Turkish Journal of Agriculture - Food Science and Technology, 10(12):2389-2396, 2022
DOI: https://doi.org/10.24925/turjaf.v10i12.2389-2396.5222

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Effects of Forage Legumes Sowing in the Fallow Year on Silage Yield and Quality Characteristics of Subsequent Cereals

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A R T I C L E I N F O

Research Article

Received : 12/04/2022
Accepted : 08/11/2022

Keywords:
Fallow
Grain
Hay
P. arvense
V. pannonica

A B S T R A C T

In this study, the effect of *P. arvense-H. vulgare* mixture and *V. pannonica* grown in the fallow year on silage yield and quality of subsequent cereals were investigated in the arid condition of Eskişehir, Turkey. The fresh weight of *P. arvense-H. vulgare* mixture with 2750 kg/da was found two-fold high than *V. pannonica*. *P. arvense-H. vulgare* mixture significantly increased the fresh and dry hay weights of cereals except for *H. vulgare* cv. İnce. In addition, the highest grain yield was obtained by growing *Triticosecale* cv. Karma in *P. arvense-H. vulgare* mixture plots. Due to the high pH and low dry matter content of triticale samples, the Fleig scores were very low, which is a quality indicator in silage. ADF and NDF ratios were the highest in *A. sativa* cv. Checato as a negative quality factor. Top-dressing of nitrogen had a positive effect on the crude protein ratio. It was concluded that production of quality roughage can be sustainably increased by growing *P. arvense-H. vulgare* mixture in barren areas in the fallow year and followed by sowed cvs. Karma, Müfitbey, and Checato in the cereal growing season.

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Introduction

Cereal-fallow rotation is performed in 3.1 million hectares of dry farming lands of Turkey due to insufficient rainfall (TUIK, 2021). However, this cropping system negatively impacts soil fertility reducing organic matter and nutrients over time (Yang et al., 2020). In this case, annual forage legumes will have an important role in soil improvement.

Legumes fix N_2 through *Rhizobia sp.* to the soil and improve soil fertility for subsequent crops (Parr et al. 2011; Christiansen et al., 2015; Liebmana et al. 2018). Due to the fact that annual forage legumes grown for hay leave the soil earlier, they leave more water and nutrients to the following crops compared to those grown for grain purposes (Christiansen et al., 2011; Ryan et al., 2012).

There are many studies on the benefits of including annual forage legumes such as *Vicia* sp. (Sommer et al., 2011; Christiansen et al., 2011) and *Pisum* sp. (Miller et al., 2018; Lenssen et al., 2018) in crop rotation in dry farming systems. However, the results of rotations varied according to ecological and soil conditions. In addition, there was not enough study on the effect of *V. pannonica* on the cereal-fallow rotation. In this study, the effects of *P. arvense-H. vulgare* mixture and *V. pannonica* on silage yield and quality of subsequent cereals were investigated under the dry conditions.

Materials and Methods

Field experiments were carried out in Arıkaya village of Alpu district in Eskişehir, Turkey (39° 57' 13.2552" and 31° 1' 49.6488") between 2018-2020. In this region, where the continental climate prevails, high values were recorded in experiment years than long years in terms of both total precipitation and average temperature (Table 1).

The organic matter of experiment soil was medium level with 3.17% (Dewi and Arbawa, 2019). Addition, it was determined that lime content was low level, pH was neutral with 6.8 and unsalted.

The experiment was arranged in split plot in randomized block with 4 replications. The main plots were pre-applications [Control 1 (C1), control 2 (C2), *Vicia pannonica* cv. Budak (VP) and *Pisum arvense* cv. Töre-

Hordeum vulgare cv. Tarm 92 mixture (PA_HV_M)] and sub-plots were cereals [*Hordeum vulgare* cv. İnce 04 (Hv_cv. İnce), *Triticum aestivum* cv. Müfitbey (Ta_cv. Müfitbey), *Avena sativa* cv. Checota (As_cv. Checota) and *Triticosecale* cv. Karma (T×S_cv. Karma)].

Sowing of Forage Legumes in Fallow Year

In the first of experiment year, the seeds of *P. arvense-H. vulgare* mixture (70%: 30%) and *V. pannonica* were sown at 15 cm row space with 10 kg/da of Diammonium phosphate (DAP) on 12.10.2018. The rates of seeding were 15 kg/da in *P. arvense*, 18 kg/da in barley and 6 kg/da in *V. pannonica*. Control 1 and control 2 plots were left bare without any treatment. Forage legumes had rosette form before winter, and when the lower pods began to fill, they were mown on 05.06.2019. Dry hay ratio (%) was measured from fresh hay weight as in the following formula in forage legumes: [(100-(Fresh hay weight) -(Dry hay weight)/ (Fresh hay weight) *100].

Sowing of Cereals

In the second year of the experiment, cereals were sown with 10 kg/da DAP to each plot on 19.10.2019. In addition, top-dressing fertilization was performed on 27.03.2019 with 10 kg/da of ammonium sulfate (21% N) only to control 2 plot as a conventional application. In the experiment, each plot consisted of 5 rows, the spacing between rows was 20 cm and each row was 4 m long (Parcel size: 5*0.20*4=4 m^2). The seeding rates of cereals were 20.5 kg/da in wheat (600 plants per m^2), 27.2 kg/da in barley (550 plants per m^2), 19.9 kg/da in triticale (600 plants per m^2) and 23.53 kg/da in oat (650 plants per m^2).

When cereal spikes reached to the milk-dough stage at different dates as indicated in Table 2, plant height, fresh, and dry hay weights were determined. In addition, grain yield was measured on 14.07.2020 in all cereals. For both grain and forage yield, after removing 0.5 m of both edges of the rows, the middle three rows of the plots (0,9 m^2) were moved with sickle.

Production of Cereal Silages and Analysis

Cereals were chopped into small pieces of 2-3 cm and pressed into 2 kg nylon bags, and the air inside was vacuumed from the mouth part, and their mouths were taped to prevent air. After the samples were kept in a dark place (24±2°C) for 6-8 weeks, their mouths were opened and the biochemical analyzes such as pH value (Chen et al., 1997), crude protein ratio (AOAC, 1990), Acid Detergent Fiber [(ADF ratio), (Van Soest, 1963)] and Neutral Detergent Fiber [(NDF ratio), (Van Soest and Wine, 1967)] of these samples were performed. Also, dry matter ratio was determined described as by AOAC (1990). In order to determine the quality of silage, the Fleig score was calculated by using the relationship between pH value and dry matter ratio as indicated in Table 3 (Kılıç, 1984).

Table 1. Climatic data pertaining to the experiment years and the average of long years.

Months	Total precipitation (mm)				Average temperature (°C)				Average relative humidity (%)			
	2018	2019	2020	LYA*	2018	2019	2020	LYA	2018	2019	2020	LYA
January	35.6	54.8	52.0	44.4	1.5	1.2	-1.1	0.0	81.8	83.4	84.2	84.0
February	37.2	50.8	50.2	27.2	5.6	3.0	3.1	1.9	78.1	78.2	76.1	79.3
March	50.2	14.0	25.4	31.1	9.3	6.4	7.2	6.0	67.8	63.1	67.6	73.0
April	11.4	31.6	13.6	29.5	13.9	9.5	10.0	10.2	56.9	66.6	61.0	70.1
May	85.8	49.0	43.6	42.6	16.6	16.4	15.2	15.0	70.5	61.3	62.1	69.8
June	55.4	37.0	113.2	34.7	19.8	20.5	18.4	19.4	64.9	65.6	68.5	66.9
July	58.4	35.4	2.2	5.2	22.2	21.2	22.7	22.4	61.7	58.6	59.0	62.1
August	29.4	2.8	4.4	17.7	22.9	22.1	22.6	22.4	59.0	57.1	53.1	64.1
September	3.4	4.4	26.4	18.0	18.6	18.2	20.5	17.7	60.2	59.0	61.8	68.1
October	24.2	17.0	31.0	36.6	13.0	14.0	14.8	12.0	72.7	68.2	68.5	76.5
November	20.4	31.8	3.0	22.0	7.4	8.0	4.7	6.1	77.3	75.2	76.8	80.4
December	46.6	100.0	10.8	22.0	2.0	2.7	4.4	1.7	86.9	88.8	80.8	84.6
Total	458	428.6	375.8	331.0	-	-	-	-		-		-
Mean	-	-	-	-	12.7	11.9	11.8	11.2	69.8	68.8	68.3	73.2

* Long years average

Table 2. Dates of mowing of cereals for silage preparation

Cereals	Mowing dates
T × S_cv. Karma	19.05.2020
Ta_cv. Müfitbey	08.06.2020
Hv_cv. İnce	30.05.2020
Av_cv. Checato	16.06.2020

Table 3. Calculation of Flieg score and quality classes by using pH and dry matter contents in silage samples

Flieg score=205+(2*Dry matter ratio)-40*pH value	
81-100	I = Very good
61-80	II= Good
41-60	III= Satisfactory
21-40	IV= Medium
20-0	V= Bad

Table 4. Variance analysis and mean values of fresh weight and dry hay ratio in forage legumes

Forage legumes	Characters	Standard error (±)	t values
	Fresh weights (kg/da)		
P. arvense-H. vulgare mixture	2750[a]	51.7	19.54*
V. pannonica	1407[b]	46.2	
	Dry hay ratios (%)		
P. arvense-H. vulgare mixture	21.25	0.47	-0.92[ns]
V. pannonica	21.75	0.25	

*Significant within the error limits of P≤0.01, ns: non-significant.

Table 5. Analysis of variance and differences between mean values of silage yield characters in subsequent cereals grown after different pre-applications (Mean ± standard error).

Factors	Plant Height (cm)	Fresh weight (kg/da)	Dry hay weight (kg/da)	Grain yield (kg/da)
		Pre-applications		
C1	83.1±3.6	1697.4±116.1[c]	585.4±50.6[c]	372.9±20.0[b]
C2	81.9±3.9	1788.4±117.7[c]	559.1±37.6[c]	339.1±28.7[c]
PA_HV_M	88.0±3.3	2294.4±152.6[a]	737.3±54.9[a]	422.9±29.5[a]
VP	84.9±3.2	1983.5±100.4[b]	655.9±36.2[b]	417.1±35.0[a]
		Cereal species		
TxS_cv. Karma	85.2±1.3[c†]	2081.4±92.4[b]	602.5±20.3[c]	539.1±18.5[a]
Ta_cv. Müfitbey	89.3±1.1[b]	2148.4±81.9[b]	817.7±30.9[a]	408.2±12.0[b]
Hv_cv. İnce	63.9±1.1[d]	1198.8±56.4[c]	383.7±20.6[d]	287.1±17.5[d]
As_cv. Checato	99.5±1.4[a]	2335.1±70.6[a]	733.7±25.3[b]	317.6±16.8[c]
		Analysis of variance		
Pre-applications (PA)	ns	**	**	*
Cereal species (CS)	**	**	**	**
PA x CS	ns	**	**	**
CV (%)	4.62	7.46	8.23	9.57

*, **: significant level of %5 and %1, respectively, ns: non-significant. †: letters show different groups at 5% level.

Table 6. Analysis of variance and differences between mean values of silage quality characters in subsequent cereals grown after different pre-applications (Mean ± standard error).

Factors	Dry matter ratio (%)	pH value	Fleig score	ADF ratio	NDF ratio	Crude protein ratio (%)
			Pre-applications			
C1	38.9±1.28	5.87±0.09[a]	47.8±6.10[bc]	34.0±0.82	56.0±0.70[b]	10.0±0.17[c]
C2	38.8±1.24	5.93±0.1[a]	45.4±6.29[c]	33.0±1.00	53.9±0.60[c]	11.3±0.32[a]
PA_HV_M	37.8±1.74	5.76±0.08[b]	50.1±6.57[b]	33.7±0.90	55.7±0.56[b]	10.7±0.19[b]
VP	38.0±1.35	5.68±0.06[b]	53.8±5.05[a]	35.0±0.79	57.3±0.58[a]	10.0±0.13[c]
			Cereal species			
TxS_cv. Karma	29.4±0.48[c†]	6.34±0.05[a]	10.2±1.83[c]	32.6±0.32[b]	54.4±0.40[c]	10.7±0.37[a]
Ta_cv. Müfitbey	41.8±0.47[a]	5.51±0.03[d]	67.9±1.30[a]	33.2±0.33[b]	55.2±0.39[bc]	10.4±0.20[ab]
Hv_cv. İnce	42.2±0.36[a]	5.75±0.03[b]	61.9±1.33[b]	31.4±0.46[c]	56.1±1.02[ab]	10.6±0.27[b]
As_cv. Checato	40.1±0.48[b]	5.63±0.03[c]	66.5±1.50[b]	38.5±0.26[a]	57.1±0.56[a]	10.1±0.16[b]
			Analysis of variance			
Pre-applications (PA)	ns	**	**	ns	*	*
Cereal species (CS)	**	**	**	**	**	*
PA x CS	**	*	*	*	**	**
CV (%)	3.69	2.03	9.53	2.76	2.36	4.73

*, **: significant level of %5 and %1, respectively, ns: non-significant. †: letters show different groups at 5% level.

The research was designed split plot in completely randomized block with four replications and data were analysed using JMP 14 program. Mean values with significant differences were compared with the LSD and t tests.

Results and Discussion

While forage legumes indicated significant differences in terms of fresh hay weight, there was no difference between dry hay ratios (Table 4). The mixture of *P.arvense-H. vulgare* produced high fresh weight with 2750 kg/da than *V. pannonica* with 1407 kg/da. On the other hand, dry hay ratio was about 21% in both forage legumes.

In contrast to this finding, Büyükburç et al. (1994) obtained a higher fresh yield from the *V. pannonica* cv. Anadolu Beyazı (2887 kg/da) than the line L-1699 of *P. arvense* (1897 kg/da) in Tokat arid conditions. However, Engin (2019) and Kalkan and Avcı (2020) reported in similar to this finding that forage pea produced higher fresh weight of than common and Hungarian vetches, respectively.

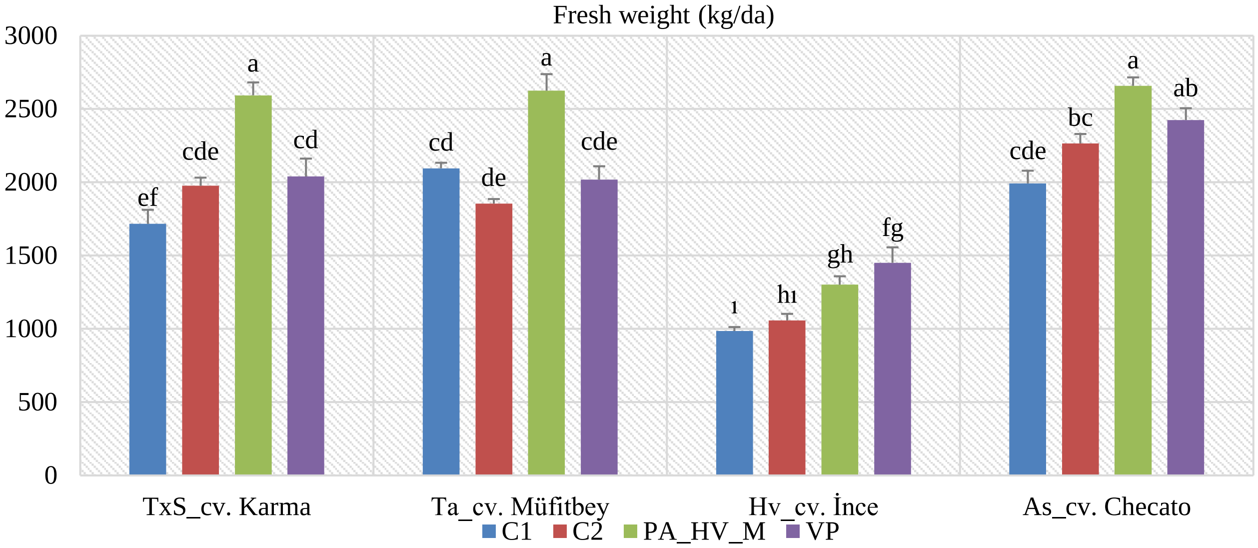

Figure 1. Fresh weight of cereals grown after various pre-applications (Vertical bars indicate mean values ± standard error at P<0.05).

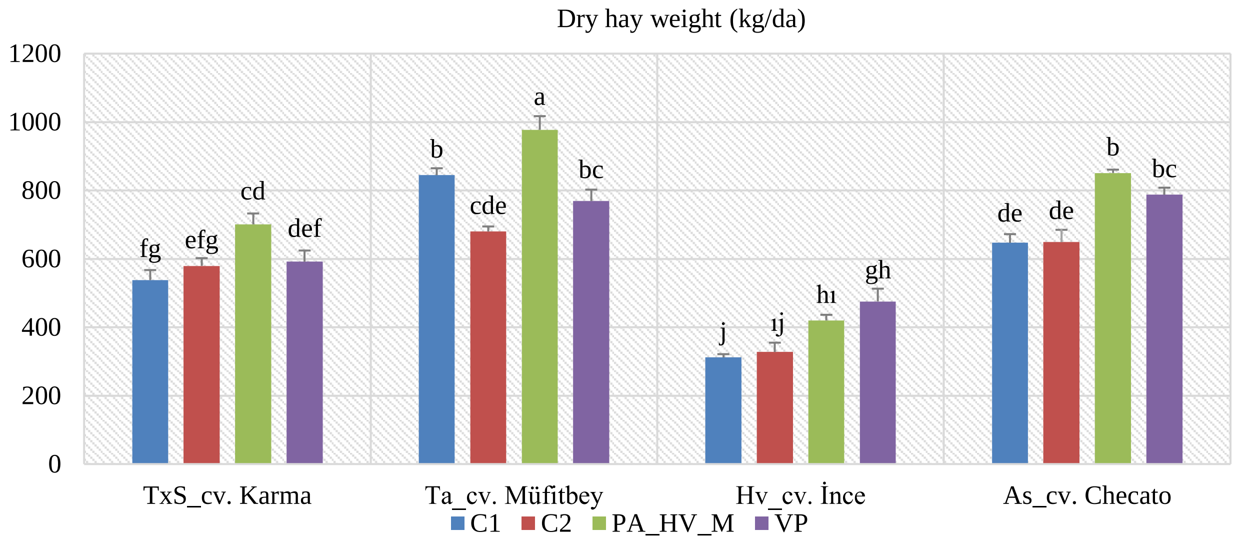

Figure 2. Dry hay weight of cereals grown after various pre-applications (Vertical bars indicate mean values ± standard error at P<0.05).

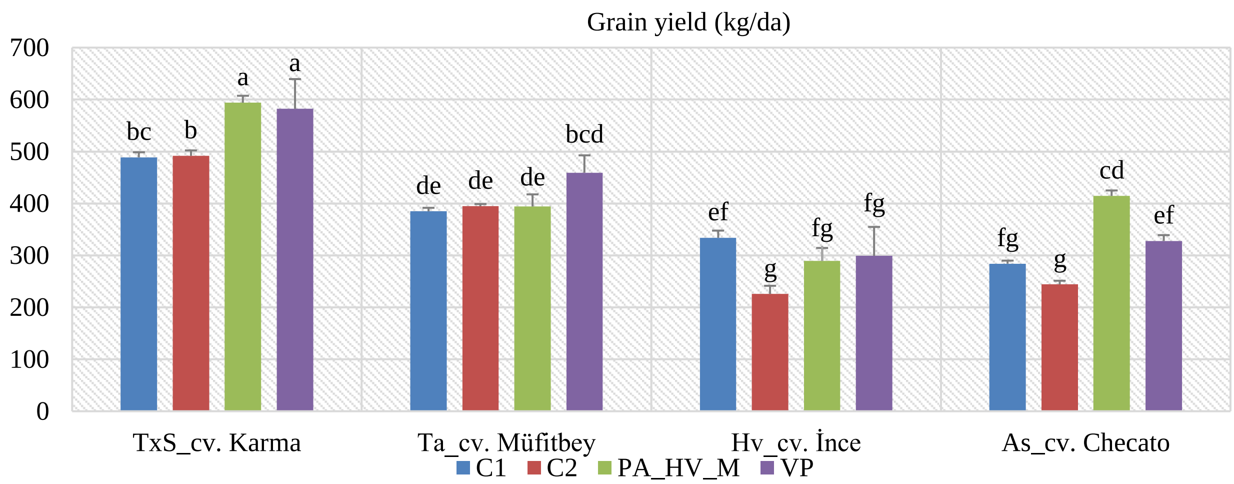

Figure 3. Grain yield of cereals grown after various pre-applications (Vertical bars indicate mean values ± standard error at P<0.05).

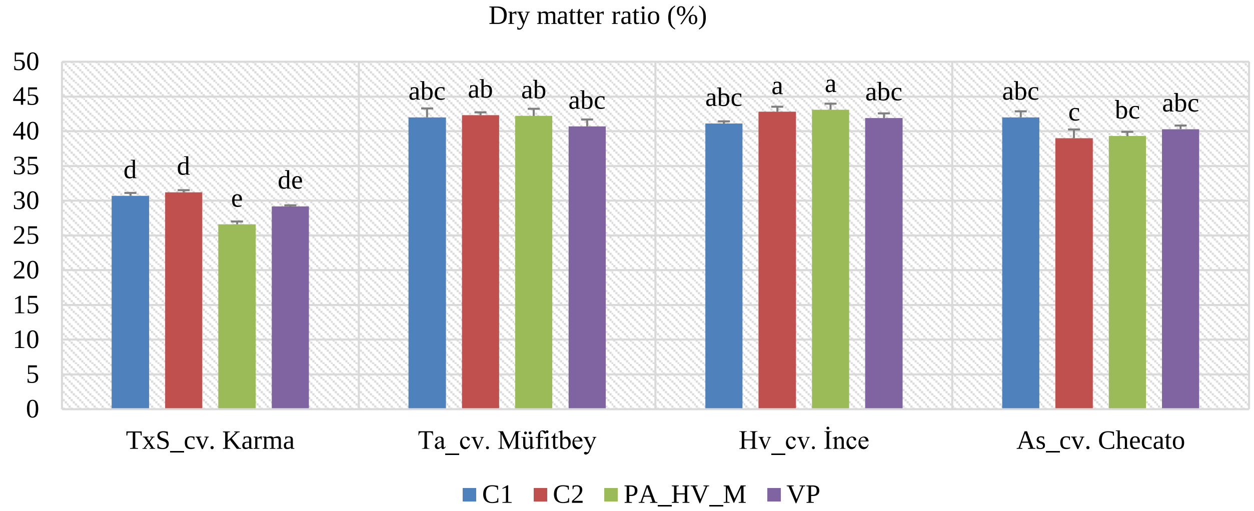

Figure 4. Dry matter ratio of silage in cereals grown after various pre-applications (Vertical bars indicate mean values ± standard error at P<0.05).

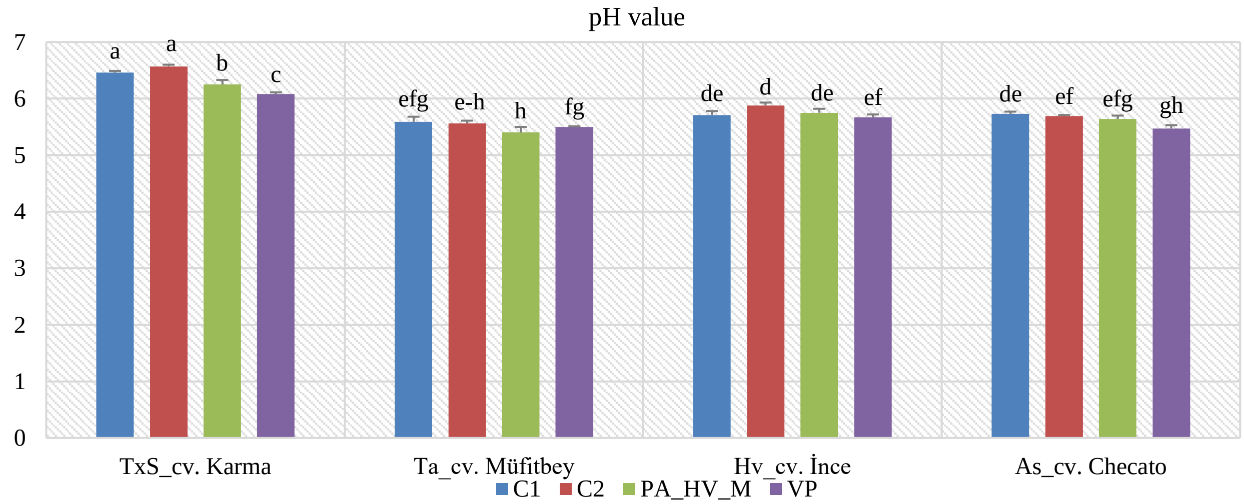

Figure 5. pH value of silage in cereals grown after various pre-applications (Vertical bars indicate mean values ± standard error at P<0.05).

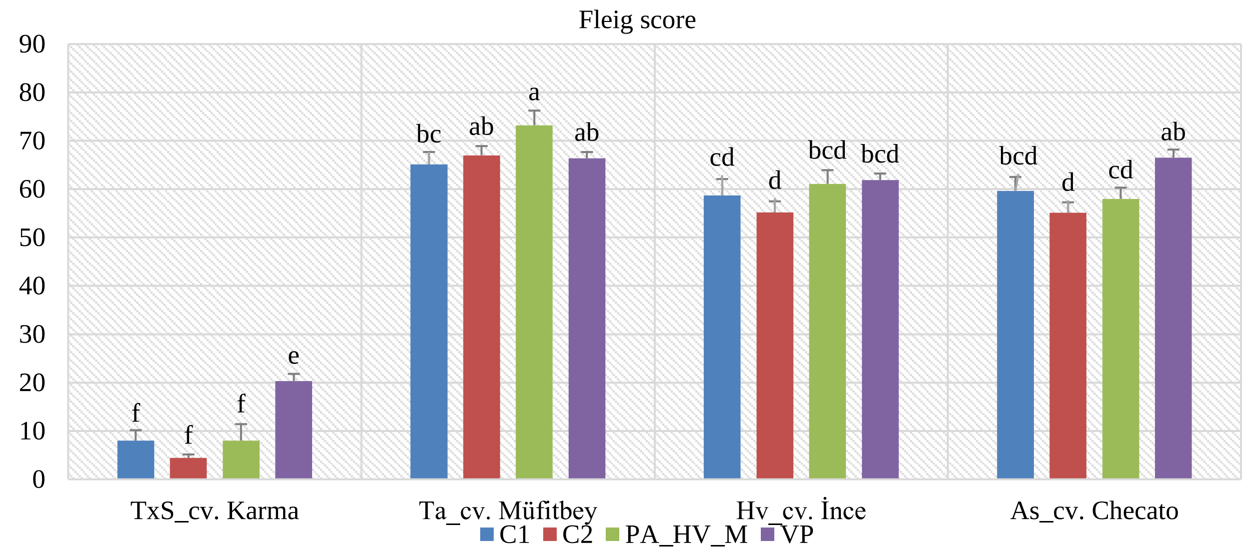

Figure 6. Fleig score of silage in cereals grown after various pre-applications. (Vertical bars indicate mean values ± standard error at P<0.05).

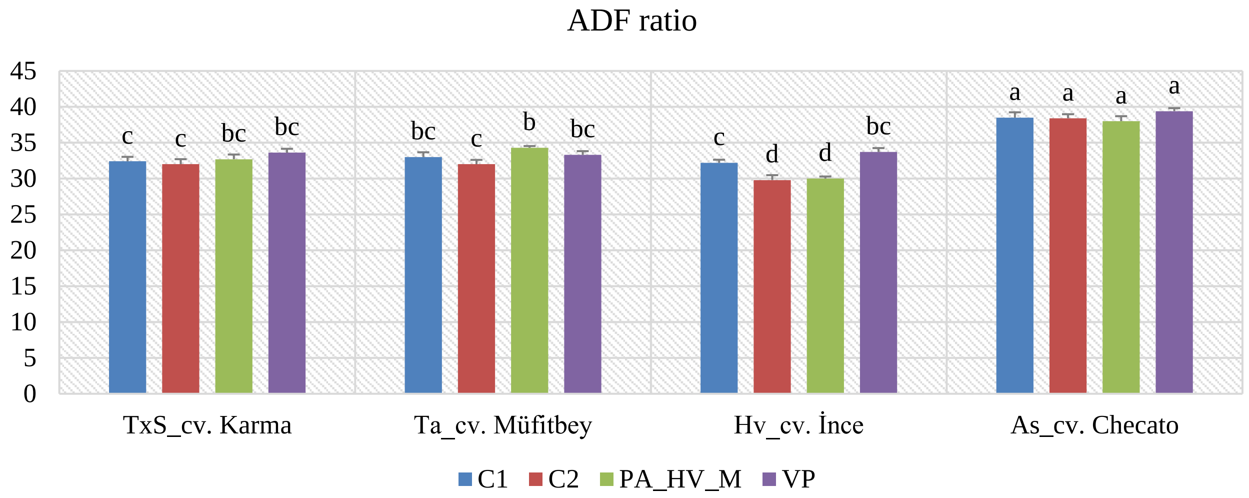

Figure 7. ADF ratio of silage in cereals grown after various pre-applications. (Vertical bars indicate mean values ± standard error at P<0.05).

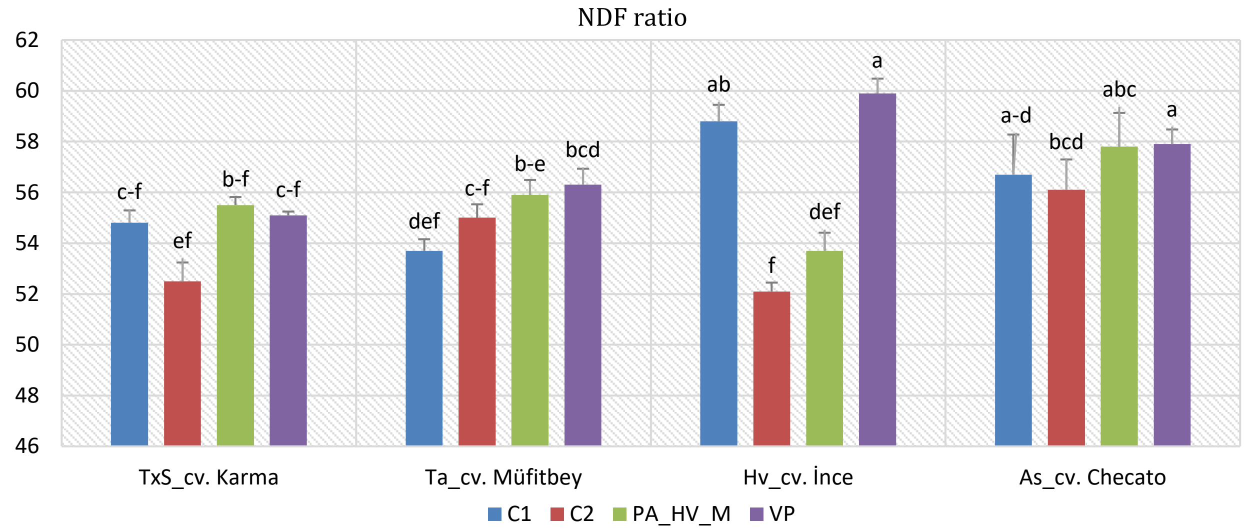

Figure 8. NDF ratio of silage in cereals grown after various pre-applications. (Vertical bars indicate mean values ± standard error at P<0.05).

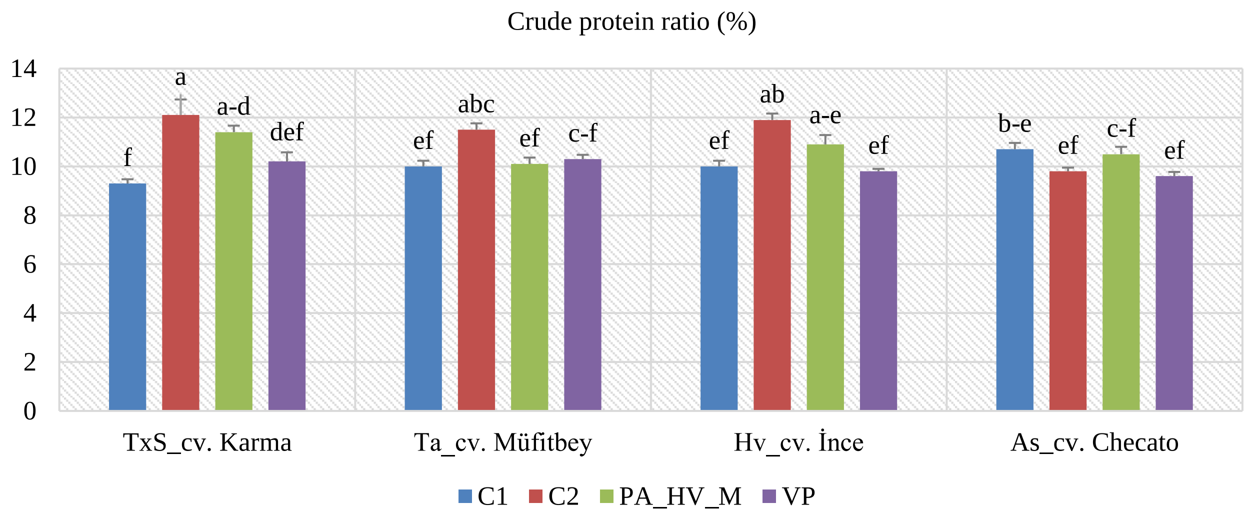

Figure 9. Crude protein ratio of silage in cereals grown after various pre-applications. Vertical bars indicate mean values ± standard error at P<0.05).

The effect of cereals on plant height was found to be significant (Table 5). Plant heights varied between 63.9 cm in İnce and 99.5 cm in Checato of cereal species. In this study, there was no differences in plant height depending on the pre-treatments contrary to Ozyazici and Manga (2000), Kavut and Geren (2015) and Kalkan and Avcı (2020). On the other hand, Zentner et al. (2004) reported that the physical and chemical improvements of soil and positive effects on subsequent crops occur in long period in arid conditions. This explains why the research results are not statistically significant.

Fresh and dry hay weights were significantly affected by the main factors and their interaction at the 1% level (Table 5). The effect of *P.arvense-H. vulgare* mixture on them had higher compared to other pre-applications. The highest fresh and dry hay weights of cereals were in Checato and Müfitbey, respectively. The application of *P.arvense-H. vulgare* mixture increased the fresh and dry hay weights of cereals except for İnce (Fig. 1 and Fig. 2). Although pre-application of *V. pannonica* was more effective in İnce, the lowest values of fresh and dry hay weights were obtained. Forage pea fixed nitrogen from the air to the soil in the range of 10.2-11.5 kg/da (Parr et al., 2011). The fixation of organic nitrogen in the soil in semi-arid conditions had positive effects on cereal yield (DõÂaz-Ambrona and MõÂnguez, 2001; Masri and Ryan, 2006; Ryan et al., 2008).

Grain yield was affected significantly from applications (Table 5). The higher grain yields were obtained from Karma in the pre-applications of *P.arvense-H. vulgare* mixture or *V. pannonica* (Fig. 3). Zentner et al. (2004) reported that forage legumes grown in the fallow year for green manuring caused a gradual and significant increase in wheat grain yield. Christiansen et al. (2015) found that legumes are excellent alternatives to wheat-fallow rotation and continuous wheat production in Mediterranean-type climates and support more efficient and sustainable production.

Silage quality characters of cereals were differed to main factors and their interaction except the effect of pre-applications on dry matter and ADF ratios (Table 6). Dry matter ratio varied significantly according to the cereals. While the Karma indicated low rates compared to other cereals, there was no significant difference between Müfitbey and İnce in all pre-applications (Fig. 4). Kavut and Geren (2015) was confirmed that there was no variation in the dry matter ratio of maize grown after different pre-applications. However, Kalkan and Avcı (2020) reported that the dry matter ratio of the following silage maize after forage legumes differed to the pre-applications under irrigated conditions.

The pH was found to be lower in the plots grown forage legumes compared to the control applications as indicated in Table 6. In cereal species, generally the lower and higher pH values were determined in Müfitbey and Karma varieties in all pre-applications, respectively (Fig. 5). In contrast to these findings, Kavut and Geren (2015) reported that the growing of forage legumes as pre-plants no effected to pH of the following silage maize samples. Also, Kavut et al. (2012) found that the pH values of triticale cultivars varied between 4.43 and 5.35. The reason for the high pH in triticale samples of this study may be that the silage samples were harvested during the period between milk and dough stages as stated by Geren (2014).

The lowest and highest of Fleig scores were in control 2 and *V. pannonica* of pre-applications, respectively (Table 6). Kavut and Geren (2015) reported that the effect of pre-plants on the Fleig score in the following silage maize samples was insignificant. On the other hand, Karma indicated distinctly a very low Fleig scores in all aplications (Fig. 6). High pH value and low dry matter ratio indicate a low Fleig score and thus poor quality of silage. In general, silage sample of cereals included satisfactory or good quality levels except Karma, which had high pH value and low dry matter. In such cases, İptaş and Avcıoğlu (1995) pointed out, adding salt to the silage samples of cereals can increase the fleig score.

The effect of pre-applications on the ADF ratio was insignificant and Checato indicated also high ADF ratios in all pre-applications (Table 6, Fig. 7). These findings showed similarities with Karabulut and Çaçan (2018) and Çaçan and Kökten (2019) about ADF ratios of barley, wheat, and triticale.

V. pannonica application increased NDF rate in silage (Table 6). The highest and lowest NDF ratios were determined in Checato and Karma, respectively. It is very difficult to explain of variation in NDF ratios of İnce according to pre-applications (Fig. 8). Checato had higher values in all pre-applications as in ADF ratios except for Control 2. In contrast to these findings, NDF rates were found to be higher in triticale and barley by Göçmen and Özaslan Parlak (2017). Çaçan and Kökten (2019) reported that NDF ratios in different cereal species varied between 55 and 59.0% in similar findings.

The common fertilization application (Control 2) in the region provided the highest increase in crude protein ratio (Table 6). Also, control 2 in İnce, Müfitbey and Karma had higher crude protein ratios that was not statistically significant in each other (Fig. 9). Researches conducted on different cereals and regions resulted in vary crude protein ratios. In contrast to these findings, Göçmen and Özaslan Parlak (2017) determined the crude protein ratio as 7.34% in triticale and 7.29% in barley. On the other hand, Kalkan (2019) reported that the highest crude protein ratios in silage maize was obtained from following narbon vetch applying 20 kg/da of nitrogen top fertilizer.

Consequently, *P. arvense-H. vulgare* mixture and *V. pannonica* grown in fallow year provided significant increases in forage and grain yields of cereals. The fresh weight was two-fold higher in *P. arvense-H. vulgare* mixture compared to *V. pannonica*. The positive effect of forage legumes on cereal yields from the first year can be related to the medium level of soil organic matter. In this study, silage quality was found to be low depending on the fleig score of triticale and it was concluded that delaying the mowing time could increase the quality. ADF and NDF ratios of oats were high, which means oat silage is more difficult to digest by livestocks. Top-dressing of nitrogen fertilization in the spring had a positive effect on the crude protein ratio. In sum, annual roughage production can be increased by grown a *P. arvense-H. vulgare* mixture instead of fallow and subsequently oats, wheat or triticale in fields with medium level of soil organic matter in arid conditions. In addition, 2-3 kg/da of top-dressing nitrogen application will positively affect grain quality of cereals.

Acknowledgements

This article was produced from the graduate thesis of Musa Saylan and this study was supported by the Eskişehir Osmangazi University BAP commission within the project numbered 202023A117.

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