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Effect of Different Ratios of Hungarian Vetch with Cereal Crop Mixtures on Hay Nutrient Value

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Abstract: This study was conducted in order to determine the changes in digestibility and energy values of hay depending on the application of Hungarian vetch-cereal crop mixtures at different ratios. The research was carried out in Çanakkale in 2009–2011. The study has been designed according to randomized complete block design, and the plots were arranged as single and mixed (3:1, 2:2, 1:3 Hungarian vetch: cereal) crop sowing systems by using three replications with sowing Hungarian vetch mixing with barley, wheat, oats and triticale. Crude cellulose (CC), digestible dry matter (DDM), total digestible nutrients (TDDM), metabolic energy (ME), net energy (NEL) and relative feed value (RFV) like characteristics was examined in this research. As the result of this research, the ratios of hay crude cellulose (CC) were not significantly important in accordance to different forms of sowing, while the values of DDM, TDDM, ME, NEL and RFV in hay were found higher in mixed sowing system than that of single sowing of cereal crops. In the study, it has been concluded that for being able to produce hay containing high nutrient value in the mixtures of Hungarian vetch with cereals then the mixture of wheat with Hungarian vetch with the ratio of 3: 1 would be suitable to sow.

Keywords: Mixtures, forage, Hungarian vetch, barley, oat, wheat, triticale

1. Introdiction

Although rangeland-dependent livestock raising is common in Turkey, rangeland herbage and forage crops grown over agricultural fields are far away from meeting roughage needs of the livestock. Therefore, majority of roughage needs is met by low-quality (hay, straw, husk and etc.) feed sources (Gökkuş, 1994). However, high-quality feeds should be used for a productive and profitable livestock operation (Gökkuş and Koç, 1996). Such a case can only be overcome through increasing both the forage crops-cultivated lands and the yields from these fields. Intercropping potentially increase yield and quality is feed crops. Intercropping is defined as the cultivation of two or more crops within the same growth season over the same field under the same natural conditions (Li, 1999; Zhang and Li, 2003; Hauggaard–Nielsen, 2006). Since fertilizers are not used in intercropping systems, productions are cheaper and environment-friendly (Bakoğlu, 2004). Vetch-cereal intercropping systems are usually sown in winter either as main or second crop. Such intercropping systems prevent lodging of vetch with weak stems, thus prevent quality losses. Therefore, vetch species are commonly intercropped with cool-season cereals (Bakoğlu and Memiş, 2002). There are several advantages of intercropping systems over sole sowings. Intercropping systems may provide a steady nutrient cycle in soils and a better pests, disease and weed control (Ramartet et al., 2002; Szumigalski and Rene, 2005). Legumes-Graminae intercropping systems are the most common intercropping systems. In these systems, legumes meet majority of the nitrogen requirement of both own and the graminae species through *Rhizobium* bacteria in their roots (Hiebsch and McCollum, 1987; Berg, 1990). Since legumes have a

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tap root system, they facilitate soil water intake and regulate soil physical structure (Rao et al., 1998). Graminae species usually have lower protein contents than the legume species (Yıldırım and Özaslan Parlak 2017). To overcome such deficiency in animal feeding, Graminae species are generally intercropped with legumes to increase protein content of roughage instead of using additional protein supplements (Robinson, 1969; Caballero et al., 1995;). In this study, Hungarian vetch was intercropped with cereals (wheat, barley, oat, triticale) at different ratios and nutritive values of resultant herbage were investigated.

2. Material and Method

Field experiments were conducted over the experimental fields of Canakkale Onsekiz Mart University (ÇOMU) Dardanos Campus in 2009/10 and 2010/11 growing seasons. Monthly average temperatures of the experimental site in 2009 and 2010 (15.9 and 16.4ºC) were greater and monthly average temperature of the year 2011 (13,8ºC) was lower than the long-term monthly average temperature (15.5ºC). The years 2009 and 2010 had greater precipitations (685.6 and 933.6 mm) and 2011 had less precipitation (548.6 mm) than the long-term average (559.1 mm). Experimental soils have clay-loam texture with moderate lime, insufficient nitrogen and phosphorus and sufficient potassium levels. Soils were poor in organic matter. "Anadolu pembesi" cultivar of Hungarian vetch (*Vicia pannonica*), "Agile" cultivar of barley (*Hordeum vulgare*), "Renan" cultivar of wheat (*Triticum aestivum*), "Servante" cultivar of oat (*Avena sativa*) and "Mikham-2002" cultivar of triticale (*Triticosecale* Wittm. *triticale*) were used as the plant material of the experiments. Sowing was performed in November of both years. Experimental materials (Hungarian vetch, barley, wheat, oat and triticale) were both sole-sown and intercropped with Hungarian vetch at different ratios. In intercropping systems, 1, 2 and 3 mixture ratios were used.

Experiments were conducted in randomized blocks design with 3 replications. Means were compared with Duncan's multiple comparison test (Düzgüneş et al., 1987). SAS statistical software was used for statistical analyses. Each block is composed of 17 plots and 2 m spacing was provided between the plots. Each plot had 5 rows 20 cm apart. Plot size was 1 m x 6 m = 6 m^2, thus total site size was 750 m^2. Sole alive seed (PAS) quantity to be sown was calculated by using mixture ratio (%), number of alive seed per square meter in mixture, thousand-seed weight (g), purity and germination ratio (%) (Altın et al., 2005).

The cell membrane components (hemicellulose, cellulose and lignin), NDF (neutral detergent fiber), ADF (acid detergent fiber) and ADL (acid detergent lignin) were determined in accordance with the methods specified by Van Soest et al. (1991). Digestible dry matter (DDM) and metabolic energy (ME) were calculated by using the equations given by Adams (1994), crude cellulose and total digestible nutrient were calculated by using the equations given by Anonymous, (2015) and net energy lactation was calculated by using the equations given by Yılmaz et al. (2015).

DDM (%) = 102.45-1.114 % ADF
ME (Kcal/kg KM) = 3704-40.27 % ADF
CC (%) = 0.75 % ADF + 3.56
TDDM (%) = 81.38 + 0.36 % CP-0.77 % ADF
NEL (Mcal/Kg KM) = ((1.044-(0.0119) × % ADF))*2.205

3. Results

Crude Cellulose

Crude cellulose (CC) is a structural carbohydrate constituting the primary building stone of cell membrane (Taiz and Zeiger, 2007). Cellulose provides resistance for the cells (plants) and digestion of the cellulose is relatively hard. Therefore, it is a significant indicator of feed nutritive values. In present experiments carried out with Hungarian vetch-cool season cereals, average crude cellulose content of the treatments was identified as 31.34%. There were significant differences in herbage CC content of the years (Table 1). The CC content of the first year (28.12%) was lower than the CC content of the second year (34.56%). On the other hand, differences in CC contents of sole sowing and intercropping systems were not found to be significant in both years. Similarly, differences in CC contents of intercropping systems and mixture ratios were not found to be significant. Among the sole sowings, the lowest CC content was obtained from triticale (26.21%) in the first year and from Hungarian vetch (32.37%) in the second year. For intercropping systems, 3Vetch-1Wheat, 2Vetch-2Barley and 1Vetch-3Oat mixtures had lower CC contents than the other mixtures in the first year. In the second year, all mixtures had closer values to each other. As the average of two years, CC contents of Hungarian vetch – barley, wheat, oat and triticale mixtures varied between 31.08 – 31.68%. Similarly, herbage CC contents of 3. 2 and 1 Hungarian vetch ratios were also quite close to each other (31.08%, 31.59% and 31.21%, respectively) (Table 1).

Table 1. Crude cellulose of sole-sown and mixtures of Hungarian vetch with cereals (%)

Mixtures	2009/10	2010/11	Mean
Hungarian vetch	28.10 a-d	32.87 b	30.49
Barley	30.11 ab	33.50 ab	31.81
Wheat	29.90 ab	34.97 a	32.44
Oat	30.16 ab	34.12 ab	32.14
Triticale	26.21 d	34.67 ab	30.44
3Vetch:1Barley	28.15 a-d	34.42 ab	31.29
2Vetch:2Barley	26.00 d	34.99 a	30.50
1Vetch:3Barley	28.21 a-d	35.06 a	31.64
3Vetch:1Wheat	25.39 d	35.32 a	30.36
2Vetch:2Wheat	30.51 a	33.92 ab	32.22
1Vetch:3 Wheat	27.26 bcd	34.09 ab	30.68
3 Vetch:1Oat	26.89 cd	34.87 ab	30.88
2 Vetch:2Oat	29.65 abc	34.95 a	32.30
1 Vetch:3Oat	26.28 d	34.95 a	30.62
3 Vetch:1Triticale	28.19 a-d	35.40 a	31.80
2 Vetch:2Triticale	27.79 a-d	34.89 ab	31.34
1 Vetch:3Triticale	29.23 abc	34.60 ab	31.92
Monoculture Means	28.90	34.03	31.47
Mixture Means	27.80	34.79	31.30
Means	28.12 b	34.56 a	31.34
Mixture type			
Vetch-Barley	27.45	34.82	31.14
Vetch-Wheat	27.72	34.44	31.08
Vetch-Oat	27.61	34.92	31.27
Vetch-Triticale	28.40	34.96	31.68
Hungarian vetch Rate			
3 Hungarian vetch	27.15	35.00	31.08
2 Hungarian vetch	28.49	34.69	31.59
1 Hungarian vetch	27.75	34.67	31.21

P_{year};<0.001, P_{plants}; 0.083, $P_{year*plants}$; 0.001, $P_{vetch\ rate}$; 0.548, $P_{mixtures}$; 0.692, $P_{year*vetch\ rate}$; 0.230, $P_{year*mixtures}$; 0.843

The present plant groups thus had ideal roughage components. Digestible Dry Matter: While the differences in digestible dry matter (DDM) values of the years and year x plant groups were found to be significant, differences in DDM of plant groups, Hungarian vetch mixtures and ratios and vetch ratios were not found to be significant (Table 7). DDM values of the herbage harvested from sole sowing plots varied between 57.16 – 65.38%. The greatest DDM values were obtained from triticale (65.38%) and Hungarian vetch (63.41%) plots in 2010. The lowest DDM values were obtained from wheat (56.28%) and oat (57.16%) plots in 2011. In mixture plots, the lowest DDM value was obtained from 3Vetch-1Triticale (55.83%) plot and the greatest DDM value was obtained from 3Vetch-1Wheat (66.23%) plot. Average DDM value of mixture plots was 60.10%. As the average of the mixtures, the greatest DDM value (60.32%) was obtained from vetch-wheat mixture and the lowest DDM value (59.69%) was obtained from vetch-triticale mixtures. Herbage DDM values varied with the vetch ratio of the mixtures. The greatest value (60.32%) was obtained from 75% vetch ratio and the lowest value (59.79%) was obtained from 50% vetch ratio (Table 2).

Table 2. Digestible dry matter of sole-sown and mixtures of Hungarian vetch with cereals (%)

Mixtures	2009/10	2010/11	Means
Hungarian vetch	63.41 a-d	58.46 a	60.94
Barley	61.32 cd	57.80 ab	59.56
Wheat	61.54 cd	56.28 b	58.91
Oat	61.27 cd	57.16 ab	59.22
Triticale	65.38 a	56.59 ab	60.99
3Vetch:1Barley	63.36 a-d	56.84 ab	60.10
2Vetch:2Barley	65.59 a	56.26 b	60.93
1Vetch:3Barley	63.30 a-d	56.18 b	59.74
3Vetch:1Wheat	66.23 a	55.91 b	61.07
2Vetch:2Wheat	60.90 d	57.37 ab	59.14
1Vetch:3 Wheat	64.28 abc	57.19 ab	60.74
3 Vetch:1Oat	64.67 ab	56.38 b	60.53
2 Vetch:2Oat	61.80 bcd	56.30 b	59.05
1 Vetch:3Oat	65.30 a	56.30 ab	60.80
3 Vetch:1Triticale	63.32 a-d	55.83 b	59.58
2 Vetch:2Triticale	63.74 a-d	56.36 ab	60.05
1 Vetch:3Triticale	62.23 bcd	56.66 ab	59.45
Monoculture Means	62.58	57.26	59.92
Mixture Means	63.73	56.47	60.10
Means	63.39 a	56.70 b	60.05
Mixture type			
Vetch-Barley	64.08	56.43	60.26
Vetch-Wheat	63.81	56.82	60.32
Vetch-Oat	63.92	56.32	60.12
Vetch-Triticale	63.10	56.28	59.69
Hungarian vetch Rate			
3 Hungarian vetch	64.39	56.24	60.32
2 Hungarian vetch	63.01	56.57	59.79
1 Hungarian vetch	63.78	56.58	60.18

P_{year};<0.001, P_{plants}; 0.083, $P_{year*plants}$; 0.001, $P_{vetch\ rate}$; 0.5483, $P_{mixtures}$; 0.102, $P_{year*vetch\ rate}$; 0.894, $P_{year*mixtures}$; 0.179

Total Digestible Nutrients

With regard to total digestible nutrients (TDDN) ratios, while the years, plant groups and year x plant groups were found to be significant, the mixture type, vetch ratio in mixture, year x vetch-cereal mixture and year x vetch ratio were not found to be significant (Table 3). In the first year of the experiments, sole-sown triticale and Hungarian vetch herbage had greater TDDN values than the others. In the second year, sole-sown Hungarian vetch had greater TDDN values than the other sole-sowings and mixtures. In mixtures, while 2Vetch-2Wheat and 2Vetch-2Oat plots had the lowest TDDN values in the first year, the TDDN values of the mixtures were not significantly different in the second year. On the other hand, TDDN values of cereal and vetch ratios in mixtures were close to each other. As the average of two years, TDDN of cereal ratios varied between 55.51 – 56.53% and TDDN of vetch ratios varied between 55.56 – 56.29% (Table 3).

Table 3. Total digestible nutrients of sole-sown and mixtures of Hungarian vetch with cereals (%)

Mixtures	2009/10	2010/11	Means
Hungarian vetch	59.77 a-e	55.88 a	57.83
Barley	58.20 b-e	53.27 b	55.74
Wheat	57.34 cde	51.75 b	54.55
Oat	57.48 cde	52.95 b	55.22
Triticale	61.47 ab	52.08 b	56.78
3Vetch:1Barley	59.42 a-e	53.02 b	56.22
2Vetch:2Barley	62.48 a	52.21 b	57.35
1Vetch:3Barley	59.90 a-e	52.13 b	56.02
3Vetch:1Wheat	62.26 a	52.00 b	57.13
2Vetch:2Wheat	56.34 e	53.33 b	54.84
1Vetch:3 Wheat	60.76 abc	52.81 b	56.79
3 Vetch:1Oat	60.06 a-d	52.40 b	56.23
2 Vetch:2Oat	56.74 de	51.91 b	54.33
1 Vetch:3Oat	60.86 abc	51.89 b	56.38
3 Vetch:1Triticale	59.48 a-e	51.70 b	55.59
2 Vetch:2Triticale	59.47 a-e	51.95 b	55.71
1 Vetch:3Triticale	58.28 b-e	52.17 b	55.23
Monoculture Means	58.85	53.19	56.02
Mixture Means	59.67	52.29	55.98
Means	59.43 a	52.56 b	56.00
Mixture Type			
Vetch-Barley	60.60	52.45	56.53
Vetch-Wheat	59.79	52.71	56.25
Vetch-Oat	59.22	52.07	55.65
Vetch-Triticale	59.07	51.94	55.51
Hungarian vetch Rate			
3 Hungarian vetch	60.30	52.28	56.29
2 Hungarian vetch	58.76	52.35	55.56
1 Hungarian vetch	59.95	52.25	56.10

P_{year};<0.001, P_{plants}; 0.008, $P_{year*plants}$; 0.001, $P_{vetch\ rate}$; 0.344, $P_{mixtures}$; 0.280, $P_{year*vetch\ rate}$; 0.265, $P_{year*mixtures}$; 0.779

Metabolic Energy

As the average of sole-sowings and mixtures, herbage metabolic energy (ME) value of the first year (2.150 Mcal/kg) was significantly greater than the ME of the second year (1.902 Mcal/kg) (Table 4). In sole sowings, triticale and Hungarian vetch had greater ME values than the others in the first year and Hungarian vetch had greater ME values than the others in the second year. In mixtures, 2Vetch-2Wheat and 2Vetch-2Oat mixtures had lower ME values than the others in the first year, but ME values of the mixtures were close to each other in the second year. Significant differences were observed in ME values of cereals in mixtures and Hungarian vetch ratios in mixtures (Table 4).

Table 4. Metabolic energy (ME) of sole-sown and mixtures of Hungarian vetch with cereals (Mcal/kg)

Mixtures	2009/10	2010/11	Means
Hungarian vetch	2.162 a-e	2.022 a	2.092
Barley	2.105 b-e	1.928 b	2.017
Wheat	2.074 cde	1.873 b	1.974
Oat	2.079 cde	1.916 b	1.998
Triticale	2.223 ab	1.884 b	2.054
3Vetch:1Barley	2.150 a-e	1.918 b	2.034
2Vetch:2Barley	2.260 a	1.889 b	2.075
1Vetch:3Barley	2.167 a-e	1.886 b	2.027
3Vetch:1Wheat	2.252 a	1.882 b	2.067
2Vetch:2Wheat	2.038 e	1.930 b	1.984
1Vetch:3 Wheat	2.198 abc	1.911 b	2.055
3 Vetch:1Oat	2.173 a-d	1.896 b	2.035
2 Vetch:2Oat	2.053 de	1.878 b	1.966
1 Vetch:3Oat	2.202 abc	1.878 b	2.040
3 Vetch:1Triticale	2.152 a-e	1.871 b	2.012
2 Vetch:2Triticale	2.151 a-e	1.880 b	2.016
1 Vetch:3Triticale	2.108 b-e	1.888 b	1.998
Monoculture Means	2.129	1.924	2.027
Mixture Means	2.159	1.892	2.026
Means	2.150 a	1.902 b	2.026
Mixture Type			
Vetch-Barley	2.192	1.898	2.045
Vetch-Wheat	2.163	1.907	2.035
Vetch-Oat	2.142	1.884	2.013
Vetch-Triticale	2.137	1.880	2.009
Hungarian vetch Rate			
3 Hungarian vetch	2.181	1.892	2.037
2 Hungarian vetch	2.126	1.894	2.010
1 Hungarian vetch	2.169	1.891	2.030

P_{year};<0.001, P_{plants}; 0.008, $P_{year*plants}$; 0.001, $P_{vetch\ rate}$; 0.367, $P_{mixtures}$; 0.262, $P_{year*vetch\ rate}$; 0.307, $P_{year*mixtures}$; 0.793

Net Energy

With regard to net energy lactation (NE_L), while the years and year x plant group were found to be significant, plant groups, mixture types, year x vetch x cereal mixture, vetch ratios and year x vetch ratio were not found to be significant (Table 5). In sole-sowings, the greatest NE_L values in 2009/10 growing season were obtained from triticale (1.510 Mcal/kg) and Hungarian vetch (1.443 Mcal/kg) plots. On the other hand, in 2010/11 growing season, significant differences were observed only between Hungarian vetch and wheat plots. In mixtures, except for 2Vetch-2Wheat plots (1.359 Mcal/kg), the others has close NE_L values to each other in the first year. The NE_L values of the mixtures were also close to each other in the second year (varied as between 1.188-1.240 Mcal/kg). Hungarian vetch – barley, wheat, oat and triticale mixtures had NEL values of between 1.310–1.339 Mcal/kg, but the differences were not found to be significant. A similar case was also valid for Hungarian vetch ratios of the mixtures (Table 5).

Table 5. Net energy of sole-sown and mixtures of Hungarian vetch with cereals (Mcal/kg).

Mixtures	2009/10	2010/11	Means
Hungarian vetch	1.443 a-d	1.277 a	1.360
Barley	1.373 cd	1.254 ab	1.314
Wheat	1.308 cd	1.204 b	1.256
Oat	1.371 cd	1.233 ab	1.302
Triticale	1.510 a	1.214 ab	1.362
3Vetch:1Barley	1.442 a-d	1.223 ab	1.333
2Vetch:2Barley	1.517 a	1.203 b	1.357
1Vetch:3Barley	1.440 a-d	1.200 b	1.320
3Vetch:1Wheat	1.536 a	1.191 b	1.364
2Vetch:2Wheat	1.359 d	1.240 ab	1.300
1Vetch:3 Wheat	1.473 abc	1.234 ab	1.354
3 Vetch:1Oat	1.486 ab	1.207 ab	1.347
2 Vetch:2Oat	1.389 bcd	1.204 b	1.297
1 Vetch:3Oat	1.507 a	1.204 b	1.356
3 Vetch:1Triticale	1.440 a-d	1.188 b	1.314
2 Vetch:2Triticale	1.455 a-d	1.206 ab	1.331
1 Vetch:3Triticale	1.404 bcd	1.216 ab	1.310
Monoculture Means	1.401	1.236	1.319
Mixture Means	1.453	1.210	1.332
Means	1.443 a	1.217 b	1.330
Mixture Type			
Vetch-Barley	1.464	1.209	1.336
Vetch-Wheat	1.456	1.222	1.339
Vetch-Oat	1.461	1.205	1.333
Vetch-Triticale	1.404	1.216	1.310
Hungarian vetch Rate			
3 Hungarian vetch	1.476	1.202	1.339
2 Hungarian vetch	1.428	1.213	1.321
1 Hungarian vetch	1.456	1.214	1.335

P_{year};<0.001, P_{plants}; 0.082, $P_{year*plants}$; 0.001, $P_{vetch\ rate}$; 0.545, $P_{mixtures}$; 0.693, $P_{year*vetch\ rate}$; 0.232, $P_{year*mixtures}$; 0.843

Relative Feed Value

Significant differences were observed only in relative feed values (RFV) the years (Table 6). As the average of the plant groups, RFV was calculated as 112.2 in the first year and as 97.7 in the second year. In sole-sowings, average RFVs varied between 96.1-122.2 in 2009/10 growing season and between 92.8-105.7 in 2010/11 growing season. In mixtures, RFVs of the first and second year respectively varied between 973.5-124.8 and between 91.9-107.9. As the average of two years, RFVs of the plant groups (102.4-108.9) were quite close to each other. Based on vetch ratio of the mixtures, RFVs varied between 104.0-106.3 (Table 6).

Table 6. Relative feed value of sole-sown and mixtures of Hungarian vetch with cereals.

Mixtures	2009/10	2010/11	Means
Hungarian vetch	117.0 ab	105.7 a	111.4
Barley	110.3 a-d	102.6 a	106.5
Wheat	100.5 bcd	97.1 a	98.8
Oat	96.1 d	100.4 a	98.3
Triticale	122.2 a	92.8 a	107.5
3Vetch:1Barley	119.9 a	106.2 a	113.1
2Vetch:2Barley	124.8 a	92.4 a	108.6
1Vetch:3Barley	111.7 a-d	98.2 a	105.0
3Vetch:1Wheat	115.4 abc	93.0 a	104.2
2Vetch:2Wheat	106.5 a-d	107.9 a	107.2
1Vetch:3 Wheat	113.3 a-d	99.4 a	106.4
3 Vetch:1Oat	117.3 ab	95.3 a	106.3
2 Vetch:2Oat	97.5 cd	92.0 a	94.8
1 Vetch:3Oat	120.0 a	92.0 a	106.0
3 Vetch:1Triticale	110.9 a-d	91.9 a	101.4
2 Vetch:2Triticale	115.6 abc	95.0 a	105.3
1 Vetch:3Triticale	108.2 a-d	98.8 a	103.5
Monoculture Means	109.2	99.7	104.5
Mixture Means	113.4	96.8	105.1
Means	112.2 a	97.7 b	105.0
Mixture Type			
Vetch-Barley	118.8	98.9	108.9
Vetch-Wheat	111.7	100.1	105.9
Vetch-Oat	111.6	93.1	102.4
Vetch-Triticale	111.6	95.2	103.4
Hungarian vetch Rate			
3 Hungarian vetch	115.9	96.6	106.3
2 Hungarian vetch	111.1	96.8	104.0
1 Hungarian vetch	113.8	97.1	105.5

P_{year};<0.001, P_{plants}; 0.149, $P_{year*plants}$; 0.031, $P_{vetch\ rate}$; 0.243, $P_{mixtures}$; 0.750, $P_{year*vetch\ rate}$; 0.700, $P_{year*mixtures}$; 0.646

4. Discussion and Conclusions

Crude cellulose and similar fibrous compounds are quite significant substances for the quality of roughage (Lithourgidis et al., 2006). Increasing ADF and NDF ratios (containing crude cellulose) result in decreased dry matter intake (Van Soest, 1994). Normally legumes have less cell membrane than the graminae (Wilson, 1993). Although graminae species are rich in cellulose, hemicellulose and NDF-like structural substances, they are poor in lignin (Smith et al., 1972). Therefore, lower membrane components were reported for legumes in several previous studies (Barnett and Posler, 1983; Höflich et al., 1990; Pınarcık, 1992; Carr et al., 2004; Ross et al., 2004; Albayrak and Ekiz, 2005; Yisehak, 2008). In present study, Hungarian vetch also had lower cell membrane components than the cereals, but the differences were not significant. Since sole sown Hungarian vetch and mixtures were harvested at green (vegetative) stage, thus, their cell membranes did not develop sufficiently, differences were not found to be significant. Membrane substances increase with the progress of plant growth and development (Cherney and Hall, 2008).

Livestock productions are highly dependent on quantity and quality of roughage consumed by the animals (Ullah, 2010). The quantity of roughage consumed varies with the nutritional values of the roughage. Dry matter intake and total digestible nutrient generally positively influenced by intercropping systems (Cabarello et al., 1995; Ullah, 2010; Sadeghpour et al., 2014). Since herbage cell membrane components decrease with

the incorporation of legumes into mixtures, herbage DDM values increase in mixtures (Büyükburç and Karadağ, 2002; Taş, 2010). However, contradictory findings were also reported by Lithourgidis et al. (2006). In present study, herbage DDM values significantly varied with the mixture formations. There is a negative relationship between DDM and NDF (Horrocks and Vallentine, 1999). Insignificant differences between NDF contents of mixtures and sole sowings were also resulted in insignificant increases in DDM values of mixtures.
Herbage TDDN values were close to each other both in sole-sowings and mixtures. TDDN values of the legumes are generally greater than the graminae species (Roberts et al., 1989; Lithourgidis et al., 2006). Therefore, incorporation of legumes into mixtures is expected to increase TDDN values of the mixtures. However, present cereals did not have different fibrous compounds from the Hungarian vetch herbage, incorporation of vetch into mixtures did not result in a significant increase in TDDN of the herbage. Since legumes have less cell membrane than the graminae, they have greater digestibility (Wilson, 1993). Since mesophyll cells of legumes are also arranged in a looser fashion, digestive bacteria easily enter into the leaf and thus digestion is facilitated (Hanna et al., 1973). With the progress of the ripening, less nutritive value losses are experienced in legumes (Sanderson and Wedin, 1989). There aren't any changes in tissue ratios in legume leaves when they ripened (Wilson, 1993), lignin ratios in cell membranes of the graminae leaves and stems are doubled with the ripening (Buxton, 1990). Although graminae species have greater fibrous sections, they have greater digestibility ratios than the legumes (Buxton and Redfearn, 1996). In general, legumes with lower cell membrane substances have greater nutritive values than the graminae species (Tan and Menteşe, 2003).

Generally increasing herbage ME values were reported for mixtures (Babayemi and Bamikole, 2006; Ajayi and Babayemi, 2008). However, significant differences were not observed in present study between the ME values of sole-sowings and mixtures. As it was stated for DDM and TDDN values, closer fibrous compounds of Hungarian vetch and cereals (barley, wheat, oat, triticale) also resulted in insignificant differences in digestibility and energy values.

Incorporation of legumes into mixtures generally increases NE_L values of the resultant herbage (Sadeghpour et al., 2014; Yılmaz et al., 2015). In present study, NE_L value of Hungarian vetch was also high. However, in general, significant differences were not observed in herbage NE_L values of both sole-sowings and mixtures. Cell protoplasm and membrane components influence herbage energy values. While increasing fibrous membrane components reduce energy values, protoplasm substances increase energy values (Cone et al., 1999; Filya et al., 2002; Blümmel et al., 2003; Aydın et al., 2007; Karabulut et al., 2007; Canbolat and Karaman, 2009; Gürsoy and Mucit, 2014). In present study, insignificant differences in CP, NDF and CC-like nutritive components of the herbage also were resulted in insignificant differences in NE_L values of sole-sowings and mixtures.

Relative feed value is an index value revealing information about herbage quality and digestibility (Horrocks and Vallentine, 1999). Generally, greater RFVs were reported for mixtures than the sole-sowings (Chapko et al., 1991; Aasen et al., 2004; Carr et al., 2004). Legumes generally have greater relative feed values than the graminae species (Lauriault and Kirksey, 2004). However, in present study, significant differences were not observed between RFVs of sole-sowings and mixtures. Insignificant differences in the other herbage quality parameters also resulted in insignificant differences in relative feed values of sole-sowings and mixtures.

In this study, effects of different mixture types and ratios on digestibility and energy values of resultant herbage were investigated. While Hungarian vetch – cereal mixtures had lower crude cellulose contents than the sole-sowings, mixtures had greater digestible dry matter, total digestible nutrient, metabolic energy, net energy lactation and relative feed values than the sole-sowings. Similar changes were also observed with increasing legume ratios in mixtures. It was concluded based on present findings that legumes incorporated into mixtures to be grown to meet the quality roughage needs significantly improved the quality of resultant herbage. For similar intercropping systems, 3Vetch-1Wheat was recommended as the ideal mixture.

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