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The Effects of Solid, Liquid and Combined Cattle Manure Applications on the Yield, Quality and Mineral Contents of Common Vetch and Barley Intercropping Mixture

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Abstract
A field experiment was conducted to evaluate the effects of solid, liquid and the combination of solid and liquid cattle manure applications on the yield, quality and mineral content of common vetch (*Vicia sativa* L.) + barley (*Hordeum vulgare* L.) intercropping mixture in 2006-2007 at Gümüşhane, Turkey. The treatments were control (no manure), two liquid (L_1 = 10 000 L ha^{-1} liquid cattle manure and L_2 = 20 000 L ha^{-1} liquid cattle manure), two solid (S_1 = 20 ton ha^{-1} solid cattle manure, S_2= 40 ton ha^{-1} solid cattle manure) and four different combinations of liquid and solid cattle manure applications (S_1L_1 = 20 ton ha^{-1} solid cattle manure + 10 000 L ha^{-1} liquid cattle manure, S_1L_2 = 20 ton ha^{-1} solid cattle manure + 20 000 L ha^{-1} liquid cattle manure, S_2L_1 = 40 ton ha^{-1} solid cattle manure + 10 000 L ha^{-1} liquid cattle manure, and S_2L_2 = 40 ton ha^{-1} solid cattle manure + 20 000 L ha^{-1} liquid cattle manure). Total forage dry matter yield (TFDMY), crude protein content (CP), crude protein yield (CPY), acid detergent fiber (ADF), neutral detergent fiber (NDF), dry matter intake (DMI), dry digestible matter (DDM), relative feed value (RFV) and mineral contents (Mg, Ca, K, P, Na, Mn, Zn, Fe and Cu) were determined to evaluate the effects of different cattle manure applications on intercropping mixtures. Solid, liquid and the combined cattle manure treatments had no effect on the TFDMY, CPY, ADF, NDF, DMI, DDM, RFV, Mg, Ca, K, Mn and Zn of the intercropping mixture except CP ($p<0.01$), P ($p<0.01$), Na ($p<0.05$), Fe ($p<0.05$) and Cu ($p<0.05$) in the first year. The treatments had significant effects on TFDMY ($p<0.01$), CP ($p<0.01$), ADF ($p<0.05$), NDF ($p<0.01$), DMI ($p<0.01$), DDM ($p<0.05$), RFV ($p<0.01$) and Zn ($p<0.01$) values of the intercropping mixture except CPY, Mg, Ca, K, P, Na, Mn, Fe and Cu in the second year.
The results of the study revealed that the common vetch and barley intercropping mixture can be fertilized with 40 ton ha^{-1} solid cattle manure to improve the yield and quality. But if mineral content of forage is more important than yield and quality for the farmer, then it may be fertilized with 20 ton ha^{-1} solid cattle manure.
Keywords: Common vetch, intercropping mixture, liquid cattle manure, solid cattle manure.

Katı, Sıvı ve Kombine Sığır Gübresi Uygulamalarının Adi fiğ + Arpa Karışımlarında Verim, Kalite ve Mineral İçerikler Üzerine Etkileri

Özet
Bu araştırma 2006 ve 2007 yılında Türkiye'nin Gümüşhane ilinde katı, sıvı ve kombine sığır gübresi uygulamalarının adi fiğ + arpa karışımında verim, kalite ve mineral içerikler üzerine etkilerini değerlendirmek için tesis edilmiştir. Araştırma kontrol (gübresiz), iki sıvı (L_1= 10 000 L ha^{-1} sıvı sığır gübresi ve L_2= 20 000 L ha^{-1} sıvı sığır gübresi), iki katı (S_1= 20 ton ha-1 katı sığır gübresi, S_2= 40 ton ha^{-1} katı sığır gübresi) ve dört kombine sığır gübresi uygulamalarından (S_1L_1= 20 ton ha^{-1} katı sığır gübresi + 10 000 L ha^{-1} sıvı sığır gübresi, S_1L_2= 20 ton ha-1 katı sığır gübresi + 20 000 L ha^{-1} sıvı sığır gübresi, S_2L_1= 40 ton ha^{-1} katı sığır gübresi + 10 000 L ha^{-1} sıvı sığır gübresi and S_2L_2= 40 ton ha^{-1} katı sığır gübresi + 20 000 L hav sıvı sığır gübresi) meydana gelmiştir. Adi fiğ + arpa karışımında farklı sığır gübresi uygulamalarının etkilerini belirlemek için kuru ot verimi, ham protein içeriği, ham protein verimi,

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asid deterjan fiber, nötr deterjan fiber, kuru madde alımı, kuru hazmedilebilir madde, nisbi yem değeri ve mineral içerikleri (Mg, Ca, K, P, Na, Mn, Zn, Fe and Cu) tespit edilmiştir.
Katı , sıvı ve kombine sığır gübresi uygulamalarının, araştırmanın birinci yılında, karışımın ham protein ($p<0.01$), P ($p<0.01$), Na ($p<0.05$), Fe ($p<0.05$) ve Cu ($p<0.05$) içerikleri hariç kuru ot verimi, ham protein verimi, asid deterjan fiber, nötr deterjan fiber, kuru madde alımı, kuru hazmedilebilir madde ve nisbi yem değerleri üzerine etkileri olmamıştır. Araştırmanın ikinci yılında ise uygulamalar, ham protein verimi, Mg, Ca, K, P, Na, Mn, Fe ve Cu içeriği hariç kuru ot verimi ($p<0.01$), ham protein ($p<0.01$), asid deterjan fiber ($p<0.05$), nötr deterjan fiber ($p<0.01$), kuru madde alımı ($p<0.01$), kuru hazmedilebilir madde ($p<0.05$), nisbi yem değeri ($p<0.01$) ve Zn ($p<0.01$) içeriği üzerine önemli etkiye sahip olmuşlardır.
Araştırma sonuçları, adi fiğ + arpa karışımlarının verim ve kalitelerini iyileştirmek amacı ile 40 ton ha^{-1} katı sığır gübresi ile gübrelenebileceğini ortaya koymuştur. Fakat eğer yemin mineral içeriği çiftçiler için verim ve kaliteden daha önemli ise o zaman 20 ton ha^{-1} katı sığır gübresi ile gübrelenebilir.
Anahtar Kelimeler: Adi fiğ, karışım, katı sığır gübresi, sıvı sığır gübresi.

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INTRODUCTION

In recent years, there has been increased interest in agricultural production systems in order to achieve high productivity and promote sustainability over time (Dhima et al. 2007). The intercropping system is one of the many different agricultural production systems used to obtain sustainability and productivity. Intercropping systems, in comparison with monoculture, reduce the amount of soil erosion (Iijima et al. 2004), increases organic matter (Açıkgöz 2001), and contributes to the N requirements of plants (Holt 1983, Zemenchik et al. 2001, Fan et al. 2006). Intercropping decreases weed ratio, plant pathogens, harm insect populations (Akman and Balabanlı 1997), the use of insecticides and herbicides in addition chemical N fertilizers (Koç et al. 2004) caused global warming (Kars and Özdilek 2010) and environmental pollution.

Intercropping is a common cropping system in forage crop production and it has been used in research studies made by Gökkuş et al. (1999), Koç et al. (2004), Ross et al. (2005), Thorsted et al. (2006), Yolcu and Serin (2009) and Yolcu et al. (2009). Intercropping legumes with cereals for forage production is a sustainable technique having several environmental benefits (Lithourgidis et al. 2007a). Therefore, intercropping of legumes with cereals is especially suited for organic forage production areas. Generally, cattle manure instead of chemical fertilizers are used for fertilizing in organic production areas. Manure is good source of plant nutrients (Mkhabela 2006) and improves the chemical, physical and biological characteristics of the soil. It increases growth and nodulation of forage legumes (Sidiras et al. 1999), earthworm biomass and the predatory capacity of the forage grass area (Raworth et al. 2004).

Effects of different chemical fertilizers in the intercropping system have been evaluated in many studies made by Altın (1987), Çomaklı et al. (1998), Karaca and Çimrin (2002), Yolcu and Turan (2008) and Yolcu and Serin (2009), Kara and Özdilek (2010) in Turkey, but there is not much study evaluating the effects of solid, liquid and the combination of solid and liquid cattle manure applications in intercropping mixture.

Therefore, the objective of the study was to investigate the effects of solid, liquid and the combination of solid and liquid cattle manure applications on yield, quality and mineral contents of the intercropping mixture of common vetch (*Vicia sativa* L.) and barley (*Hordeum vulgare* L.) under field conditions.

MATERIALS AND METHODS

This study was carried out at the research farm of Kelkit Aydın Doğan Vocational Training School of Gümüşhane University, at an elevation of 1400 m under irrigated conditions in 2006 and 2007. The research area is located within the north eastern region (40° 08' N, 39° 25' E) of Turkey.

Common vetch (*Vicia sativa* L.) + barley (*Hordeum vulgare* L.) intercropping mixtures were planted in cross seeding patterns in the springs of 2006 and 2007. The experiment was designed in a factorial arrangement of randomized complete block design with three replications. The size of each plot was 3.0 m long by 1.68 m wide, with 24 cm row spacing.

The average temperatures in the growing season (April-July) were 15.4 and 15.6°C, in 2006 and

Table 1. Climatic data of the research location in 2006 and 2007 and the long-term average (1975-2006) at Kelkit, Turkey.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep	Oct.	Nov.	Dec.	Total/Mean
Years	Total Precipitation (mm) (Montly) * Numbers of mean rainy and snowy day **												
2006*	30.8	45.1	77.3	108.3	85.4	24.2	20.4	0.7	23.5	70.9	87.4	12.8	586.8
2007*	53.0	25.3	52.0	35.1	40.7	32.2	1.1	31.4	1.2	54.3	98.6	69.0	493.9
1975-2006**	11.4	11.5	13.3	13.7	15.9	10.5	4.4	3.8	5.5	9.6	10.1	11.9	10.1
Mean air temperature (°C) (Monthly)													
2006	-3.1	0.6	5.8	9.7	13.6	19.4	18.7	24.2	16.2	12.3	3.9	-2.5	9.9
2007	-1.9	-0.2	3.6	5.4	17.3	18.2	21.6	21.6	18.6	12.9	3.7	-0.8	10.0
1975-2006	-1.8	-0.9	3.2	9.5	13.4	16.9	20.1	19.9	16.5	11.2	4.9	0.4	9.4
Mean relative humidity (%) (Monthly)* Period of mean bringing light (hours)**													
2006*	72.6	70.5	66.7	69.6	69.3	67.2	72.8	58.0	69.2	73.8	72.7	70.7	69.4
2007*	69.5	66.1	69.6	68.2	59.0	65.8	57.6	64.6	60.1	69.2	74.3	77.4	66.8
1975-2006**	1.3	3.7	5.1	6.2	7.4	9.3	10.1	10.0	8.1	5.6	2.1	0.8	5.8

Table 2. Physical and chemical soil characteristics of the research location at Kelkit, Turkey.

Soil Depth (cm)	Texture class	pH	Lime ($CaCO_3$%)	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	O.M. (%)
0–30	Clay-Loamy	7.54	17.25	70.0	386	2.03
30–60	Clay-Loamy	7.62	15.52	61.7	491	1.51
60–90	Clay-Loamy	7.70	15.18	09.2	456	1.45
Mean	Clay-Loamy	7.62	15.98	47.0	444	1.66

Table 3. Treatments for different levels of solid, liquid and the combination of solid and liquid cattle manure.

Treatments	
Control	no manure
L_1	10 000 L ha^{-1} liquid cattle manure
L_2	20 000 L ha^{-1} liquid cattle manure
S_1	20 ton ha^{-1} solid cattle manure
S_2	40 ton ha^{-1} solid cattle manure
S_1L_1	20 ton ha^{-1} solid cattle manure + 10 000 L ha^{-1} liquid cattle manure
S_1L_2	20 ton ha^{-1} solid cattle manure + 20 000 L ha^{-1} liquid cattle manure
S_2L_1	40 ton ha^{-1} solid cattle manure + 10 000 L ha^{-1} liquid cattle manure
S_2L_2	40 ton ha^{-1} solid cattle manure + 20 000 L ha^{-1} liquid cattle manure

2007, respectively. These average temperatures were higher than the long-term mean (15ºC, 1975-2006). The mean relative humidity in the same period was 69.7 and 62.7% in 2006 and 2007, respectively. The growing period in 2007 was drier than that of 2006 (Table 1). Total precipitation was 238.3 and 109.1 mm in the same periods in 2006 and 2007, respectively. There were 2 and 7 days with frost in April in 2006 and 2007, respectively.

The soils in the study area were loamy clay, slightly alkaline (pH=7.62), poor-middle level in organic matter (1.66%), middle in available P (47.0 P_2O_5 ha^{-1}) and rich in K content (444.0 K_2O ha^{-1}) (Table 2). The second year of this study was established at another part of the same field which has similar properties.

Plots were fertilized with different levels of solid, liquid and the combination of solid and liquid cattle manure as shown in Table 3 in the spring of each year. Solid cattle manure before seeding and cattle manure after seeding was applied in the plots. The properties of used solid and liquid cattle manure are given in Table 4. The plots were irrigated two times at 15 days intervals after precipitations in a year (Serin and Tan 2001) for reaching field capacity.

The common vetch and barley mixture was harvested in the milk stage of barley (Tan and Serin 1996). The intercropping mixture (common vetch + barley) samples were harvested from 1 m^2 areas from each plot. Forage species of the intercropping mixture were separated as common vetch (called as common vetch I) and barley (called as barley I).

Table 4. Some properties of solid (S) and liquid (L) cattle manures used in research (2006-2007).

Manure	pH	Moisture	Dry Matter	O. M.	N	P	K	Ca	Mg	Na	Fe	Zn
		%			ppm							
2006 (S)	7.5	84.2	15.8	24.8	3100	2000	1400	2900	988	680	438	580
2006 (L)	6.7	-	-	-	5800	800	4900	100	87	65	42	44
2007 (S)	7.5	84.8	15.2	25.6	3200	1800	900	3300	985	680	415	545
2007 (L)	6.8	-	-	-	6000	1200	4200	200	88	68	36	30
Mean (S)	7.5	84.5	15.5	25.2	3150	1900	1150	3100	987	680	427	563
Mean (L)	6.8	-	-	-	5900	1000	4550	150	88	67	39	37

Common vetch (I) and barley (I) samples were oven-dried at 68ºC for 48 h, and ground to pass through a 1 mm sieve.

The nitrogen content of the common vetch (I) and barley (I) were determined according to the Kjeldahl method (Bremner 1996) with a Vapodest 10 Rapid Kjeldahl Distillation Unit (Gerhardt, Konigswinter, Germany). Crude protein contents of the common vetch (I) and barley (I) were calculated by multiplying the N contents by a coefficient of 6.25 (Frank 1975). ADF and NDF contents of the common vetch (I) and barley (I) were determined according to Van Soest (1963). Dry digestible matter, dry matter intake and relative feed value of the common vetch (I) and barley (I) were calculated according to equations adapted from common formulas for forages issued by Schroeder (1994):

DDM % = 88.9-(0.779 * ADF %), DMI %= 120 / NDF %

RFV=(DDM % * DMI %)/1.29

The P contents of the common vetch (I) and barley (I) were determined after wet digestion using a H_2SO_4-$HClO_4$ acid mixture (4:1 v/v) (Anonymous 2005). The phosphorus contents of the common vetch (I) and barley (I) in the extraction solution were measured spectrophotometrically using the indophenol-blue and ascorbic acid method (Anonymous 2005) and an Aqumat UV/VIS spectrophotometer (Thermo Electron Spectroscopy LTD, Cambridge, UK). The K, Ca, Mg, Fe, Mn, Zn and the Cu contents of the common vetch (I) and barley (I) were determined after wet digestion using a H_2SO_4-$HClO_4$ acid mixture (4:1 v/v) and a Perkin-Elmer 360 atomic absorption spectrophotometer (Perkin-Elmer, Waltham, Massachusetts, USA) (Anonymous 2005). The CP, CPY, ADF, NDF, DMI, DDM, RFV, P, K, Ca, Mg, Na, Fe, Mn, Zn and Cu contents of the common vetch + barley intercropping mixture was calculated as weighted means considering the botanical composition. Data was statistically evaluated using the JMP procedure (Anonymous 2002) and mean separations were compared with the LSD test method.

RESULTS AND DISCUSSION

Since the effects by year are important for all parameters evaluated, the results are presented by year. The total forage dry matter yield, CPY, NDF, DDM, P and Na values were higher in the second year, and CP, ADF, DMI, RFV, Mg, Ca, Zn and Fe values were higher in the first year for the intercropping mixture.

The differences between years probably resulted from the different total precipitations in the growing periods and different frost days that occured in April which caused a lowering in the common vetch seedlings ratio. Therefore, the common vetch (I) in the total forage yield was also lower in 2007 than that obtained in 2006 (Figure 1).

Total forage dry matter yield, crude protein content and crude protein yield

Manure application in all forms had no significant effects on total forage dry matter yields in the first year, but there were significant differences among the treatments in total forage dry matter yield of the second year (Table 5). Total forage dry matter yields in S_2L_2 (3060.30 kg ha^{-1}) and S_2L_1 (2692.83 kg ha^{-1}) were higher than the other treatments in the second year. Control, S_1 and S_2 treatments yielded 2066.43, 2453.70, 2666.13 kg ha^{-1} total forage dry matter, respectively. Liquid cattle manure application did not increase the total forage dry matter yields of the intercropping mixture as compared to the control, but solid and combined cattle manure applications increased total forage dry matter yields of the intercropping mixture. Lanyasunya et al. (2007) and Yolcu (2008) also reported that solid cattle manure applications increased yields. Dry matter yields of common vetches (I) and barleys (I) were not significantly different in both study years.

Table 5. Effects of solid, liquid and combination of solid and liquid cattle manure applications on the total forage dry matter yield and quality parameters of the intercropping mixture.

	TFDMY (kg/ha)	CP (%)	CPY (kg/ha)	ADF (%)	NDF (%)	DMI (%)	DDM (%)	RFV
2006								
Control	1652.33	13.95B	230.50	30.26	50.57	2.39	65.32	121.65
L_1	1849.33	14.02B	259.28	32.77	46.42	2.69	63.37	132.92
L_2	1895.00	13.10BC	248.25	34.36	47.56	2.57	62.13	124.57
S_1	1849.33	11.69D	216.19	34.15	51.19	2.36	62.29	114.29
S_2	1928.03	13.94B	268.77	33.20	47.77	2.61	63.04	128.01
S_1L_1	2106.00	12.16CD	256.09	33.71	48.22	2.55	62.64	124.23
S_1L_2	1950.66	15.69A	306.06	35.11	50.36	2.41	61.55	115.51
S_2L_1	1783.60	13.62B	242.93	31.16	47.81	2.62	64.62	132.87
S_2L_2	2149.33	11.70D	251.47	33.61	49.65	2.45	62.72	119.48
Mean	1907.07B	13.32A	253.28B	33.15a	48.84b	2.52a	63.08b	123.73a
Lsd		1.17**						
2007								
Control	2066.43C	11.43CD	235.96	29.34c	56.21A	2.14D	66.04a	109.57CD
L_1	1883.80C	13.43B	251.58	34.45a	55.86AB	2.15CD	62.06c	103.80E
L_2	1756.57C	14.19B	250.94	30.97bc	54.71ABC	2.20CD	64.78ab	110.66CD
S_1	2453.70B	12.28C	300.84	34.41a	54.64ABC	2.21CD	62.09c	106.26DE
S_2	2666.13B	15.31A	409.29	32.59ab	47.06E	2.55A	63.51bc	125.56A
S_1L_1	2602.20B	10.68D	279.27	30.11bc	54.01BCD	2.22BCD	65.45ab	112.83BC
S_1L_2	2618.70B	14.27B	375.31	29.96bc	52.24D	2.30B	65.56ab	117.17B
S_2L_1	2692.83AB	10.58D	288.17	31.85abc	54.49ABC	2.21BCD	64.09abc	109.93CD
S_2L_2	3060.30A	11.21D	342.86	31.15bc	53.82CD	2.24BC	64.64ab	112.46BC
Mean	2422.29A	12.60B	303.80A	31.65b	53.67a	2.25b	64.25a	112.03b
Lsd	385.96**	0.97**		2.90*	2.03**	0.09**	2.26*	5.69**
LsdYear	124.19**	0.35**	39.17**	1.12*	1.50**	0.09**	0.87*	5.07*
LsdM x Y	372.58**	1.04**						

*Significant at 5% level. **significant at 1% level; Values followed by small and capital in a column shows significantly differences at $p< 0.05$ and $p< 0.01$ levels. Respectively

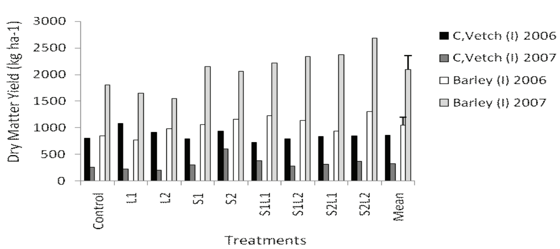

Fig 1. The effects of years on the total forage dry matter yields of Common vetch (I) and Barley (I).

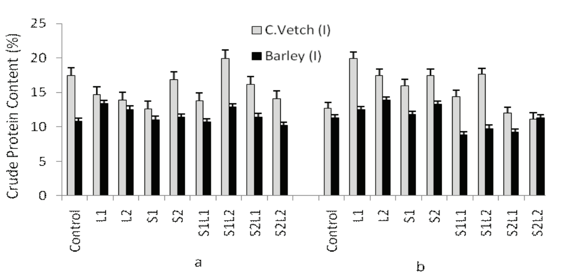

Fig 2. The effects of cattle manure applications on the crude protein content of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd (0.01)=1.13. 0.91 for common vetch; 0.52. 0.49 for barley in study years. respectively).

The manure applications significantly ($p<0.01$) affected the crude protein content of the intercropping mixture (Table 5). The highest crude protein contents was obtained in the S_1L_2 treatment (15.69%) in the first year and in the S_2 treatment (15.31%) in the second year for the intercropping mixture. In the first year of study, both solid and liquid cattle manure applications did not increase the crude protein content of the intercropping mixture (Table 5). The liquid manure application in the second year had significant affect on the crude protein contents of the intercropping mixture. Since precipitation was almost half of the first year amount in the second year, liquid manure might serve both as a nutrient source and water to the mixture in the second year. This result in the second year water holding property of solid cattle manure application might have arised from better showing in less precipitation conditions. Control, L_1, L_2 applications resulted in the occurrence of 11.43, 13.43 and 14.19% crude protein in the second year. Others also reported that liquid manure applications increased N recovery of oat (Zhang et al. 2006), plant N concentration of corn (Evans et al. 1977;

Lithourgidis et al. 2007b) and crude protein of grass (Blonski et al. 2004). Solid cattle manure applications increased the crude protein content compared to the control in the second year. This result in the second year water holding property of solid cattle manure application might have arised from better showing in less precipitation conditions. Control, S_1 and S_2 treatment plots yielded 11.43, 12.28, 15.31% crude protein contents of the intercropping mixture (Table 5) in the second year. Similarly, increases were reported in N levels of corn with solid beef manure application by Evans et al. (1977) and in crude protein of tall wheat grass with composted dairy manure application by Butler and Muir (2006). However, Yolcu (2008) determined that solid cattle manure application did not affect the crude protein content of wheat and barley. The combined cattle manure applications except S_1L_2 decreased crude protein content of intercropping mixture in each year. The solid, liquid and the combined cattle manure applications affected the crude protein contents of common vetch (I) and barley (I) (Figure 2).

Solid, liquid and the combined cattle manure applications had no significant affects on the crude protein yield of the intercropping mixture (Table 5), common vetch (I) and barley (I) in both the study years.

Acid detergent fiber, neutral detergent fiber, dry mattter intake, dry digestible matter and relative feed value

Solid, liquid and the combined cattle manure applications had no effect on the ADF and NDF of the intercropping mixture in the first year. Others also reported the effectiveness of solid cattle manure in ADF and NDF (Yolcu 2008), dairy slurry application in ADF and NDF (Min et al. 2002), broiler litter application in NDF (Sleugh et al. 2006) and dairy compost application in ADF (Muir 2002). In the second year, cattle manure applications affected the ADF ($p<0.05$) and NDF ($p<0.01$) contents of the intercropping mixture.

The lowest ADF content was 29.34% in the control plots and the L1 (34.45%) and S1 (34.41%) treatments caused higher ADF contents than the other treatments for intercropping mixture in the second year (Table 5). All cattle manure applications yielded higher ADF contents than those of the control. Also in one other study, low, middle and high levels of swine lagoon effluent applications had higher ADF contents than those of the control in bermuda grass (Adeli et al. 2005). The NDF contents of the intercropping mixture decreased by the solid, liquid and combined cattle manure applications in the second year. Adeli et al. (2005) also reported that the medium and high levels of swine lagoon effluent application except low level decreased the NDF content of johnson grass and bermuda grass. Control, L_1 and L_2 applications yielded 56.21, 55.86 and 54.71% NDF contents, respectively (Table 5). S_1 and S_2 applications caused 54.64 and 47.06% NDF contents. S_1L_1, S_1L_2, S_2L_1 and S_2L_2 combined manure applications caused 54.01, 52.24, 54.49 and 53.82% NDF contents, respectively. The manure applications had no significant effect on the ADF and NDF contents of common vetch (I) and barley (I) in the first year, while the differences in ADF (Figure 3) and NDF were significant (Figure 4) in the second year of the experiment.

Solid, liquid and the combined cattle manure applications had no effect on DMI, DDM and RFV of the intercropping mixture in the first year. Cattle manure applications significantly affected the DMI ($p<0.01$), DDM ($p<0.05$) and RFV ($p<0.01$) contents of the intercropping mixture in the second year.

The cattle manure applications resulted in higher dry matter intake than those of the control of the intercropping mixture in the second year. The highest dry matter intake content was obtained in the S_2 treatment plots (2.55%) (Table 5). Digestible dry matter values were significantly ($p<0.05$) affected by manure applications. Pholsen et al. (2005) stated that cattle manure applications affected the dry matter degradability of signal grass. The highest DDM was in the control plots (66.04%) (Table 5). The other treatments decreased the DDM content of the intercropping mixture compared to the control. The lowest RFV was determined in the L1 treatment plots (103.80) and the highest RFV value was obtained in the S_2 treatment plot (125.56) of the intercropping mixture in the second year (Table 5).

Solid, liquid and the combined cattle manure applications had no effect in DMI, DDM and the RFV of the common vetch (I) and barley (I) in the first year, but there were differences in DMI (Figure 5), DDM (Figure 6) and RFV (Figure 7) in the second year.

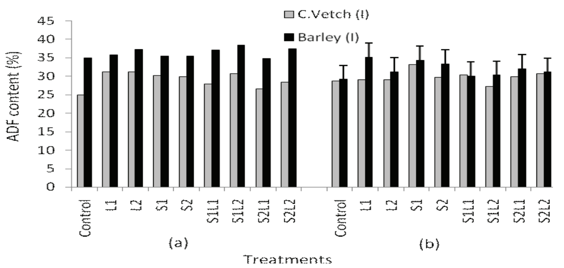

Fig 3. The effects of cattle manure applications on the ADF content of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd= 3,78 for barley in 2007).

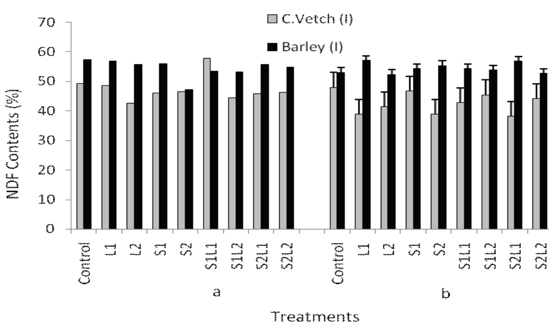

Fig 4. The effects of cattle manure applications on the NDF content of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd (0.01)=5.05 for common vetch; 1.52 for barley in 2007).

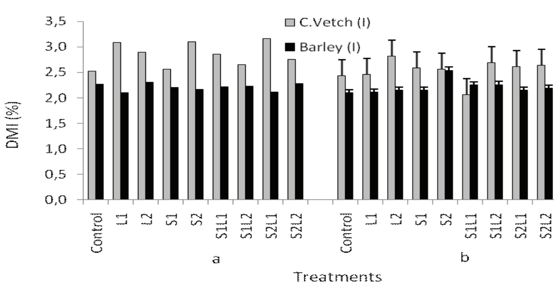

Fig 5. The effects of cattle manure applications on the DMI values of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd(0.01)=0.31 for common vetch; 0.06 for barley in 2007).

Mineral Contents

The solid, liquid and combined cattle manure applications had no effect on the Mg contents of the intercropping mixture in both years (Table 6). Yolcu (2008) also pointed that solid cattle manure applications had no effect on the Mg of cereals. However Singh and Dahiya (1980) reported that farmyard manure application decreased Mg concentration of oat and Walker and Bernal (2008) noted that poultry manure increased the Mg concentrations in *beta maritime* and *beta vulgaris*.

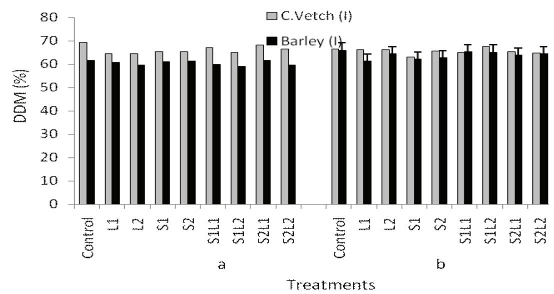

Fig 6. The effects of cattle manure applications on the DDM values of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd (0.05)=2.94 for barley in 2007).

The calcium content of the intercropping mixture was not affected by different cattle manure applications (Table 6). Yolcu (2008) also reported that solid cattle manure applications had no effect on Ca in cereals, but Walker and Bernal (2008) noted that application of poultry manure increased Ca concentrations in *beta maritime* and *beta vulgaris*. The potassium content of the intercropping mixture in cattle manure applications was not significantly different (Table 6). In other studies, it was reported that manure had no effect on the K of the maize shoot in 2002 (Iqbal et al. 2007) and of cereals (Yolcu 2008). However the linear relationship between forage K content and dairy manure compost application was reported by Butler and Muir (2006).

The phosphorus (P) content of the intercropping mixture was significantly affected ($p<0.01$) by the different cattle manure applications in the first year. The highest P content were obtained with the S_1 application in the intercropping mixture, and there was no significant difference between S_1 (2922 mg kg^{-1}), control (2789 mg kg^{-1}), S_2L_2 (2669 mg kg^{-1}) and L_2 (2584 mg kg^{-1}) treatments (Table 6). Other studies noted that the manure application increased plant P concentration and P uptake in corn (Lithourgidis et al. 2007b) and P uptake and percentage of recovery in oat (Zhang et al. 2006).

Different cattle manure applications significantly affected ($p<0.05$) the Na content of the intercropping mixture in the first year, however it was not affected in the second year. Walker and Bernal (2008) pointed that application of poultry manure had no effect on the Na in *beta maritime* and *beta*

Table 6. Effects of solid, liquid and combination of solid and liquid cattle manure applications on mineral contents of the intercropping mixture.

	2006 (mg kg^{-1})								
	Mg	Ca	K	P	Na	Mn	Zn	Fe	Cu
Control	2175	6844	11903	2789AB	1395ab	114	739	569bcd	168ab
L_1	2106	6561	11506	2483BCD	1242bcd	98	441	388d	204a
L_2	2147	5973	11977	2584ABCD	1292abcd	126	514	457cd	174ab
S_1	2203	6993	11167	2922A	1456a	167	334	778ab	185ab
S_2	2208	6268	10782	2291CD	1146cd	151	589	662abc	229a
S_1L_1	2157	6827	10753	2452BCD	1228bcd	150	111	646abcd	218a
S_1L_2	2121	6290	11534	2501BCD	1251bcd	117	597	662abc	218a
S_2L_1	2127	5964	12589	2261D	1131d	114	229	838a	128b
S_2L_2	2244	6404	11417	2669ABC	1335abc	164	160	692abc	142b
Mean	2165a	6456a	11514	2550b	1275b	133	413a	633a	185
LSD				393.17*	196*			267.74*	61.44*
	2007 (mg kg^{-1})								
Control	1911	4828	11001	3719	1859	131	224AB	473	278
L_1	2013	5432	11906	3796	1896	137	195ABCD	637	156
L_2	1937	4046	11421	3138	1643	115	188BCD	450	170
S_1	1942	4447	11263	4453	2226	93	213ABC	277	173
S_2	1963	5208	11651	3266	1635	126	108CD	428	191
S_1L_1	1971	4883	11233	3240	1615	116	302A	563	186
S_1L_2	1885	4829	12038	3222	1611	99	124BCD	465	221
S_2L_1	2068	5501	12565	3125	1562	114	103D	375	175
S_2L_2	1915	4499	11737	3026	1513	119	136BCD	297	212
Mean	1956b	4853b	17290	3443a	1729a	177	1779b	441b	3442.72
LSD	1911						110.11		
LSDYear	2013	391.60**		333.77**	168**		139.53**	85.83**	
LSDM x Y								257.48**	

*Significant at 5% level. **significant at 1% level; Values followed by small and capital in a column shows significantly differences at p< 0.05 and p< 0.01 levels, respectively.

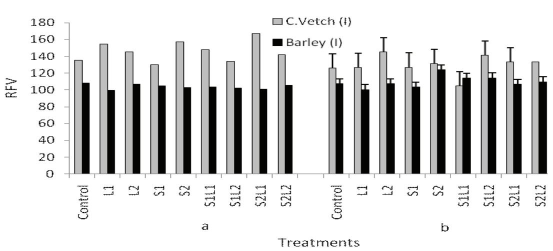

Fig 7. The effects of cattle manure applications on the RFV values of common vetch (I) and barley (I) in 2006 (a) and 2007 (b). (lsd=17.03 for common vetch (0.01); 5.75 for barley (0.05) in 2007).

vulgaris. The highest Na contents was gained from S_1, and there were no significant differences between the S_1 (1456 mg kg^{-1}), control (1395 mg kg^{-1}), S_2L_2 (1335 mg kg^{-1}) and L_2 (1292 mg kg^{-1}) treatments in the intercropping mixture (Table 6). There were no important differences in terms of Mn content among the different cattle manure applications in the intercropping mixture (Table 6).

The different cattle manure treatments had no effect on the Zn content in the first year, while the differences ($p<0.01$) were significant in the second year. Sleugh et al. (2006) also reported the differences in Zn concentration of sorghum-sudangrass in broiler litter application in each of three years. S_1L_1 (302 mg kg^{-1}), control (224 mg kg^{-1}), S_1 (213 mg kg^{-1}) and L_1 (195 mg kg^{-1}) treatments caused the higher Zn contents than that of other treatments in the intercropping mixture (Table 6). Lipoth and Schoenau (2007) also indicated that long-term repeated applications of manure fertilizer sometimes increased the plant availability of Zn.

Differences ($p<0.05$) were obtained in Fe content of the intercropping mixture in the first year (Table 6). Similarly, the differences in Fe content were found in broiler litter fertility treatments in one year of the three years of the study on sorghum-sudangrass (Sleugh et al. 2006). The highest Fe content was determined in S_2L_1, and there were no significant differences between S_2L_1, S_1, S_2L_2, S_1L_2, S_2 and S_1L_1 treatments in the first year. Solid and combined manure treatments increased the Fe content of the intercropping mixture while the liquid manure treatments decreased. Singh and Dahiya (1980) also reported that farmyard manure application increased Fe concentration up to a definite level and then decreased in oat.

The different cattle manure treatments had a significant effect ($p<0.05$) on the Cu contents in the intercropping mixture in the first year. Similar differences in the Cu content were reported in the broiler litter fertility applications in two years of the three year of study conducted on sorghum-sudangrass (Sleugh et al. 2006). S_2, S_1L_2, S_1L_1 and L_1 cattle manure treatments caused higher Cu contents in the intercropping mixture in the first year as 229, 218, 218 and 204 mg kg^{-1}, respectively. S_2L_1 and S_2L_2 treatments resulted in a small decrease in Cu contents of the intercropping mixture. Most of the other treatments generally increased the Cu contents of the intercropping mixture. Lipoth and Schoenau (2007) also stated that manure is a source of Cu and Zn and repeated manure application sometimes results in an increase in plant availability of Cu.

CONCLUSION

Separating each crop in the intercropping mixture is not a practical method for the farmer. Therefore, results should be evaluated according to the intercropping mixture. The farmers desire to increase yield, quality and mineral contents of forage with cattle manure treatments. High crude protein content, dry matter intake, digestible dry matter and relative feed value, low acid detergent fiber and neutral detergent fiber and rich mineral content under maximum tolerable concentration are important quality indicators in forages.

In our study, the solid and the combined cattle manure treatments significantly increased the total forage dry matter yield in the intercropping mixture. Generally, the crude protein content, NDF, DMI and RFV values were positively affected by the manure treatments. While ADF values of forage in the manure treatments increased, DDM values decreased in the intercropping mixture.

Generally, the results of the experiment indicated that manure treatments have a great importance to improve hay yield, quality and mineral content. Thus, common vetch and barley intercropping mixtures for yield and quality can be fertilized with 40 ton ha^{-1} solid cattle manure (S2 treatment) which had similar properties of the solid cattle manure used in our study. If farmers need forages rich in mineral content, they may fertilize with 20 ton ha^{-1} solid cattle manure (S1 treatment). This study will supply important information about fertilizing with cattle manure to farmers who will start for the first time organic forage crop production on their fields.

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