety selection”, “seed quality” and “sowing rate” as the cost items in alfalfa cultivation and pointed out that these issues should not be considered separately.

Although the number of seeds is low in different regions in Turkey and the distance between rows has been studied, no research has been found on the seed amount and row spacing of Bilensoy 80 alfalfa cultivar in Tokat Kazova, which is located in the transition zone climate zone. This study was conducted to determine the effects of different row spacings and sowing rates on the hay quality characteristics of Bilensoy-80 alfalfa cultivar under Tokat-Kazova ecological conditions.

2. Material and Methods

The research was conducted under ecological conditions of Tokat-Kazova located at between 40° 19` North latitude and 40° 19` East longitudes and with an altitude of 595 m between the years 2014-2016. Experimental soils were rich in lime and potassium, clay-loam in texture, alkaline, but poor in organic matter (Anonymous 2014). Bilensoy-80 alfalfa cultivar was used as the plant material. This widely-grown and well-adapted cultivar was developed by Ankara Field Crops Central Research Institute and registered in 1984. It is listed in 4-5 dormancy group. Experiments were conducted in randomized complete block design in split plots with 4 replications. Experimental treatments are composed of 6 different sowing rates (5, 10, 15, 20, 25 and 30 kg ha^{-1}) and 4 different row spacings (15, 30, 45 and 60 cm). Row spacings were placed in main plots and sowing rates were placed in sub-plots. Experimental plots were 5 m long and each plot had 6 rows. Based on row spacings, plot sizes were arranged as 0.15 x 6 x 5 = 4.5 m^2, 0.30 x 6 x 5 = 9 m^2, 0.45 x 6 x 5 = 13.50 m^2, 0.6 x 6 x 5 = 18 m^2. When the plants reached 10% flowering, two side rows and 50 cm sections from the top and bottom of each plot were omitted as to consider side effects and harvest was performed from the remaining plot area (Avcıoglu et al. 2009).

Since alfalfa is a perennial crop and the first year is its establishment year (2014), observation and measurements were not taken in the first year. Observations and measurements were made in the 2^{nd} (2015) and 3^{rd} (2016) years (Anonymous 2001). Quality analyses were conducted in accordance with the studies of Sleugh et al. (2000); Bulgurlu & Ergül (1978); Van Soest et al. (1991) and Sheaffer et al. (1995). Variance analysis was applied to the experimental data by using the MSTAT-C statistical software in accordance with the randomized complete block design in split plots. Significant means were compared with the use of Duncan’s multiple comparison test (Yurtsever 2011).

3. Research Findings and Discussion

3.1. Crude protein ratio (%)

According to variance analysis of separate years data, row spacing, sowing rate and row spacing x sowing rate interactions had significant effects on crude protein ratio in the first year of the study; sowing rate and row spacing x sowing rate interactions had significant effects on crude protein ratio in the second year of the study. According to variance analysis of combined years data, year, year x row spacing, row spacing x sowing rate, year x sowing rate and row spacing x year x sowing rate interactions had significant effects on crude protein ratio. Average crude protein ratios for different row spacing-sowing rate combinations in the experimental years and as averaged values of two years are provided in Table 1.

Table 1- Averaged crude protein ratios (%) for different row spacings and sowing rates in the experimental years and in the combination of two years

Years	*Row Spacing*	*Sowing Rate*						
		5 kg ha⁻¹	*10 kg ha⁻¹*	*15 kg ha⁻¹*	*20 kg ha⁻¹*	*25 kg ha⁻¹*	*30 kg ha⁻¹*	*Average*
2015	15 cm	20.4 f-n[2]	20.3 g-p	20.5 d-m	19.5 o-t	20.2 h-p	19.2 q-t	20.0 D[*]
	30 cm	20.1 l-q	19.2 rst	19.7 m-t	19.4 p-t	19.7 m-t	19.0 t	19.5 E
	45 cm	19.9 k-s	20.8 b-k	19.6 n-t	20.4 f-n	19.9 l-s	19.5 o-t	20.0 D
	60 cm	20.0 j-r	19.1 st	20.1 ı-q	20.6 c-l	20.2 g-o	20.1 ı-p	20.0 D
	Avg.	20.1 C[+]	19.8 CD	20.0 C	20.0 C	20.0 C	19.5 D	19.9 B[1]
2016	15 cm	21.3 b-e	21.4 bc	21.3 bcd	21.1 b-g	20.6 c-l	21.5 ab	21.2 A
	30 cm	20.7 c-l	20.2 h-p	21.3 bcd	20.4 e-m	21.6 ab	22.2 a	21.1 AB
	45 cm	19.7 m-t	20.6 c-l	21.3 bcd	21.0 b-h	20.8 b-k	20.4 e-m	20.6 C
	60 cm	21.2 b-f	20.8 b-k	20.3 g-o	20.9 b-ı	20.8 b-j	20.9 b-ı	20.8 BC
	Avg.	20.7 B	20.7 B	21.1 AB	20.9 B	20.9 AB	21.3 A	20.9 A
Combined Years	15 cm	20.8 ab[3]	20.8 ab	20.9 a	20.3 b-f	20.4 a-f	20.4 a-f	20.6
	30 cm	20.4 a-f	19.7 g	20.5 a-e	19.9 efg	20.6 abc	20.6 abc	20.3
	45 cm	19.8 fg	20.7 abc	20.5 a-e	20.7 abc	20.3 a-f	20.0 d-g	20.3
	60 cm	20.6 abc	19.9 efg	20.2 c-g	20.8 abc	20.5 a-d	20.6 a-d	20.4
	Avg.	20.4	20.3	20.5	20.4	20.5	20.4	20.4

*: Means indicated with the similar capital letters in the same column are not significantly different at P≤0.05 according to Duncan's test; [+]: Averaged values of year x sowing rate combinations indicated with similar capital letters are not significantly different at P≤0.01 according to Duncan's test; [1]: The averages of the years indicated with different letters are not significantly different; [2]: Row spacing x year x sowing rate interactions indicated with similar lower case letters are not significantly different at P≤0.01 according to Duncan's test; [3]: Averaged values of row spacing x sowing rate combinations indicated with similar lower-case letters are not significantly different at P≤0.01 according to Duncan's test.

The average crude protein ratio was determined as 19.9% in the first year and 20.9% in the second year of the study. There were significant differences in average crude protein ratios of the years (Table 1).

In the first year of the study, row spacings significantly affected crude protein ratio. On the other hand, significant row spacing x year interactions revealed that effects of row spacings on crude protein ratio varied with the years. In terms of year x row spacing interactions, the lowest value (19.5%) was obtained from 30 cm row spacing of 2015 and the greatest values (21.2 and 21.1%) were respectively obtained from 15 and 30 cm row spacings of 2016.

Separate analyses of the years revealed that sowing rates significantly affected crude protein ratios. On the other hand, significant year x sowing rate interactions revealed that effects of sowing rates on crude protein ratios varied with the years. In the first year, row spacing of 30 cm resulted in significantly lower crude protein ratio than the other row spacings tested while row spacing of 15 cm gave significantly higher crude protein ratio than the other row spacings with the exception of 30 cm in the second year. In terms of crude protein ratio, while the sowing rate of 5 kg ha^{-1} was found to be the optimum sowing rate in the first year of the study, 30 kg ha^{-1} sowing rate was identified as the optimum sowing rate in the second year of the study. At sowing rate of 5 kg ha^{-1}, population density was lower, thus greater number of branches and consequently greater crude protein ratios were achieved. On the other hand, in the second year of the study, change in population resulted in greater crude protein ratio at 30 kg ha^{-1} sowing rate. Similarly, Hansen & Krueger (1973) obtained the highest crude protein ratio from the low sowing rate (45 kg ha^{-1}) in the first year and from the higher sowing rate (135 kg ha^{-1}) in the second year.

Karadag et al. (2011) conducted a study with different alfalfa cultivars under the same ecological conditions as in this study and indicated Bilensoy-80 cultivar as prominent with crude protein ratio. Stout (1998) reported insignificant differences in crude protein ratios of alfalfa under different row spacings.

Present findings on crude protein ratios are in agreement with the findings of earlier studies (Hansen & Kreuger 1973; Stout 1998; Avci et al. 2009; Scholtz 2009; Saruhan & Kusvuran 2011; Yavuz 2011; Cinar 2012; İnal 2015; Acikbas et al. 2017; Erdel 2017).

3.2. Acid detergent fiber content (%)

Variance analysis revealed that sowing rates had significant effect on ADF ratio in the first year of the study. Additionally, significant differences were observed in ADF ratio depending on the year. Combined analysis of the years revealed that year x sowing rate and row spacing x year x sowing rate interactions were statistically significant for this character.

Acid detergent fiber ratios of the years and two-year averages under different row spacings and sowing rates are provided in Table 2.

The average ADF ratio was determined as 35.5% in the first year and 30.9% in the second year of the study. ADF ratio significantly varied with the years (Table 2).

In the first year of the study, sowing rates significantly affected ADF ratios. On the other hand, significant year x sowing rate interactions revealed that effects of sowing rates on ADF ratios varied with the years.

Table 2- ADF Ratios (%) for different row spacings and sowing rates in the experimental years and in the combination of two years

Years	*Row Spacing*	*Sowing Rates*						
		5 kg ha^{-1}	*10 kg ha^{-1}*	*15 kg ha^{-1}*	*20 kg ha^{-1}*	*25 kg ha^{-1}*	*30 kg ha^{-1}*	*Average*
2015	15 cm	34.5 cd[1]	34.6 cd	35.3 a-d	35.7 a-d	35.6 a-d	36.1 a-c	35.3
	30 cm	36.1 abc	35.0 bcd	35.6 a-d	35.2 a-d	35.9 a-d	36.3 ab	35.7
	45 cm	36.0 abc	35.4 a-d	36.7 a	35.9 a-d	35.2 a-d	35.5 a-d	35.8
	60 cm	34.6 cd	35.2 a-d	36.0 abc	35.2 a-d	34.3 d	35.5 a-d	35.1
	Avg.	35.3 AB[+]	35.1 B	35.9 A	35.5 AB	35.3 AB	35.9 A	35.5 A[*]
2016	15 cm	30.3 fg	30.8 ef	31.1 ef	30.9 ef	30.7 ef	30.7 ef	30.8
	30 cm	31.7 ef	31.0 ef	30.6 ef	31.1 ef	30.6 ef	29.0 g	30.7
	45 cm	30.5 efg	31.5 ef	32.0 e	31.5 ef	31.9 ef	31.8 ef	31.5
	60 cm	30.8 ef	30.4 efg	30.4 efg	31.3 ef	31.5 ef	30.3 fg	30.8
	Avg.	30.8 CD	30.9 CD	31.0 CD	31.2 C	31.1 CD	30.5 D	30.9 B
Combined Years	15 cm	32.4	32.7	33.2	33.3	33.2	33.4	33.0
	30 cm	33.9	33.0	33.1	33.2	33.3	32.7	33.2
	45 cm	33.3	33.5	34.4	33.7	33.6	33.7	33.7
	60 cm	32.7	32.8	33.2	33.3	32.9	32.9	33.0
	Avg.	33.1	33.0	33.5	33.4	33.2	33.2	33.2

[*]: Means indicated with different capital letters are significantly different from each other; [+]: Year x sowing rate combinations indicated with similar capital letters are not significantly different at P≤0.05 according to Duncan's test; [1]: Row spacing x year x sowing rate combinations indicated with similar lower case letters are not significantly different at P≤0.05 according to Duncan's test.

Thus, optimum sowing rate for a low ADF content of the forage was 10 kg ha^{-1} in the first year while it was 30 kg ha^{-1} in the second year (Table 2). Combined analysis of the years revealed that row spacing x year x sowing rate interactions had significant effects on ADF ratios. Such a case indicated that effects of row spacing x sowing rate interactions varied with the years. Thus, optimum row spacing x sowing rate combination for a low ADF content in the first year was 60 cm x 25 kg ha^{-1} while 30 cm x 30 kg ha^{-1} in the second year.

Stout (1998) indicated insignificant differences between of 15 cm row spacing and 30 cm row spacing in ADF ratio and reported that the lowest ADF ratio was obtained at sowing rate of 22.4 kg ha^{-1}. Besides, Min et al. (2000) indicated that high stand densities (278 plants/m^2 or more) did not increase herbage yield and forage quality of alfalfa compared with low plant population densities (100 plants/m^2 or less). Thus, using lower seeding rates may enable alfalfa producers to reduce the establishment costs and increase their marginal profit.

Present findings on ADF ratios of alfalfa plants under different sowing rates and row spacings are in agreement with the results of earlier studies (Scholtz 2009; Avci et al. 2011; Yavuz 2011; Yücel et al. 2011; Yüksel 2012; Gündel et al. 2014; İnal 2015; Engin 2016; Yilmaz & Albayrak 2016; Acıkbas et al. 2017; Erdel 2017).

3.3. Neutral detergent fiber content (%)

Sowing rates and sowing rate x row spacing interactions had significant effects on NDF ratio in the first year and row spacings and row spacing x sowing rate interactions had significant effects on NDF ratios in the second year of the study. Combined analysis of the years revealed that row spacings, years, row spacing x sowing rate, year x sowing rate and row spacing x year x sowing rate interactions had significant effects on NDF ratio.

The NDF ratios in the experimental years and average of two years under different row spacings and sowing rates are provided in Table 3.

The averaged NDF ratio was determined as 42.3% in the first year and 41.5% in the second year, and there were significant differences between the averaged NDF values of the years (Table 3).

Table 3- NDF Ratios (%) for different row spacings and sowing rates in the experimental years and in the combination of two years

Years	*Row Spacing*	*Sowing Rate*						
		5 kg ha^{-1}	*10 kg ha^{-1}*	*15 kg ha^{-1}*	*20 kg ha^{-1}*	*25 kg ha^{-1}*	*30 kg ha^{-1}*	*Average*
2015	15 cm	41.8 b-ı[2]	40.7 f-j	42.1 b-h	42.5 a-g	42.4 b-g	42.8 a-d	42.1
	30 cm	42.6 a-f	42.1 b-h	42.0 b-h	40.7 f-j	43.2 abc	43.4 ab	42.3
	45 cm	42.2 b-h	42.7 a-f	44.3 a	42.2 b-h	42.2 b-h	43.4 ab	42.8
	60 cm	42.4 b-g	42.3 b-g	42.7 a-e	42.5 a-g	40.6 g-j	41.5 b-j	42.0
	Avg.	42.3 AB[+]	42.0 AB	42.8 A	42.0 B	42.1 AB	42.8 A	42.3 A[1]
2016	15 cm	40.0 ıj	39.7 ı	40.8 e-j	40.3 hıj	40.7 f-j	40.5 g-j	40.3 C[*]
	30 cm	42.1 b-h	42.0 b-h	41.0 d-j	43.4 ab	42.0 b-h	41.0 d-j	41.9 AB
	45 cm	42.3 b-g	43.4 ab	42.3 b-h	42.2 b-h	41.6 b-j	41.1 d-j	42.2 A
	60 cm	41.1 d-j	41.4 c-j	41.9 b-h	41.6 b-j	41.6 b-ı	41.1 d-j	41.5 B
	Avg.	41.4 BC	41.6 BC	41.5 BC	41.9 B	41.5 B	40.9 C	41.5 B
Combined Years	15 cm	40.9 fg[3]	40.2 g	41.5 def	41.4 def	41.6 def	41.7 c-f	41.2 B[4]
	30 cm	42.4 bcd	42.1 b-e	41.5 def	42.1 b-e	42.6 abc	42.2 bcd	42.1 A
	45 cm	42.3 bcd	43.1 ab	43.3 a	42.2 bcd	41.9 c-f	42.3 bcd	42.5 A
	60 cm	41.8 c-f	41.9 c-f	42.3 bcd	42.1 cde	41.1 efg	41.3 def	41.7 AB
	Avg.	41.8	41.8	42.1	41.9	41.8	41.9	41.9

[*]: Means indicated with the similar capital letters in the same column are not significantly different at P≤0.01 according to Duncan's test; [1]: Averaged values of the Years indicated with different capital letters are significantly different; [+]: Year x sowing rate combinations indicated with the similar capital letters are not significantly different at P≤0.05 according to Duncan's test; [2]: Row spacing x year x sowing rate combinations indicated with the similar lowercase letters are not significantly different at P≤0.05 according to Duncan's test; [3]: Row spacing x sowing rate combinations indicated with the similar lowercase letters are not significantly different at P≤0.01 according to Duncan's test; [4]: Means indicated with the similar capital letters in the same column are not significantly different at P≤0.05 according to Duncan's test.

Although there were no significant differences among the mean NDF values of row spacings in the first year, row spacings significantly affected NDF ratio in the second year of the study (Table 3). According to two-year averages, the lowest NDF ratio (41.2%) was obtained from 15 cm row spacing and the highest (42.5%) from 45 cm row spacing. Present findings revealed that 15 cm row spacing could be optimal row spacing for a low NDF content of forage in alfalfa.

In the first year of the study, sowing rates had significant effects on NDF ratios. On the other hand, significant year x sowing rate interactions (Table 2) revealed that effects of sowing rates on NDF ratios varied with the years. Thus, optimal sowing rate for a low NDF content was 20 kg kg ha^{-1} in the first year while the optimal sowing rate was 30 kg ha^{-1} in the second year.

Combined analysis of the years revealed that row spacing x sowing rate interactions had significant effects on NDF ratios. Such a case indicated that effects of sowing rates on NDF ratios varied with the row spacings. Significant row spacing x year x sowing rate interactions revealed that effects of row spacing x sowing rate interactions on NDF ratios varied with the years. Accordingly, optimal combination of row spacing and sowing rate was 60 cm row spacing with a sowing rate of 25 kg ha^{-1} in the first year while it was 15 cm row spacing with a sowing rate of 10 kg ha^{-1} in the second year of the study (Table 3).

Low plant population in narrow row spacing resulted in taller plants leading to an increase in leaf / stem ratio and lower NDF ratios. Iwaasa et al. (1996) also indicated that sowing rates did not have significant effects on NDF ratio.

Present findings on NDF ratios under different row spacings and sowing rates are in agreement with the results of previous studies (Min et al. 2000; Scholtz 2009; Avci et al. 2011; Yücel et al. 2011; Albayrak & Türk 2013; Engin 2016; Yilmaz & Albayrak 2016; Acikbaş et al. 2017; Erdel 2017).

3.4. Relative feed value

Sowing rates had significant effects on relative feed values in the first year while row spacings had significant effects on relative feed values in the second year. Row spacing x sowing rate and year x sowing rate interactions had significant effects on relative feed values in both years.

Averaged relative feed values in the experimental years and averages of two years under different row spacings and sowing rates are provided in Table 4. The average relative feed value was determined as 137.8 in the first year and 148.7 in the second year of the study. There were significant differences between the averaged relative feed values of the years (Table 4).

In the second year of the study, row spacings greater than 15 cm caused significant decreases in relative feed values. As the average of two years, the highest relative feed value (145.8) was obtained from 15 cm row spacing and the lowest one (141.0) from 45 cm row spacing.

Table 4- Relative feed values for different row spacings and sowing rates in the experimental years and in the combination of two years

Years	*Row Spacing*	*Sowing Rate*						
		5 kg ha^{-1}	*10 kg ha^{-1}*	*15 kg ha^{-1}*	*20 kg ha^{-1}*	*25 kg ha^{-1}*	*30 kg ha^{-1}*	*Average*
2015	15 cm	141.6	144.2	138.7	137.4	137.5	136.0	139.2
	30 cm	135.0	141.7	138.8	143.1	134.8	131.3	137.5
	45 cm	136.9	136.3	128.9	138.7	139.8	135.1	136.0
	60 cm	137.4	139.7	135.0	136.6	145.2	138.1	138.7
	Avg.	137.7 BCD^{+}	140.5 B	135.4 CD	139.0 BC	139.3 B	135.1 D	137.8 B*
2016	15 cm	154.0	154.2	150.6	152.0	151.5	151.5	152.3 A
	30 cm	145.4	148.4	152.3	142.7	147.9	152.8	148.3 B
	45 cm	147.3	141.5	144.9	147.1	147.3	148.4	146.1 B
	60 cm	150.0	148.2	147.1	146.9	146.4	149.8	148.1 B
	Avg.	149.2 A	148.1 A	148.7 A	147.2 A	148.3 A	150.6 A	148.7 A
Combined Years	15 cm	147.8 ab^{1}	149.2 a	144.7 b-e	144.7 b-e	144.5 b-f	143.8 b-f	145.8 A^{2}
	30 cm	140.2 fgh	145.1 b-e	145.6 a-d	142.9 c-g	141.4 d-g	142.1 c-g	142.9 AB
	45 cm	142.1 c-g	138.9 gh	136.9 h	142.9 c-g	143.6 b-f	141.8 c-g	141.0 B
	60 cm	143.7 b-f	144.0 b-f	141.1 efg	141.8 c-g	145.8 abc	144.0 b-f	143.4 AB
	Avg.	143.5	144.3	142.0	143.1	143.8	142.9	143.3

*: Averaged values of the years indicated with different letters are significantly different; $^{+}$: Year x sowing rate combinations indicated with the similar capital letters are not significantly different at P≤0.05 according to Duncan's test; ^{1}: Row spacing x sowing rate combinations indicated with the similar lowercase letters are not significant different at P≤0.01 according to Duncan's test; ^{2}: Means indicated with the similar capital letters in the same column are not significantly different at P≤0.01 according to Duncan's test.

Sowing rate had significant effect on relative feed value while relative feed value was not significantly influenced by sowing rate in the second year (Table 4). Therefore, year x sowing rate interaction was statistically significant. In the first year of the study, the optimal sowing rate for a high relative feed value was 10 kg ha^{-1}.

According to combined analysis of the years, row spacing x sowing rate interaction was statistically significant. Thus, the optimal combination of row spacing and sowing rate for a high relative feed value was 15 cm row spacing with a 10 kg ha^{-1} sowing rate. Since relative feed value is calculated with the use of ADF and NDF values, as it was expected, the treatments with low ADF and NDF values yielded high relative feed values since there is a negative relationship between ADF - NDF ratios and relative feed value.

Present findings revealed that under present ecological conditions, alfalfa plants should be sown at 10 kg ha^{-1} sowing rate and 15 cm row spacing for high relative feed values. Present are in agreement with the results of Albayrak & Türk (2013), Engin (2016) and Acikbas et al. (2017).

4. Conclusions

From the results of the study conducted two years under Tokat-Kozova conditions, it was concluded that 15 cm row spacing and 10 kg ha^{-1} sowing rate should be applied in order to obtain satisfactory results in terms of hay quality of alfalfa plants under ecological conditions of Tokat-Kazova and in similar ecologies. Present findings revealed that agronomic practices played a great role in alfalfa cultivation and such practices varied considerably with the regions and ecological conditions. Further research is recommended to be conducted on different alfalfa cultivars with different dormancy groups.

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