Turk J
Field Crops
2018, 23(1), 38-48
DOI: 10.17557/tjfc.419124

GRAIN YIELD, FORAGE YIELD AND FORAGE QUALITY OF DUAL PURPOSE WHEAT AS AFFECTED BY CUTTING HEIGHTS AND SOWING DATE

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Received: 15.02.2018

ABSTRACT

Dual purpose wheat production can help to produce the forage needed for livestock feeding, without reducing the sowing area of reserved for grain production. To determine the proper management techniques that reduce the loss of grain yield crops in dual purpose systems is very important. The objectives of this study were to investigate the effects of sowing date and cutting heights on grain yield, forage yield and nutritive value of dual-purpose wheat. The experimental design was split-plot under randomized complete block design, sowing dates (early, normal and late) as the main plot treatments and cutting heights (5, 7.5 and 10 cm) as the subplot treatments with three replications. Forage yield and forage protein yield were significantly affected by sowing date. Maximum forage yield and forage protein yield were obtained at normal sowing date (20 November) in both years, while maximum grain yield was obtained at early sowing date (20 October). The effect of sowing date on forage quality characters varied between years. Deeper cutting increased forage yield, while decreased grain yield. The effects of cutting heights on forage quality were different between years. The cutting treatments caused the decrease yield of the grain, but dual-purpose system for winter wheat was an advantageous crop system when evaluated in terms of the total amount of production. The height of 7.5 cm can be recommended as a suitable cutting height in term of the total crop quantity.

Keywords: Cutting height, dual-purpose, forage yield, grain yield, sowing date, wheat

INTRODUCTION

Lack of forage is one of the most important problems of livestock feeding during the winter and early spring and winter cereals provide a very good quality forage for the these season when they are cut or grazed in suitable vegetative stage (Balabanlı et al., 2010; Geren, 2014; Naveed et al., 2014; Kim and Anderson, 2015; Hajighasemi et al., 2016; Munsif et al., 2016). Winter cereals have the ability to regenerate vegetative parts such as stems and leaves after cutting or grazing and they produce grain after this regeneration. For this reason, winter cereals may produce both grain and roughage for livestock in the same growing season with the production system defined as dual-purpose (Royo et al., 1999; Harrison et al., 2011; Hajighasemi et al., 2016; Munsif et al., 2016). Cereals as dual-purpose are practiced in many countries, such as the United States, Canada, Argentina, Morocco, Pakistan, Syria, Uruguay, Australia, and Mediterranean countries as source of high quality roughage in winter or early spring period (Harrison et al., 2011). Although grazing and cutting of winter cereals are a method applied to compensate the feed gap some years in Turkey, it is not made as consciously. It is also very limited in the number of scientific studies (Celen and Soya, 1999; Ozturk and Caglar, 1999; Balkan et al., 2011). Whereas there are quite suitable conditions for the dual-purpose use of winter grains in the Mediterranean and Aegean Regions of Turkey where the Mediterranean climate prevails.

Winter wheat (*Triticum aestivum* L.) is one of the frequently used species in the dual-purpose systems (Dunphy et al., 1982; Royo et al., 1997; Epplin et al., 2000; Hossain et al., 2003; Arzadún et al., 2006; Afridi et al., 2010; Hastenpflug et al., 2011; Darapuneni et al., 2016). Dual-purpose wheat production is a complex process depend on many factors ranging from management techniques to environment. This bi-directional production can be affected by many management factors such as fertilization, sowing date, difference grazing / cutting applications, species / cultivar used, seeding rate (Dunphy et al., 1982; Bonachela et al., 1995; Epplin et al., 2000; Arzadún et al., 2006; Francia et al., 2006; Butchee and Edwards, 2013; Naveed et al., 2014; Darapuneni et al., 2016). Climatic conditions have also an important influence on dual purpose grain production. Low temperatures in winter moths and high temperatures at the end of the growing season lead to loss of yield and quality due to a decrease in growth rate, premature ripening and prevention of pollination. Inadequate soil water content and prolonged drought periods cause severe yield losses (Harrison et al., 2011).

Sowing date is one of foremost management factors effect on both grain yield and forage yield in dual purpose wheat growing and it is one of the important goals that some researchers are trying to identify (Epplin et al., 2000; Lyon et al., 2001; Arzadún et al., 2006; Darapuneni et al., 2016). Although studies have been carried out about dual purpose cereal production under the Mediterranean climatic condition (Bonachela et al., 1995; Royo et al., 1999; Francia et al., 2006), there is little information about the convenient sowing date of dual purpose wheat.

The amount of leaves remaining after cutting or grazing affect the amount of sunlight captured and plant regrowth. Grain yield is also affected (Butchee and Edwards, 2013). The amount of aboveground plant parts removed also affects the amount of produced forage (Arzadún et al., 2006). Although several studies have been conducted to investigate the effects of cutting height in dual purpose wheat production, these studies mainly have focused on grain yield and forage yield (Sharrow, 1990; Arzadún et al., 2006; Butchee and Edwards, 2013).

The objectives of this study were to investigate the effect of sowing date and cutting height on grain yield, forage yield and forage quality of dual purpose winter wheat under Mediterranean conditions. For this purpose, we tried to interpret the forage quality through Digestible Dry Matter (DDM), Dry Matter Intake (DMI) and Relative Feed Value (RFV) values calculated using these values in addition to Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL). While RFV is a frequently used criterion for pricing and evaluating the quality of forage crops, there is little work in with RFV of forage quality of dual-purpose cereals (Rohweder et al., 1978; Moore and Undersander, 2002; Hackmann et al., 2008; Kim and Anderson, 2015).

MATERIALS AND METHODS

Site description

The field trials were conducted during consecutive two growing seasons (2013-14 and 2014-15) at Agricultural Research Station of Mustafa Kemal University, Hatay province in the Eastern Mediterranean regions of Turkey (located at 36° 15' N). The soil of experimental area had clay soil with pH of 7.12, 6.45% $CaCO3$, 74.1 kg ha^{-1} phosphorus, and 1.93% organic matter at the depth of 30 cm. The region has typical Mediterranean climate with hot-dry summers and mild-rainy winters and climatic data of the location during the experiment period were summarized in Figure 1. There were quite drought and higher warm conditions according to normal climatic conditions in the first year of the experiment, but in the second year of the experiment, especially during the January, March and April much rainfall occurred.

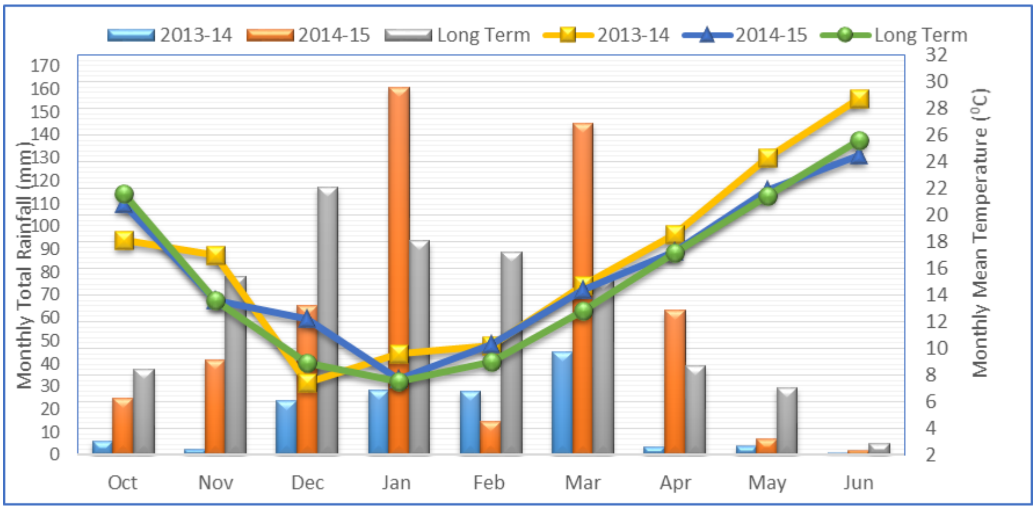

Figure1. Monthly mean air temperature and total rainfall during the study and long term data (means of 20 years)

Experimental design and treatments

Treatments had factorial arrangement in a split plot within complete randomized block design with 3 replications. The main plot treatments were sowing dates: an early (20 October), normal (20 November) and late (20 December). The sub-plot treatments consisted of three clipping heights of 5, 7.5 and 10 cm at early jointing stage of wheat (Zadoks 31) (Zadoks et al., 1974). Also, no-cutting treatment as control was taken into account in the experiment for grain yield and related traits. As plant material wheat (cv. Masaccio) seeds were used for dual purpose (grain and forage). A subplot size was 0.8 × 5 m, having 4 rows (with inter-row spacing of 20 cm). Sowing was performed by hand. Seeding rate was 500 viable seed in m^{-2}. Plants were irrigated to ensure the germination and emergence at early sowing date after sowing. No irrigation performed at normal and late sowing dates because there was sufficient moisture in the soil. In the first year, all plots were irrigated two times on 10 March, 2014 and 12 April, 2014 due to extreme drought (Figure 1).

The second year the field was not irrigated because the amount of precipitation was sufficient. Fertilizer rates of 60 kg ha^{-1} N and P_2O_5 were applied at sowing. Additionally, amount of nitrogenous fertilizer was applied as top dressing in two split part at full tillering stage and after cutting for forage at the rate of 50 kg ha^{-1} as urea. On 5 March 2014 and 8 March 2015, herbicide included 2,4-D was applied for weed control.

Measurement and sampling procedures

Harvest and sampling procedures were made in 4 m of the middle two rows of each plot (0.4 × 4= 1.6 m^2). Sowing dates and dates to durations from sowing to cutting were shown in Figure 2. To harvest for forage, plants were cut with scissors to a stubble height of 5, 7.5 and 10 cm at jointing stage of wheat (Zadoks 31). After measuring fresh forage yield, 500 g green forage sample from each treatment was taken and then they were dried at 65 °C for dry matter determinations. Dried samples were ground in a mill to pass a 1 mm screen for chemical analysis. Harvest and sampling for grain were made on 3 June 2014 and 8 June 2015. After threshing and harvesting cleaned grains were weighed with an electronic scale and converted into grain yield kg ha^{-1}. Also, 1000 seed weight and hectoliter weight were determined from these samples. Before the harvest, 10 spike samples were taken from each plot to determine spike length, spike weight, grain number per spike and grain weight per spike. 100 g grain sample was ground in a mill to pass a 1 mm screen for nitrogen analysis.

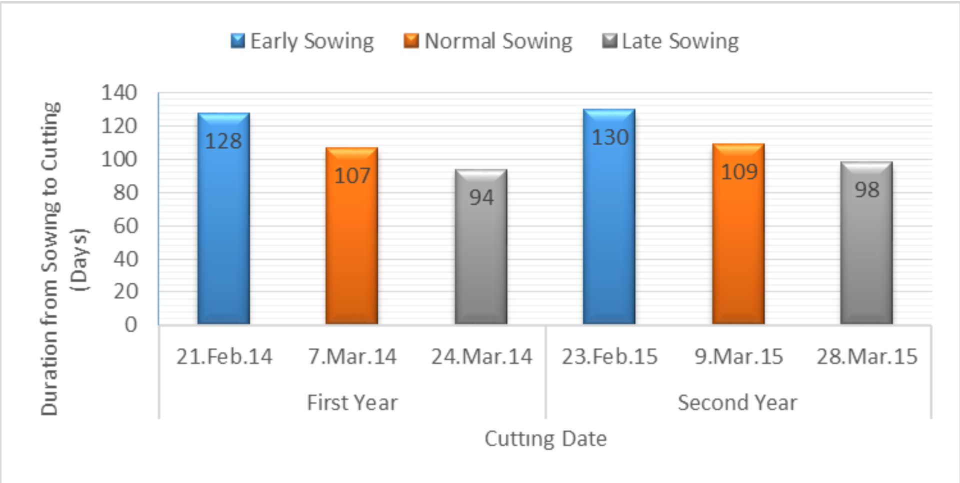

Figure 2. Sowing and cutting dates and durations from sowing to cutting

Quality analysis and calculations

Crude protein was determined in both grain and forage samples. Nitrogen contents were determined by the Kjeldahl procedure and crude protein concentration was calculated by the formula of N concentration × 6.25. Fiber analysis (NDF, ADF and ADL) were done according to the sequential method of Van Soest et al. (1991) by adding α-amylase without sodium sulfite and using the ANKOM filter bag system with A220 fiber analyzer (ANKOM Technology, Fairport, NY) for forage samples. Relative feed value (RFV) calculated by using ADF (related dry matter digestibility) and NDF (related intake potential) is an index indicating forage quality. RFV is calculated as fallow according to Rohweder et al. (1978).

DDM = 88.9 – (0.77×ADF%)

DMI= (120/NDF%)

RFV= DDM% × DMI% × 0.775

Where, DDM was digestible dry matter as % of dry matter, and DMI was dry matter intake as a % of animal body weight.

Statistical analysis

Data were analyzed by using the MSTAT-C computer software program. The ANOVA was performed by using split plot design with the 3 main plot treatments (sowing dates) and 3 sub-plot treatments (cutting heights) for forage yield and properties and the 3 main plot treatments (sowing dates) and 4 sub-plot treatments (three cutting heights and a control) for grain yield and properties replicated three times. Treatment mean differences were separated by using Fisher’s protected least significant difference (LSD) at P = 0.05 significance level.

RESULTS AND DISCUSSION

Forage yield and quality

Responses to sowing dates

Fresh forage yield, dry matter yield, protein content, protein yield, NDF content, DMI and RFV were significantly influenced by sowing dates during both years. ADF content, DDM and lignin content were significantly affected by sowing dates only second year (Table 1 and 2). The maximum fresh forage yield of 23.1 t ha^{-1} and 20.7 t ha^{-1} were obtained from normal sowing date during first and second years, respectively. Early or late sowing dates as compared to normal sowing date were caused to a decrease in fresh forage yield during two years. Generally, dry matter yields showed similar trends with fresh forage yields depending on sowing dates. Dry matter yields were ranged 2.12 t ha^{-1} to 3.10 t ha^{-1} in the first year and 1.85 t ha^{-1} to 2.84 t ha^{-1} in the second year. The highest dry matter yield was obtained from normal sowing dates in the first year, but dry matter yield obtained from early sowing date was statistically similar with dry matter yield obtained from normal sowing date in second year. Determined dry matter yields at late sowing date were statistically lower from the others both two years. The results demonstrated that dual purpose wheat can be sown at normal sowing date (20 November) for maximum forage yield. Early and late sowing of dual purpose wheat decreased forage yield (Table 1). While most of the previous researchers recommended early sowing for high forage production, the suitable sowing date in our study was determined to be the normal sowing date. Some of the previous researchers recommended early sowing for high forage production during fall also (Bonachela et al., 1995; Hossain et al., 2003; Lyon et al., 2001), normal sowing date was the optimal sowing date in our study for higher forage yields during late winter or early spring. Early sowing did not provide an advantage for winter and spring forage production, while provided an advantage for fall forage production, but this situation may vary among years. Wheat is a plant very sensitive to high soil and weather temperatures at germination, emergence and seedling stages and high temperatures plays a critical role in establishment (Darapuneni et al., 2016). The higher temperature and water deficiency in the experimental area continued during October (Figure. 1), so the expected benefit from early planting did not appear (Lyon et al., 2001). Royo et al. (1997) reported that cutting dates had greater influence on forage production than sowing dates. Yearly weather conditions significantly affect obtained forage yield depending on sowing date (Islam et al., 2014). As we have seen in our results, early sowing resulted in a 12.5 % reduction in dry matter yield compared to normal sowing in the first year, while this difference was 6 % in the second year. The negative effect of late sowing on the forage yield was greater from early sowing. Late planting reduced yield of dry matter by 31.6 % and 34.9 % compared to normal planting in the first and second years, respectively. Main reason for this is the shortening of the vegetation period. Similar results have been emphasized by other researchers (Garcia del Moral et al., 1995; Epplin et al., 2000; Lyon et al., 2001; Hossain et al., 2003; Arzadún et al., 2006).

Table 1. Fresh forage yields, dry matter yields, protein contents, protein yields and NDF contents of dual purpose wheat at different sowing dates in the 2013-14 and 2014-15 periods.

	Sowing Dates	Fresh Forage Yield (t ha^{-1})	Dry Matter Yield (t ha^{-1})	Protein Content (g kg^{-1})	Protein Yield (t ha^{-1})	NDF Content (g kg^{-1})
2013-14	**Early**	19.0 b^{+}	2.71 b	235.4 b	0.64 b	446.2 ab
	Normal	23.1 a	3.10 a	239.1 b	0.74 a	473.2 a
	Late	13.4 c	2.12 c	283.8 a	0.60 b	409.9 b
	LSD	2.29**	0.28**	36.0*	0.08*	37.2*
2014-15	**Early**	17.5 b	2.67 a	195.6 c	0.52 b	443.3 b
	Normal	20.7 a	2.84 a	213.6 b	0.61 a	457.2 a
	Late	11.5 c	1.85 b	247.3 a	0.46 b	396.4 c
	LSD	1.23**	0.27**	11.0**	0.08*	11.5**

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at P<0.05
* Significant at the 0.05 probability level, ** Significant at the 0.01 probability level, ns; not significant at P ≤ 0.05

The maximum protein contents were determined at late sowing date in both year. Protein contents of early and normal sowing dates were statistically similar in the first year, but different in the second year. Forage protein contents tended to increase depending on the delaying sowing date (Lyon et al., 2001; Arzadún et al., 2006). Arzadún et al. (2006) explained this phenomenon with a higher proportion of leaf rust (*Puccinia recondita*) that happened with earlier sowing dates. Other conducted cutting studies (Royo et al., 1997; Lyon et al. 2001; Arzadún et al., 2006; Tian et al., 2012; Islam et al., 2014; Kim and Anderson, 2015) reported that forage crude protein contents of cereals cut late winter or early spring were above 200 g kg^{-1}. Also, observed these crude protein values were above the maintenance requirement levels for grazing cattle (Islam et al., 2014). This situation shows that cereals are an excellent roughage source for winter and early spring. Although higher forage protein contents were observed at late sowing date during two years, the maximum protein yield of 0.74 t ha^{-1} and 0.61 t ha^{-1} were obtained from normal sowing dates due to higher dry matter yields during first and second years. Protein yields were statistically indifferent for early and late sowing dates during two years. NDF contents were ranged 409.9 g kg^{-1} to 473.2 g kg^{-1} in the first year and 396.4 g kg^{-1} to 457.3 g kg^{-1} in the second year. NDF contents obtained at the normal sowing dates were statistically higher than obtained at the early and late sowing dates in both years.

Table 2. ADF contents, ADL contents, DDM, DMI and RFV values of the dual purpose wheat at different sowing dates in the 2013-14 and 2014-15 periods.

	Sowing Dates	ADF Content (g kg^{-1})	ADL (g kg^{-1})	DDM (% of DM)	DMI (% of BW)	RFV
2013-14	**Early**	239.2	15.9	70.3	2.69 b^{+}	146.0 b
	Normal	246.2	16.4	69.7	2.55 b	137.7 b
	Late	222.6	15.2	71.6	2.94 a	163.4 a
	LSD	ns	ns	ns	0.23*	14.2*
2014-15	**Early**	233.0 b	15.5 b	70.8 a	2.71 b	148.6 b
	Normal	245.3 a	17.6 a	69.8 b	2.62 c	142.0 c
	Late	233.2 b	16.0 b	70.7 a	3.03 a	166.0 a
	LSD	8.14*	0.72**	0.62*	0.07**	3.63**

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at $P<0.05$

* Significant at the 0.05 probability level, ** Significant at the 0.01 probability level, ns; not significant at $P \leq 0.05$

ADF content, ADL content and DDM were not significantly affected by sowing dates in first year, but effects of sowing dates on ADF content, ADL content and DDM were significant in the second year (Table 2). The highest values for ADF content and ADL content were obtained at normal sowing date while the lowest DDM value was determined at normal sowing date. DMI and RFV values obtained at the late sowing date were higher than other sowing dates. DMI and RFV values of early and normal sowing dates were statistically similar in the first year, but these values were higher at the early sowing date in the second year (Table 2). Although, quality properties of forage (ADF content, NDF content, DDM, DMI and RFV) were generally positively affected from late sowing, differences between years showed that forage quality associated with environmental conditions (Arzadún et al., 2006). While RFV is a frequently used criterion for pricing and evaluating the quality of forage crops, there is little work in with RFV of forage quality of dual-purpose cereals. RFV values of normal sowing dates were lower than observed late sowing dates. According to RFV, the quality of produced wheat forage was 1st grade at all sowing dates (Rohweder et al., 1978). Although forage quality increased with delayed sowing, forage yield and grain yield decreased. Thus, all these characteristics should be taken into consideration when deciding on the sowing date for dual purpose wheat.

Responses to cutting heights

The effects of cutting heights on fresh forage yield, dry matter yield and protein content were statistically significant in both years while the effects of cutting heights on ADF, ADL, DDM and RFV were statistically significant only in the second year. Protein yield significantly affected by cutting heights only in the first year. The effects of cutting heights were insignificant in terms of NDF and DMI in both two years (Table 3 and 4). Fresh forage and dry matter yields tended to decrease depending on the increased cutting heights. The highest fresh forage yields were obtained from cutting heights of 5 cm in each years. These values were 20.7 t ha^{-1} and 18.0 t ha^{-1}, in the first year and in the second year, respectively. Dry matter yields ranged from 2.29 to 2.96 t ha^{-1} in the first year while ranged from 2.21 to 2.60 t ha^{-1} in the second year. The maximum dry matter yields were determined at cutting height at 5 cm during each year. This is a consequence of the removal of more above ground parts of wheat in lower cutting heights (Sharrow, 1990; Ahmed et al., 2001). The fact that dry matter yields of 5 and 7.5 cm heights were similar in the second year indicated that forage yield was significantly affected by ecological conditions during growing period.

Protein contents were ranged 244.3 g kg^{-1} to 265.7 g kg^{-1} during the first year and 208.3 g kg^{-1} to 216.7 g kg^{-1} during the second year. In both years, plots clipped 10 cm height produced higher protein content than other cutting heights. This situation might be associated with increasing fresh leaves proportions in higher cutting heights. Unlike the result of the our present study, Song et al. (2009) and Kim et al. (2016) reported that the effects of cutting heights were insignificant on forage protein content. Protein contents of deeper cuttings were lower while dry matter yields were higher. The effects of cutting heights were significant in terms of protein yield in first year but not significant in second year. In the first year, protein yield of 5 cm cutting height was higher than of 10 cm cutting height. Forage protein content was negatively related to forage yield due to available N distributing in a greater volume of plant tissue (Garcia del Moral et al., 1995). This situation resulted that protein yield observed at 5 cm cutting height was higher than at 10 cm cutting height in the first year, but there weren't difference among cutting heights in term protein yield in the second year.

Table 3. Fresh forage yields, dry matter yields, protein contents, protein yields and NDF contents of dual purpose wheat at different cutting heights in the 2013-14 and 2014-15 periods.

	Cutting Heights (cm)	Fresh Forage Yield (t ha^{-1})	Dry Matter Yield (t ha^{-1})	Protein Content (g kg^{-1})	Protein Yield (t ha^{-1})	NDF Content (g kg^{-1})
2013-14	**5**	20.7 a^{+}	2.96 a	244.3 b	0.72 a	436.3
	7.5	19.0 b	2.70 b	248.8 b	0.66 ab	438.4
	10	15.8 c	2.29 c	265.7 a	0.60 b	454.2
	LSD	0.95**	0.18**	16.6*	0.07	Ns
2014-15	**5**	18.0 a	2.60 a	208.3 b	0.53	437.1
	7.5	16.9 b	2.54 a	216.7 b	0.54	432.3
	10	14.9 c	2.21 b	231.7 a	0.51	427.4
	LSD	0.64**	0.12**	10.1**	ns	Ns

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at P<0.05
* Significant at the 0.05 probability level, ** Significant at the 0.01 probability level, ns; not significant at P ≤ 0.05

In the second year, ADF contents and ADL contents were decreased depending on increasing cutting height, while DDM and RFV were increased with increased cutting heights. In the second year, ADF content, ADL content, DDM and RFV values ranged 221.7 to 252.8 g kg^{-1}, 15.4 to 17.4 g kg^{-1}, 69.2 % to 71.6% and 147.8 to 156.4, respectively (Table 4). Generally, forage quality properties were positively influenced from the higher cutting heights in the second year. However, the effects of cutting heights were insignificant in terms of forage quality properties except protein contents in the first year. Kim and Anderson (2015) obtained lower NDF content values and higher RFV values compared with our NDF content and RFV values for wheat harvested same stage. NDF content and ADF content values varied depend on years (Lyon et al., 2001).

Table 4. ADF contents, ADL contents, DDM, DMI and RFV values of dual purpose wheat at different cutting heights in the 2013-14 and 2014-15 periods.

	Cutting Heights (cm)	ADF Content (g kg^{-1})	ADL Content (g kg^{-1})	DDM (% of DM)	DMI (% of BW)	RFV
2013-14	**5**	233.2^{+}	16.2	70.7	2.77	152.0
	7.5	242.4	15.8	70.0	2.75	149.1
	10	232.3	15.6	70.8	2.67	146.6
	LSD	ns	ns	ns	ns	ns
2014-15	**5**	252.8 a	17.4 a	69.2 c	2.75	147.8 c
	7.5	237.1 b	16.4 b	70.4 b	2.79	152.4 b
	10	221.7 c	15.4 c	71.6 a	2.82	156.4 a
	LSD	4.64**	0.80**	0.35**	ns	3.70**

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at P<0.05
* Significant at the 0.05 probability level, ** Significant at the 0.01 probability level, ns; not significant at P ≤ 0.05

Grain yield and properties

Responses to sowing dates

Grain yields were ranged 3.04 t ha^{-1} to 4.34 t ha^{-1} in the first year and 3.00 t ha^{-1} to 4.35 t ha^{-1} in the second year. Grain yields of early sowing dates were statistically higher from the other sowing dates in both years (Table 5). Grain yield of normal sowing date was statistically similar with the grain yield of late sowing date in the first year. Generally, the delaying of sowing date led to a decrease in grain yield. According to mean values of two years grain yield of normal and of late sowing dates were 17.4% and 30.5% lower than of early sowing date, respectively. Similarly, Garcia del Moral et al. (1995) and Bonachela et al. (1995) reported that grain yield decreases with delayed sowing while some other researchers reported opposite results (Lyon et al., 2001; Arzadún et al., 2006). These differences were under the influence of environmental conditions and applied grazing and cutting practices. Also, early sowing didn't benefit for forage yield in our study. Therefore, it is important to consider production targets (more forage or more grain) and climate conditions when the sowing date is decided (Hossain et al., 2003).

Table 5. Grain yields, number of grain m^{-2}, 1000-grain weights, hectoliter weights, number of grains spike $^{-1}$, grain weight spike $^{-1}$, spike lengths and protein contents of dual purpose wheat at different sowing dates in the 2013-14 and 2014-15 periods.

	Sowing Dates	Grain Yield (t ha^{-1})	Grain Number (m^{-2})	1000-Grain Weight (g)	Hectoliter Weight (kg hL^{-1})	No. of Grains Spike^{-1}	Grain weight (g spike^{-1})	Spike Length (cm)	Protein Content (g kg^{-1})
2013-14	**Early**	4.34 a^{+}	12933 a	33.5 b	77.9 b	32.4 a	1.37 a	7.06	128.5 b
	Normal	3.54 b	9944 b	35.5 a	79.7 a	29.0 b	1.20 b	6.39	127.7 b
	Late	3.04 b	10491 b	28.5 c	77.3 b	27.6 b	1.03 c	6.59	134.9 a
	LSD	0.59**	1383.0**	1.62**	1.05**	2.86*	0.14**	ns	57.0*
2014-15	**Early**	4.35 a	12694 a	34.3 a	78.1 b	33.9 a	1.33 a	7.96 a	126.6 b
	Normal	3.64 b	10459 b	34.7 a	79.9 a	29.7 b	1.32 a	6.77 b	129.2 b
	Late	3.00 c	10369 b	28.4 b	76.8 c	26.8 b	0.97 b	6.29 b	135.8 a
	LSD	0.27**	809.1**	2.63**	0.79**	4.08*	0.12**	0.58**	44.0**

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at P<0.05

* Significant at the 0.05 probability level, ** Significant at the 0.01 probability level, ns; not significant at P ≤ 0.05

Grain number per m^{-2} was significantly higher at the early sowing date than other sowing dates. Grain number of early sowing dates were 12933 and 12694 number m^{-2} in the first and second years, respectively. Grain numbers of normal and late sowing dates were statistically similar in the both years (Table 5). 1000-grain weights were ranged 28.5 to 35.5 g and 1000- grain weight was higher than recorded at early and late sowing dates in the first year. 1000- grain weights of early and normal sowing dates were statistically similar in the second year while 1000- grain weight obtained at late sowing date was statistically lower than obtained at late sowing date (Table 5). The maximum hectoliter weights of 79.7 kg hL^{-1} and 79.9 kg hL^{-1} were determined from normal sowing date during first and second years, respectively. Hectoliter weights of early and late sowing dates were statistically similar in the first year while hectoliter weight determined at late sowing date was statistically lower from the others in the second year (Table 5). Number of grains and grain weights per spike tended to decrease depending on the delaying sowing date. The maximum grain numbers and grain weights per spike were obtained from early sowing dates both two years. Number of grains per spike were ranged 27.6 to 32.4 number spike^{-1} during the first year and 26.8 to 33.9 number spike^{-1} during the second year. Grain weights per spike were ranged 1.03 to 1.37 g spike^{-1}during the first year and 0.97 to 1.33 g spike^{-1} during the second year. Grain numbers and grain weights per spike of normal and late sowing dates were statistically similar in both years. Number of grains per m^{-2}, grain weights and number per spike tended to decrease depending on the delaying sowing dates, while 1000-grain weight and hectoliter weight were higher at normal sowing date as compared to late sowing time. This situation indicate that early sowing caused more grains number in unit area but the grains formed were smaller or similar for early and normal sowing dates. The increased number of grains led to an increase in seed yield at early sowing time. The decrease in the number of grains did not cause any change or increase in grain weight, but the increase in grain weight can't compensate for the loss caused by the decrease in grain number (Sinclair and Jamieson, 2006). A decrease in the number of grains in late sowing was the result of a decrease in net photosynthesis products due to the shorter growing period (Munsif et al., 2016). Furthermore, the high temperatures at anthesis may have reduced grain number per spike and grain weight per spike (Ferris et al., 1998; Chandra et al., 2014). Spike lengths were statistically indifferent in the first year while statistically different in the second year. Spike lengths were ranged 6.39 cm to 7.06 cm in the first year and 6.29 cm to 7.96 cm in the second year. Spike lengths recorded at the early sowing dates were statistically higher than recorded at the normal and late sowing dates during second year. This may be one of the reasons for higher yields at early sowing date due to the spike length is one of the characters that affect the yield (Shahzad et al., 2007). Late sowing recorded lower grain yield resulted in higher grain protein contents. The highest protein contents of grain were recorded at late sowing dates during both years. These values in the first and second years were determined as 134.9 g kg^{-1} and 135.8 g kg^{-1}, respectively. Protein contents of grain were statistically higher at late sowing date than early and normal sowing dates while were statistically indifferent for early and normal sowing dates during two years. The heat stress in the grain filling period depending on late sowing caused the protein content to increase due to the lack of sufficient starch accumulation in the grain (Motzo et al., 2007; Hakim et al., 2012).

Responses to cutting heights

Generally, maximum values were recorded in the no-cut plots. Grain yields were ranged 2.89 t ha^{-1} to 4.89 t ha^{-1} in the first year and 3.04 t ha^{-1} to 4.74 t ha^{-1} in the second year. Grain yields tended to decrease depending on the decreased cutting heights. Grain yields of no-cut plots were statistically higher from the other cutting height in both years. In both years the lowest grain yields were obtained from plots cutting height of 5 cm. Grain yield recorded at 7.5 cm cutting height was statistically lower than recorded 10 cm cutting height in the first year, but they were not significant in the second year (Table 6).

Table 6. Grain yields, number of grain m^{-2}, 1000-grain weights, hectoliter weights, number of grains spike $^{-1}$, grain weight spike $^{-1}$, spike lengths and protein contents of dual purpose wheat at different cutting heights in the 2013-14 and 2014-15 periods.

	Cutting Heights (cm)	Grain Yield (t ha^{-1})	Grain Number (m^{-2})	1000-grain Weight (g)	Hectoliter Weight (kg hL^{-1})	Number of Grains per Spike	Grain weight per Spike g)	Spike length (cm)	Protein Content (g kg^{-1})
2013-2014	**No-Cut**	4.89a^{+}	13477a	36.8 a	78.1	31.4	1.36	7.27 a	140.0 a
	5	2.89 d	9200c	31.2 b	78.1	29.2	1.10	6.28 b	127.6 b
	7.5	3.28 c	10577b	30.9 b	78.4	28.5	1.19	6.46 b	128.2 b
	10	3.51 b	11236b	31.0 b	78.5	29.5	1.14	6.72 b	125.8 b
	LSD	0.18**	923.9**	2.09**	ns	ns	ns	0.52**	64.0**
2014-2015	**No-Cut**	4.74 a	12923 a	36.8 a	79.3 a	32.3 a	1.38 a	7.46 a	140.0 a
	5	3.04 c	9759 c	30.9 b	76.9 b	29.9 b	1.24 ab	6.68 b	126.1 b
	7.5	3.37 b	10859 b	30.8 b	77.8 b	28.9 b	1.11 b	6.72 b	128.2 b
	10	3.50 b	11155 b	31.3 b	79.1 a	29.4 b	1.10 b	6.86 b	128.2 b
	LSD	0.27**	962.7**	1.31**	1.06**	1.51**	0.18*	0.30**	36.0**

$^{+)}$ Values with the different small letter in a column in a year are significantly different according to the LSD test at P<0.05
* Significant at the 0.05 probability level,** Significant at the 0.01 probability level, ns; not significant at P ≤ 0.05

All cutting treatments significantly reduced grain yield compared to no-cut plots. Decreased cutting heights had negative effect on grain yield. Although (Arzadún et al., 2006) stated that wheat grain yield was not significantly affected by cutting height, our results have shown that the cutting height in dual-purpose system is an important management technique on penalties in grain yield. The reduction in grain yield in deeper cuttings can be explained by the capture of less solar radiation due to more leaf area removal.

All cutting treatments have caused a negative impact on investigated grain characters when compared to control. Grain number per m^{-2} was negatively affected by cutting treatments. The maximum grain number per m^{-2} were determined in the no-cut plots in both years. While grain number per m^{-2} of 5 cm cutting height was lower than other cutting treatments, grain number per m^{-2} of 7.5 and 10 cm cutting heights were similar in the both years (Table 6). 1000- grain weights recorded in the no-cut plots were statistically higher from the others cutting heights in both years. The maximum 1000-grain weights were obtained from no-cut plots during two years but 1000-grain weights determined other cut plots were statistically similar during both years (Table 6). Hectoliter weights were ranged 78.1 to 78.5 kg hL^{-1} in the first year, but differences among these values were insignificant. Hectoliter weight values of the no- cut plots and 10 cm cutting height were higher than of 5 cm and 7.5 cm cutting heights in the second year. Numbers of grains per spike were ranged 28.5 to 31.4 in the first year, but differences among these values were insignificant. In the second year, numbers of grains per spike values determined in the no-cut plots were higher than the others, while values determined cut plots were statistically similar. The effects of cutting heights were insignificant in terms of grain weight per spike during first year while grain weight per spike value determined in the no- cut plot was higher than the others in the second year. Spike lengths were ranged 6.28 cm to 7.27 cm during the first year and 6.68 cm to 7.46 cm during the second year Grain protein contents recorded in the no-cut plots were statistically higher from the other cutting heights during both years. The maximum grain protein contents of 140.0 kg g^{-1} were obtained from no-cut plots in both two years. Protein contents determined in cut plots were statistically similar (Table 6). The effects of cutting heights were insignificant in terms of those characters, except grain number per m^{-2}. Although there were not significant difference in most of the examined characteristics, differences in number of grain in the unit area are the main cause of differences in grain yield (Dreccer et al., 2009; Butchee and Edwards, 2013). Grain number per m^{2} of 5, 7.5 and 10 cm cutting heights were 28.1%, 18.7% and 15.1% lower than control (no-cut), respectively, as considered mean values of two years. The reduction of cutting height from 10 cm to 7.5 cm caused a 3% decrease in the number of grains per unit area, while the reduction of cutting height from 10 cm to 5 cm resulted extra more than 10 % reduction. This result shows that the critical cutting height was 7.5 cm for a similar dual purpose system.

Interaction effects

The factor interactions that were statistically significant in both years in this section were interpreted. In the study, the effect of sowing date x cutting height interactions were statistically insignificant in term of any traits associated with forage yield and quality. The effect of the sowing time and the cutting height interaction was significant on grain yield and protein ratio among properties associated with grain in both years.

Grain yields were ranged 2.71 t ha^{-1} to 5.23 t ha^{-1} in the first year and 2.23 t ha^{-1} to 5.23 t ha^{-1} in the second year among all sowing date × cutting heights combinations (Figure 3). The highest grain yield was obtained from no-cut plots that sown in early sowing dates in both years. Changes in cutting heights caused statistically significant differences in early sowing date, whereas grain yields determined at 5, 7.5 and 10 cm cutting heights in normal and late sowing dates were statistically not different. Grain yields obtained at 10 cm cutting heights of early sowing date were statistically similar with grain yields obtained no-cut plots of normal and late sowing dates in both years. This situation indicated that dual purpose wheat can be produced without significant loss of grain yield by sowing a month earlier than normal sowing date and cutting from 10 cm stubble height. Early sowing was generally recommended in dual purpose cereal production for decreasing grain yield loss (Epplin et al., 2000; Hossain et al., 2003; Arzadún et al., 2006). However, the yield and quality of forage should also be considered when deciding on the sowing date and cutting height.

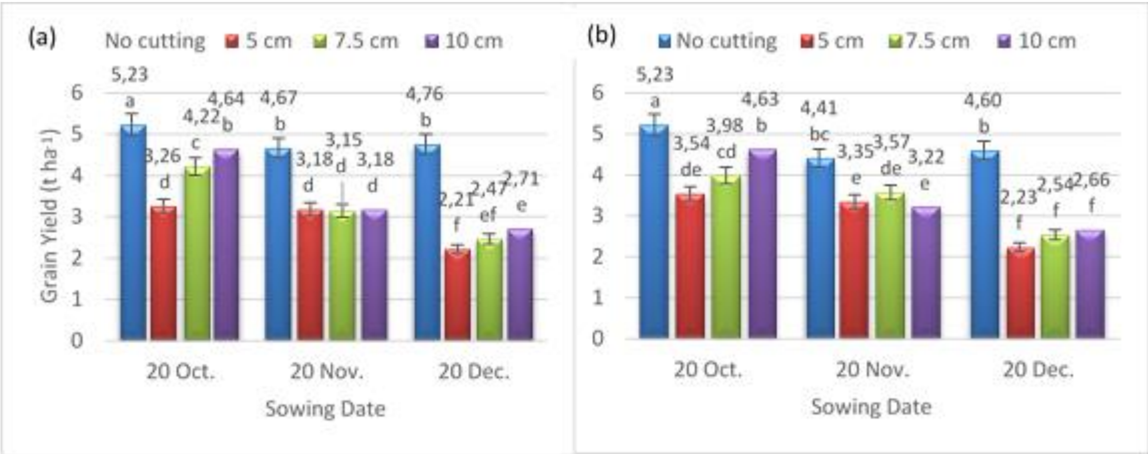

Figure 3. Effect of sowing date × cutting height on grain yield (a) in the first year and (b) in the second year

Grain protein contents were ranged 115.0 g kg^{-1} to 149.0 g kg $^{-1}$ in the first year and 111.3 g kg^{-1} to 145.7 g kg^{-1} in the second year among all sowing date × cutting heights combinations (Figure 4). Grain protein contents decreased with delayed sowing date in no-cut plots, whereas increased with delayed sowing date in cutting applied plots. Grain protein contents decreased with delayed sowing date in no-cut plots, whereas increased with delayed sowing date in cutting treatments. Garcia del Moral et al. (1995) reported that there was a negative relationship between grain yield and grain protein content in cereals, but that the reason for this was not yet fully understood. Also, the heat stress in the grain filling period depending on late sowing causes the protein content to increase due to the lack of sufficient starch accumulation (Motzo et al., 2007; Hakim et al., 2012).

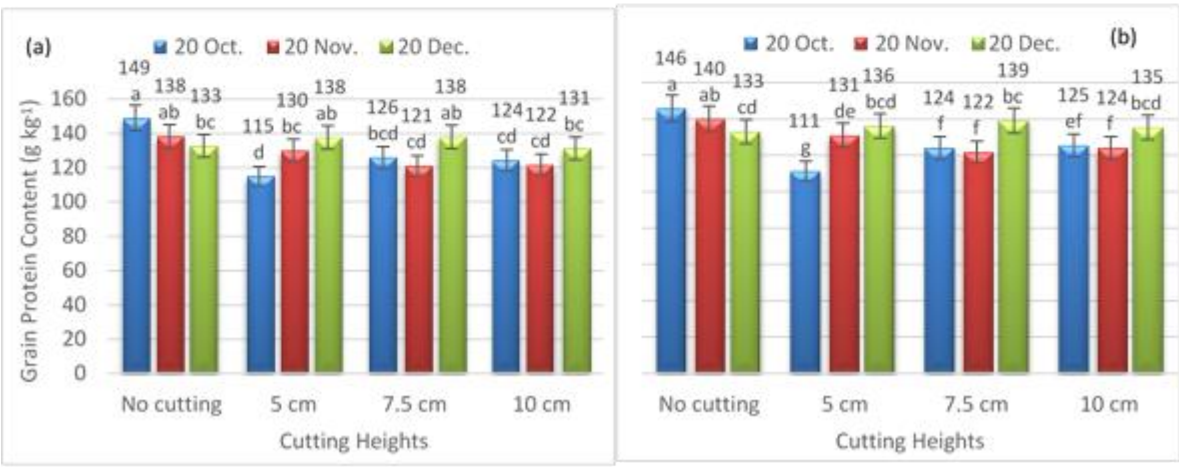

Figure 4. Effect of sowing date × cutting height on grain protein contents (a) in the first year and (b) in the second year

CONCLUSIONS

The results of the research showed that the cutting treatments caused the grain yield decrease. However, it was seen that the dual-purpose system was an advantageous crop system when evaluated in terms of the total amount of production. As a matter of fact, yield was 4.89 t ha^{-1} in the only grain system (two years mean) whereas total 5.91 t ha^{-1} (3.29 t ha^{-1} grain + 2.62 t ha^{-1} forage in 7.5 cm cutting height) in the dual-purpose system. A similar situation was also true for protein yield. The different effects of changing sowing date on grain yield and forage yields make it difficult to determine the proper sowing date in the dual-purpose system. The needs of farm and the economic values of the products should be taken into account when deciding on sowing date. It should also be considered as a risk factor for water deficit and irrigation need that may occur at early sowing date. Similar things can be said in the cutting heights. However, a height of 7.5 cm can be recommended as a suitable cutting height in term of the total crop amount.

ACKNOWLEDGEMENTS

The authors thank Dr. Mehmet Atak (Mustafa Kemal University, Turkey) for his valuable comments on the manuscript. We are also grateful to ProGen Seed Inc., Turkey for provided wheat seed.

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