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Hay Production of Smooth Bromegrass (*Bromus inermis* Leyss.) as Influenced by Various Management Practices in Highlands

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ABSTRACT: The effects of sowing time and companion crop on hay yield, weed rate and some hay quality parameters of smooth bromegrass were determined in 2014 and 2015. Smooth bromegrass was sown in spring and summer period with or without wheat as a companion crop. The study was established according to the experimental design of randomized complete blocks in irrigated conditions with three replications. Sowings mixed with companion crop in spring produced higher dry matter yield in the first year and in the second year. Mixed sowing with companion crop decreased the rate of weeds in the first year from 76.7% to 7.8%. Sowing time was not effective on hay quality, but the use of companion crop decreased the crude protein content and increased ADF and NDF ratios in the establishment year.

Keywords: Hay yield, hay quality, companion crop, sowing time

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INTRODUCTION

Smooth bromegrass (*Bromus inermis* Leyss.) is a long-lived perennial grass that grows from a deeply-extensive creeping rhizome. It is adapted to the poor soils, drought and cold climate conditions associated with the Eastern Anatolia region of Turkey. It has great importance for animal feeding in areas where it is adapted because of high yield potential and palatability (Dumlu et al., 2013; Unal and Mutlu, 2015). Moreover, it is an excellent erosion prevention plant on marginal and sloping land because of the interlocking root system. Researches show that dry matter yield in smooth bromegrass varies between 7588 and 11920 kg ha^{-1} (Cinar et al., 2016; Saritas et al., 2017).

In highland areas, perennial grass species, such as smooth bromegrass are planted in the spring or autumn and forage is not harvested until the following year because of short growing period. Therefore, there are two important problems in the first year in smooth bromegrass cultivation. The first one is the low yield from the field in the first year, and the other is the invasion of the weeds (Miller, 1984). Generally, the use of companion crop is common to solve these problems in perennial forage crops (Lanini et al., 1991). The use of companion crops in perennial forage sowing has been a long established agricultural practice in the world. The companion crop germinates and grows faster than perennial forage plants and provides additional competition against rapidly growing weeds. It offers greater yield, reduces weed competition and erosion risk and improves land-use efficiency (Lanini et al., 1991; Wiersma et al., 1999). Examples of these applications are common in perennial legume forage crops such as alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pretense* L.). Tan and Serin (2004), Cupina et al. (2010) and Acar et al. (2011) found that a companion crop such as wheat, triticale and pea increased the yield in the first year and reduced weed invasion. Companion crops can reduce weed populations and, in some cases, eliminate the need for herbicides during the establishment period (Canevari et al., 2007). Although mixed sowing with companion crop is very common practice in forage legumes, the effect on the grasses has not been investigated in detail. In the few old studies conducted, Buglass (1964), Elliott (1972) and Chastain and Grabe (1989) found that the use of a companion crop in establishment of grasses resulted in a decrease in seed yield. The fertile tillers that produce seeds in the grasses are formed in the autumn of the previous year (Langer, 1973). The use of companion crop reduces seed yields because it reduces reproductive tillers (Bean, 1978). However, there is a lack of knowledge about the effects of companion crops on hay yield and weed growth in perennial grasses.

Usually another way to control weeds is to arrange the sowing time. Sowing time in plants has a great impact on yield and affects the results of the agricultural applications (Ezeaku et al., 2017). Autumn-sown crops have less weed problems than spring-sown crops (Cupina et al., 2010). If the sowing of perennial forage crops is applied at the end of summer (August), yields will be higher next year compared to this of autumn sowing (Tan et al., 2009). Already in the summer in high altitude regions, the stress of the temperature is not very severe. However, sowing in autumn in high altitudes may not produce sufficient yield in the next year (Dumlu et al., 2013). In addition, the effects of sowing time on weeds rate in smooth bromegrass were not investigated. The aims of this study were to determine yield, quality and weed rate of forage that could be obtained in the establishment and subsequent year from smooth bromegrass seeded with or without a cereal companion crop, and determine whether sowing time.

MATERIALS AND METHODS

The research was conducted at the University of Ataturk Agricultural Research Station in 2014 and 2015 in Erzurum (39°55'N and 41°61'E), Turkey. Erzurum, where the experiment is conducted, has an altitude of 1860 m and a continental climate. The total annual rainfall in Erzurum province in 2014

and 2015 was 342.8 mm and 433.5 mm, respectively. The average annual temperature was recorded 6.7 ^{o}C and 7.4 ^{o}C. The average temperature of the years was occurred higher than the average long-term (1950-2013) temperature; the total rainfall in 2014 was less than the long-term rainfall while it was higher in 2015 than the long-term rainfall (Figure 1).

The texture of the experiment area soil is clay loam, and total salt was 0.05%, pH was 7.41, lime was 1.5%, organic matter was 0.85%, plant-available P_2O_5 was 62 kg ha^{-1} and K_2O was 1180 kg ha^{-1}. According to these data, the experiment soil is light calcareous, salt-free, slightly alkaline, very poor in organic matter, poor in plant-available phosphorus and rich in potassium (Kacar, 2012).

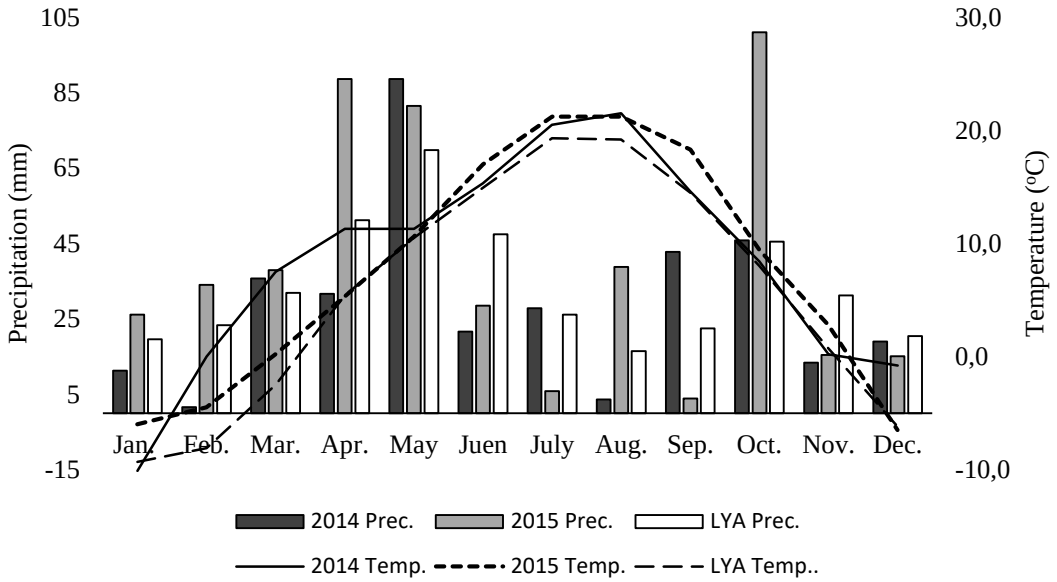

Figure 1. Monthly temperature (lines) and precipitation (bars) of study months in Erzurum 2014, 2015 and long term average (LYA)

The field study was established on the randomized complete block design with three replications. In this study, a population of smooth bromegrass (*Bromus inermis* Leyss.) was sown in two different periods, which were spring (May 2014) and summer (August 2014). Sowing was performed both as a single and mixed crop with wheat (*Triticum aestivum* L.). Alternative Kirik wheat landrace was used as a companion crop. Smooth bromegrass was sown at 15 kg ha^{-1} in 30 cm row spacing. The plots consist of 5 rows, they size were 3.0 m long by 1.5 m wide. Fertilizer was applied during seeding at the rate of 150 kg N ha^{-1} and 50 kg P_2O_5 ha^{-1}. In the second year (2015), only 150 kg N ha^{-1} was applied in the parcels (Tan, 2018). Wheat was sowing by broadcasting into plots at the rate of 100 kg ha^{-1} before sowing smooth bromegrass (Tan and Serin, 2004). Plots were irrigated once every 8-10 days in the summer period in both years. The plots, which had been mixed-planted, were harvested at the milk stage of wheat maturity in the establishment year (2014), and the plots, which had been planted as a single crop, were harvested in the first week of October. In the 2015, all harvests were made at the beginning of the flowering of smooth bromegrass (Tan, 2018). Dry matter yield was determined by harvesting 2 m x 0.9 m strip from the middle of the parcels. Fresh forages were weighed and dried by being left in the open air first and then in the drying oven at 65 ^{o}C for 48 hours, and then their dry matter yield was determined. The weed rates of hay (%) was determined on a dry weight basis by separately weighing weed and smooth bromegrass in the area of 1 m^2 randomly chosen from each plots. The density of weed was determined by separately counting the weed species in the frames of 1 m^2 which were randomly

thrown in the plots. Each sample has been grinded, and its nitrogen analysis has been made by Kjeldahl method (AOAC, 1997), acid detergent fiber (ADF) and neutral detergent fiber (NDF) analyses has been made by Ankom Fiber Analyzer (Van Soest et al., 1991). The ratios of crude protein, ADF and NDF in mixtures has been calculated in a scaled way by taking smooth bromegrass, weeds and companion crop concentration into consideration.

The data obtained from this experiment were subjected to analysis of variance, and where statistical significance difference were observed, the means were compared using the LSD multiple range test according to MSTAT-C software program (Yildiz and Bircan, 2003).

RESULTS AND DISCUSSION

In this study, the use of companion crop and different sowing times have significantly affected the dry matter yield of smooth bromegrass (Table 1). In the establishment year (2014), the dry matter yields in the parcels sown mixed with companion crop were higher than the yields of pure sown parcels. This higher yield resulted from the companion crop that is aggressive and fast growing plant. Fast-establishing plant species that do not overwinter in winters cold regions have potential as companion crops to increase sowing year yields without reducing perennial forage establishment (Coulman et al., 2019). Although statistically insignificant, the high yield in the plots mixed with the companion crop continued in the second year. It was determined in the other studies that the mixing of the perennial forage plant with a companion crop increased the biomass production in the establishment year (Lanini et al., 1991; Acar et al., 2011; Coruh and Tan, 2016). Contrary to the findings of Lanini et al. (1991) and Waddington and Bittman (1983), but in agreement with those of Sheaffer et al. (1988) and Tan and Erkovan (2004), no decrease in hay yield was observed in the second year in the plots mixed with the companion crop. Sowings in the spring produced higher dry matter yield than summer sowings with and without companion crop. Especially in the spring, the sowings mixed with the companion crop gave higher yield (6697 kg ha^{-1}; Table 1). Long growing season would provide an advantage for spring-seeded forages, particularly for a slow-establishing species like smooth bromegrass. Different effects of companion crop depending on sowing times caused interaction (s. time x c. crop) to be significant. In the spring and mixed with companion crop sowings, smooth bromegrass regrew vigorously because of the longer growing season before winter. Otherwise, the smooth bromegrass seedlings entering the winter without adequate development cannot produce their actual yields in the next year (in the first yield year). As a result, forage yields of the following year are relatively low. Establishment with wheat companion crop in the planting year (2014) depressed dry matter production in the year after planting (2015) in spring-seeded stands, but increased productivity in summer-seeded stands, resulting in a significant year x companion crop interaction ($P<0.01$).

In the pure sowings, 15% and 32% of the hay obtained from spring and summer sowings respectively were smooth bromegrass, the other rates were weeds (Figure 2). In mixed sowings with companion crop, weed ratios significantly decreased. In mixed sowings, the rates of smooth bromegrass, weed and companion crop in spring-sown are 17%, 7% and 76%, respectively. These rates were determined as 18.9%, 8.1% and 73% in summer-sown, respectively. These results showed that the companion crop decreased the rate of weed both in the first year and in the second year, and made a significant contribution to the first year hay yield.

Table 1. Effect of companion crop and sowing time on dry matter yields in the establishment and second year

Sowing Time	Companion Crop	Dry Matter Yield (kg ha^{-1})		
		2014	**2015**	**Mean**
Spring	Solo-sowing	2377	5933	4155
	Mixed-sowing	7087	6307	6697
Mean		4731	6120	5426 A
Summer	Solo-sowing	1523	5387	3455
	Mixed-sowing	3870	5653	4762
Mean		2697	5520	4108 B
	Solo-sowing	1950	5660	3805 B
	Mixed-sowing	5478	5980	5729 A
Mean		3714 B	5820 A	4767
F test (LSD Values)				
Year			** (764)	
S. Time			** (764)	
Year x S. Time			* (779)	
C. Crop			** (764)	
Year x C. Crop			** (1081)	
S. Time x C. Crop			* (779)	
Year x S. Time x C. Crop			* (1102)	

Means in the same columns and lines followed by the same letters are not significantly different
*: P<0.05, **: P<0.01

In the establishment year, weeds rate was found as 68.3-85.0% in pure sowings and it was lower in summer plantings (Table 2). The rate of weeds in mixed sowing was 6.7-9.0%. In the second year, the rate of weeds in mixed sowing was lower than the pure sowing in the first year. It is quite clear that the use of companion crop prevents weeds. The effect of the companion crop was observed especially in the establishment year and continued in the second year (year x c. crop). For perennial forage establishments, higher weed infestation is observed in the first year, for there is not a strong plant cover on the field. Other studies have shown that the companion crop reduces the development of weeds (Sheaffer et al., 1988; Lanini et al., 1991). In this study, weed rates of summer sowings were lower than spring sowings. Already Cupina et al. (2010) reported that weeds are more problems in spring planting. Weed problems are usually less with late-summer seeding than with seedings done in spring (Hall and Collins, 2017). Vough et al. (1995) also explained that autumn-seeded forages experience less weed competition than spring-seeded stands.

In the experiment area, 16 and 12 weeds species were identified in the sowing year and second year, respectively (Figure 3). *Centaurea solstitialis, Capsella bursa-pastoris, Polygonum belardii* and *Papaver dubium*, which were seen in the first year, disappeared in the second year. The most common weeds in the first year were *Amaranthus retroflexus* (9.3 units m^{-2}) and *Convolvulus arvensis* (8.5 units m^{-2}). *A. retroflexus* decreased to 1.5 units m^{-2} with a significant decrease and *C. arvensis* was found to be 8.2 units m^{-2} with a slight decrease in the second year.

In the present study, the crude protein content of hay did not change according to the sowing time, but significant changes were observed depending on years and companion crop use (Table 3). In the first year and pure sown plots, the crude protein content of the hay was higher. In the first year, the dry matter content of pure sown smooth bromegrass is low and the crude protein content is high (Klebasedel, 1993). Depending on the properties of the companion crop, the crude protein content of the mixture varies (Tan and Serin, 2004). In the second year, crude protein ratios decreased with increasing dry matter yield of smooth bromegrass. In the research, companion crop x sowing time interaction was found to be significant on crude protein content (P<0.05). The highest crude protein content (14.01%) was determined in summer time and pure sowings in the first year. In the second year, the ratios of crude

protein were similar among all treatments. Similarly, Cupina et al., (2010) determined the low variation in protein content of red clover after clipping companion crop.

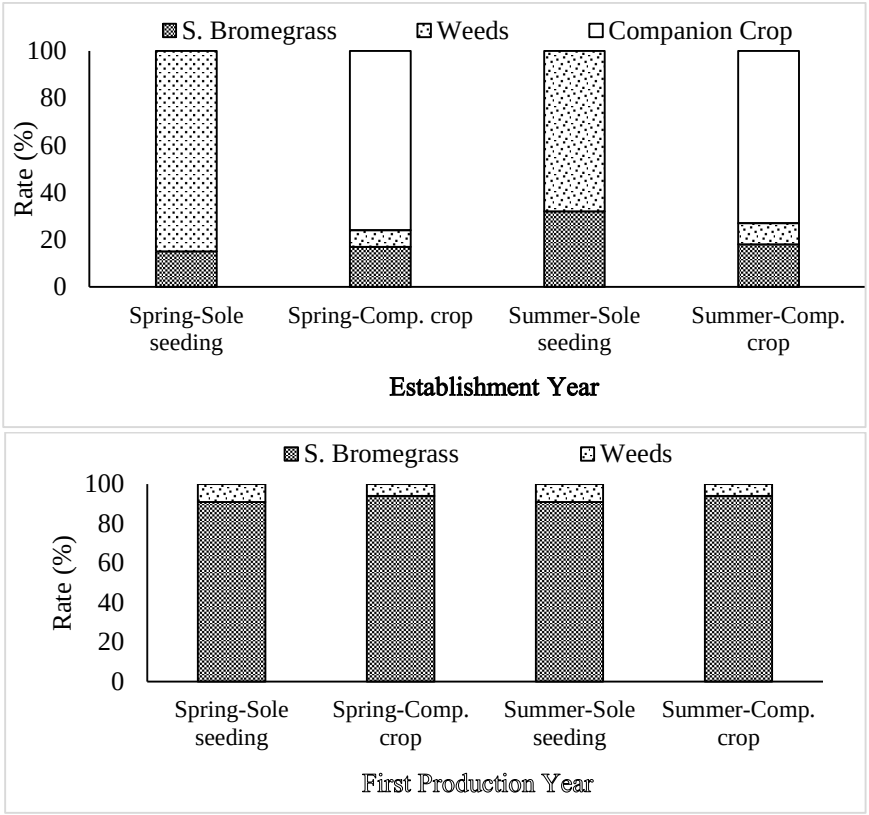

Figure 2. Smooth bromegrass, companion crop and weed proportions of hay in establishment and second year

Table 2. Effect of companion crop and sowing time on weed rate of hay in the establishment and second year

Sowing Time	**Companion Crop**	**Weed Rate (%)**		
		2014	**2015**	**Mean**
Spring	Solo-sowing	85.0	8.7	46.8
	Mixed-sowing	6.7	5.7	6.2
Mean		45.8	7.2	26.5 A
Summer	Solo-sowing	68.3	9.3	38.8
	Mixed-sowing	9.0	5.7	7.3
Mean		38.7	7.5	23.1 B
	Solo-sowing	76.7	9.0	42.8 A
	Mixed-sowing	7.8	5.7	6.8 B
Mean		42.3 A	7.3 B	24.8
F test (LSD Values)				
Year			** (4.7)	
S. Time			* (3.4)	
Year x S. Time			* (4.8)	
C. Crop			** (4.7)	
Year x C. Crop			** (6.6)	
S. Time x C. Crop			* (4.8)	
Year x S. Time x C. Crop			** (6.8)	

Means in the same columns and lines followed by the same letters are not significantly different
*: P<0.05, **: P<0.01

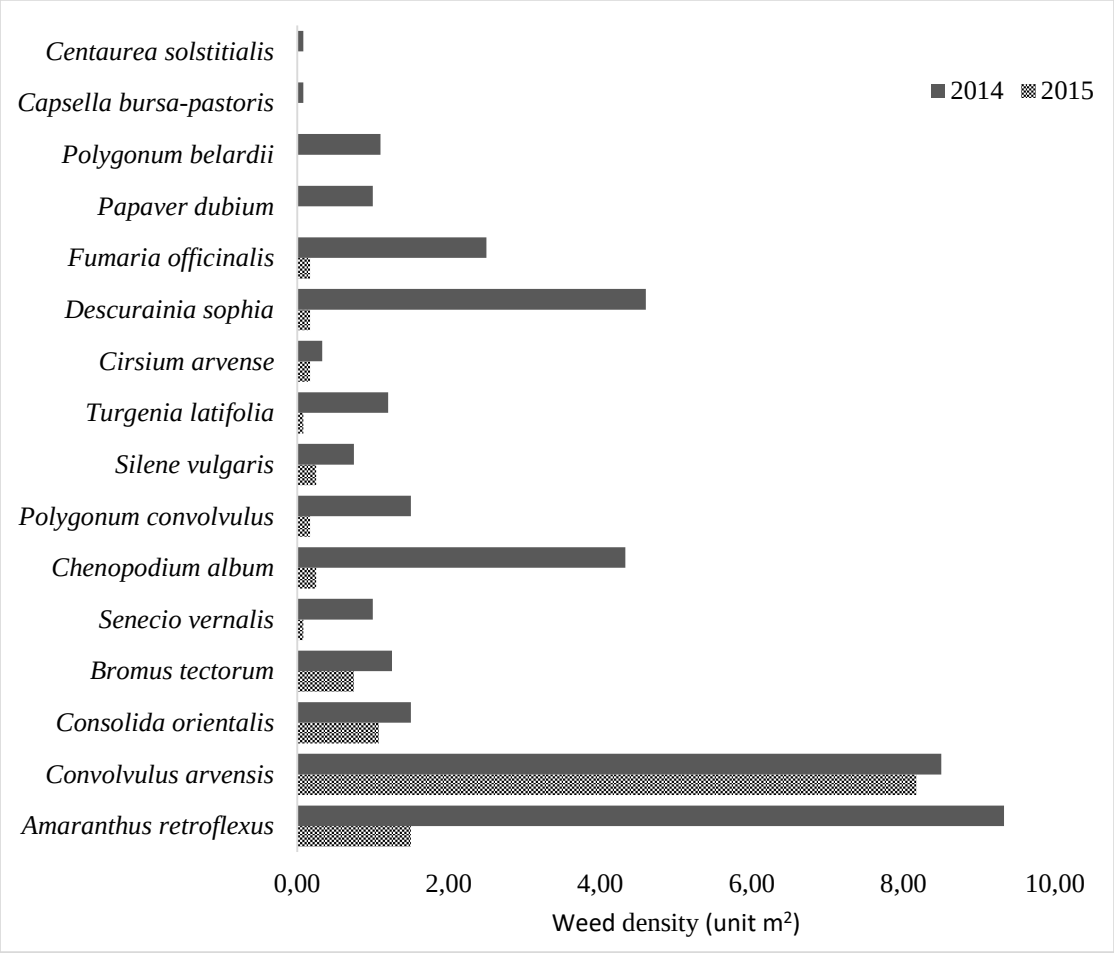

Figure 3. Weed density in the establishment and subsequent year

Table 3. Effect of companion crop and sowing time on crude protein ratio of hay in the establishment and second year

Sowing Time	Companion Crop	Crude Protein Ratio (%)		
		2014	**2015**	**Mean**
Spring	Solo-sowing	13.24	12.36	12.80
	Mixed-sowing	13.20	12.20	12.70
Mean		13.22	12.28	12.75
Summer	Solo-sowing	14.01	12.38	13.19
	Mixed-sowing	12.22	12.75	12.49
Mean		13.12	12.56	12.84
	Solo-sowing	13.62	12.37	13.00 A
	Mixed-sowing	12.71	12.48	12.59 B
Mean		13.17 A	12.42 B	12.80
F test (LSD Values)				
Year			** (0.34)	
S. Time			ns	
Year x S. Time			ns	
C. Crop			** (0.35)	
Year x C. Crop			** (0.49)	
S. Time x C. Crop			* (0.35)	
Year x P. Time x C. Crop			** (0.69)	

Means in the same columns and lines followed by the same letters are not significantly different
*: P<0.05, **: P<0.01, ns: non-significant

The rates of ADF and NDF showed significant changes due to years and companion crop use (Table 4). The second year the ADF and NDF rates of the hay were higher. Because in the second year,

smooth bromegrass grew more strongly, and the ratio of the stem inside the hay increased and structural materials in the tissues increased. Hunt et al. (2016) demonstrated that nutritive values of forages, established in this case without herbicides are improved in the second year after seeding compared with the first year after seeding. Glover et al. (2004) have also identified that the ADF and NDF ratios of smooth bromegrass changed according to years. The rates of ADF and NDF in the plots mixed with the companion crop are higher than the pure sown plots. This is especially due to the first year because there is wheat as a companion crop in mixtures. In general, the high structural materials of wheat hay produced this result (Beck et al., 2009). Already in this study, the companion rate of hay was high in the mixed plots in the establishment year (Figure 2).

Table 4. Effect of companion crop and sowing time on acid detergent fiber (ADF) and neutral detergent fiber (NDF) ratio of hay in the establishment and second year

Sowing Time	Companion Crop	ADF (%)			NDF (%)		
		2014	2015	Mean	2014	2015	Mean
Spring	Solo-sowing	35.15	37.54	36.34	40.16	47.17	43.67
	Mixed-sowing	38.48	37.79	38.14	47.22	45.80	46.76
Mean		36.82	37.67	37.24	43.94	46.49	45.21
Summer	Solo-sowing	32.72	37.78	35.25	35.26	47.27	41.26
	Mixed-sowing	37.90	38.72	38.31	48.12	47.77	47.95
Mean		35.31	38.25	36.77	41.69	47.52	44.61
	Solo-sowing	33.94	37.66	35.80	37.71	47.22	42.47
	Mixed-sowing	38.19	38.26	38.22	47.92	46.79	47.35
Mean		36.06 B	37.96 A	37.01	42.82 B	47.00 A	44.91
F test (LSD Values)							
Year		** (1.04)				** (1.11)	
S. Time		ns				ns	
Year x S. Time		** (1.47)				** (1.57)	
C. Crop		** (1.04)				** (1.11)	
Year x C. Crop		** (1.47)				** (1.57)	
S. Time x C. Crop		ns				** (1.57)	
Year x S. Time x C. Crop		ns				* (1.61)	

Means in the same columns and lines followed by the same letters are not significantly different
*: P<0.05, **: P<0.01, ns: non-significant

CONCLUSION

In the high altitude areas, such as Eastern Anatolia, the smooth bromegrass cannot grow sufficiently in the establishment year. Therefore, low forage yield is obtained and weeds are invading the field. Some weeds may have a high feed value for animal, but generally weeds in farmland are not desirable (Khan et al., 2013). Mixing with a companion crop such as wheat increases both forage yield and the prevention of weed infestation. This application, which is made by reducing the sowing rate in irrigated conditions, has no negative effect on the yield of the following year; on the contrary, in the second year, the yield was higher and the weed ratio was lower. Forage quality was directly related to the smooth bromegrass, weed and companion crop contents of the harvested forage. The use of companion crop reduced the crude protein content of the hay taken in the establishment year and increased the ADF and NDF ratios. However, these negative effects on hay quality in the second year were lower. Dry matter yields were higher in spring-sown, but weed ratio was also high in this sowing time. There was no significant effect of sowing time on herbage quality. According to the results of this study, the mixed sowing of smooth bromegrass with wheat companion crop in the spring sowing time can be recommended.

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Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contiıbutions

The authors declare that they have contributed equally to the article.

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