

THE EFFECT OF SEWAGE SLUDGE APPLICATIONS ON YIELD AND QUALITY OF VETCH + BARLEY MIXTURE*

Seda RAJABI KHIABANI, A. Esen CELEN**

Ege University, Faculty of Agriculture, Dept. of Field Crops, Bornova, Izmir, TURKEY

* This work is part of the PhD thesis

** Corresponding author: esen.celen@ege.edu.tr

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ABSTRACT

This study was conducted in Bornova experimental fields of Department of Field Crops, Faculty of Agriculture, University of Ege, Turkey during 2015 and 2016, in order to determine the effects of treated sewage sludge on yield and quality of vetch + barley mixture. The experimental design was in Randomized Complete Block Design (RCBD) with four replications. In the trial, 10 t ha⁻¹, 20 t ha⁻¹ and 30 t ha⁻¹ treated sewage sludge were used in addition to the control and mineral fertilizer application and some characteristics such as plant height, botanical composition, fresh herbage yield, dry matter rate, dry matter yield, the rates of crude protein and crude ash, the yields of crude protein and crude ash, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) rates were determined. The results showed that plant height, botanical composition, fresh herbage yield and dry matter yield were significantly affected by the applications. In the study which the highest vetch and barley plant height and dry matter yield were obtained with sewage sludge applications of 20 and 30 t ha⁻¹, the highest vetch rate in botanical composition was obtained with control and mineral fertilizer applications. Sewage sludge applications of 10, 20 and 30 t ha⁻¹ gave the highest barley rate in botanical composition. Dry matter rate, crude ash rate and yield, crude protein rate and yield, NDF and ADF rates were not affected by mineral fertilizer and sewage sludge applications. When the results are evaluated in general, according to the soil analysis results and heavy metal amounts from the sewage sludge, it is concluded that 20 or 30 t ha⁻¹ sewage sludge can be used in vetch + barley mixtures.

Keywords: Mineral fertilizer, mixture, quality, sewage sludge, yield

INTRODUCTION

Animals need roughage (60% roughage - 40% concentrate) for their daily diets (Anonymous, 2016). Therefore, livestock sector has to meet a significant part of its quality roughage need from meadow-pasture and forage crop production. Vetch + barley mixtures are one of the most important forage crops grown for this purpose. Asci et al. (2015) reported that in intercropping systems; sowing, cultivar, species used in mixtures and mixture rate may significantly affect the hay yields, quality of the mixture and the interspecies competition in mixtures.

Intensive and uncontrolled use of chemical fertilizers causes pollution of the surface and groundwater. Recently, in many countries, the use of organic fertilizers is preferred against soil, water and environmental pollution caused by the excessive use of chemical fertilizers. This has increased the need and use of organic fertilizers (Rosenberg, 2006).

One of the methods that increase the quality and productivity of agricultural soils in order to increase the forage crops farming is use of organic matter. Considering the scarcity of organic matter in soils (Yalcin et al., 2011), it is known that mixing organic sources into the soil is very important. In addition to good agricultural practices, organic matter is very important in traditional agriculture, too. The benefits of using sewage sludge such as low cost and increased yield are stated by many researchers (Barbeiro et al., 2013; Collivignarelli et al., 2015; Iticescu et al., 2015; Schiopu et al., 2015; Uzun et al., 2011; Sumner, 2000). The aim of this research was to investigate the effect of treated sewage sludge (TSS) on yield and quality of vetch + barley mixture.

MATERIALS and METHODS

Experimental site

The experiment was carried out during 2015-16 and 2016-17 growing seasons at Bornova experimental fields (38°27.236 N, 27°13.576 E) of Agricultural Faculty of

Ege University, Izmir, Turkey. The experimental site is in the Western Anatolia region of Turkey, where the Mediterranean climate prevails with a long-term mean annual temperature of 18.1 °C. Long-term mean annual precipitation is 688.9 mm, representing about most of

rainfalls during the winter and spring (Table 1). Long-term mean annual potential evapotranspiration is 1,570 mm.

Table 1. Average temperature (AT) and total precipitation (TP) of the experimental area at Bornova – İzmir, Turkey

	Long Year Average (1970-2013)		2015		2016		2017	
	AT (°C)	TP (mm)	AT (°C)	TP (mm)	AT (°C)	TP (mm)	AT (°C)	TP (mm)
January	9.0	112.2	8.9	125.1	8.5	161	6.3	237.6
February	9.2	99.7	9.5	101.9	13.6	76.5	10.4	55.6
March	11.8	82.9	11.7	75.6	13.8	103	13.3	72.2
April	16.1	46.4	15.9	46.4	18.9	12.8	16.6	15.7
May	21.0	25.4	20.8	30.9	21.2	28.2	21.7	27
June	26.0	7.5	25.6	9.8	27.7	9.2	26.5	1.8
July	28.3	2.1	28.0	1.8	29.9	1.2	29.8	1.4
Agust	27.9	1.7	27.7	2.6	29.4	3.0	29.4	0.3
September	23.9	19.9	23.7	15.0	25.1	6.4	24.6	0.9
October	19.1	43.2	18.8	45.3	19.2	1.4	18.8	45.7
November	13.8	109.7	14.0	94.8	14	101	13.3	62.1
December	10.5	137.9	10.6	141.1	6.8	15.2	11.8	73.9
Ave.-Total	18.1	688.9	17.9	690.3	19.0	518.6	18.5	594.2

The soil of the experiment area is clay loam, slightly alkaline, low in organic matter, calcareous, high in available Cu, Zn and Mn, low in Fe. Some selected

properties and total heavy metal concentrations in TSS used in the experiment is given in Table 2.

Table 2. Analysis results of the treated sewage sludge used in the experiment

pH		7,18	Na	mg kg ⁻¹	1390,5
EC	µS cm ⁻¹	1945	Fe	mg kg ⁻¹	12754,96
Organic matter	%	51,20	Cu	mg kg ⁻¹	176,5
Organic C	%	29,66	Zn	mg kg ⁻¹	1376,59
Lime	%	5,35	Mn	mg kg ⁻¹	350
N	%	2,99	Ni	mg kg ⁻¹	69,73
P	%	0,2275	Pb	mg kg ⁻¹	17,44
K	%	0,34	Cr	mg kg ⁻¹	112,53
Ca	%	6,36	Cd	mg kg ⁻¹	2,83
Mg	%	2,04	B	mg kg ⁻¹	16,1

Field experiment

Five different applications including the control, mineral fertilizer, TSS sewage sludge 10 t ha⁻¹, 20 t ha⁻¹ and 30 t ha⁻¹ as dry matter were compared in a field trial arranged in the Randomized Complete Block Design with four replications in 2015 and 2016. The plot dimensions were 2 m width and 5 m length and each parcel had 10 rows of 20 cm spacing. The TSS used in the experiment was obtained from the wastewater treatment plant of Metropolitan Region, Izmir city. TSS was added to the soil at the rates of 10 t ha⁻¹, 20 t ha⁻¹ and 30 t ha⁻¹ as dry matter. Also 60 kg N, 60 kg P₂O₅, 60 kg K₂O ha (15.15.15 composed fertilizer) were applied to the mineral fertilizer plots at the same time and was mixed into the soil to 15 cm dept. Vetch (*Vicia sativa* L.) cv. Alper (150 kg ha⁻¹)

and barley cv. Sancak (50 kg ha⁻¹) (Tan and Serin, 1996) were sown by hand on December 08, 2015 in first year and on December 12, 2016 in second year. Weeds were removed by hand as needed. Since the experiment was conducted during the winter months, there was no additional irrigation. Necessary measurements were made before harvest. After removing one row from each side and 50 cm from each side as an edge effect, the remaining area was harvested and the yields per hectare were found by calculation from the data obtained. In the trial following characters were evaluated: Plant height, botanical composition, fresh herbage yield, dry matter rate, dry matter yield, crude protein rate, crude protein yield, crude ash rate, crude ash yield, NDF and ADF rates.

In each plot, plant heights was measured from harvest area before harvest. Botanical composition was found by cutting the plants in the 0.5 m² quadrates randomly placed in each plot, separating into leguminous and gramineous elements and proportioning to the total weight. Forage on a area of 6.4 m² in each plot was cut at 5 cm above ground level approximately and fresh weight recorded. Harvested fresh herbage (1 kg) was dried to a constant weight at 105°C during 24 h for calculating dry matter. Crude protein (CP) and crude fash (CA) were determined using standard techniques as prescribed by AOAC (1991). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations were analysed by the sequential detergent analysis method (Goering and VanSoest, 1970).

Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 17 (SPSS, 2008). LSD test was used to find if differences in the treatments were significant at P≤0.05 (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The significance of the F values of year, application and application x year interaction variance components for measured characteristics are shown in Table 3. It could be seen in Table 3 that the differences between years were significant for vetch plant height, vetch rate in botanical composition, barleyb rate in botanical composition, fresh herbage yield, dry matter rate, dry matter yield, crude ash yield, crude protein yield and NDF rate at 0.01 level. Applications also had significant F values for vetch plant height, vetch botanical composition, barley plant height, barley botanical composition and fresh herbage yield at 0.01 level. Dry matter yield was affected from applications at 0.01 statistically important level. Application x year was significant for crude ash rate at 0.01 significant level.

Table 3. The significance of F Values of the variation for characteristics based on the analysis of variance combined over two years

Characteristic	Year	Application	Application x Year
Vetch plant height	**	**	n.s
Vetch botanical composition (%)	**	**	n.s
Barley plant height	n.s	**	n.s
Barley botanical composition (%)	**	**	n.s
Fresh herbage yield (t ha ⁻¹)	**	**	n.s
Dry matter rate (%)	**	n.s	n.s
Dry matter yield (t ha ⁻¹)	**	*	n.s
Crude ash rate (%)	n.s	n.s	*
Crude ash yield (t ha ⁻¹)	**	n.s	n.s
Crude protein rate (%)	n.s	n.s	n.s
Crude protein yield (t ha ⁻¹)	**	n.s	n.s
NDF (%)	**	n.s	n.s
ADF (%)	n.s	n.s	n.s

Plant height

In the first year, a higher plant height for vetch was obtained with 106.8 cm, while in the second year a lower plant height was obtained with 76.7 cm. Considering the fertilizer applications, the highest vetch plant heights were 101.1 and 94.8 cm with 30 t and 20 t ha⁻¹ sewage sludge applications respectively, while the plant height of the control application of 85.1 cm gave the smallest value. Only fertilizer applications were effective in barley plant height, and the highest plant heights were obtained as 113.8 and 107.9 cm from 30 t and 20 t ha⁻¹ sludge applications, respectively. The lowest plant height was taken from control plots with 86.1 cm (Table 4). 10 t ha⁻¹ sludge application and mineral fertilizer application were also included in the same statistical group. The fact that vetch heights in the second year are lower than that of the first year can be attributed to the higher botanical composition of barley in the second year, as can be seen in Table 4. Vetch may have been suppressed by barley. This

can be attributed to the fact that barley emerged faster than vetch, took benefit from high January rainfall and developed better than vetch. In addition, it can be said that due to the slow release of nitrogen in the sewage sludge, the plant could be taken benefits from this nitrogen continuously. It was found in the study that sewage sludge was more effective on barley plant height than vetch. This may be attributed to the better response of grain to nitrogen. Karaca and Cimrin (2002), who investigated the effect of nitrogenous and phosphorus fertilizer applications on the plant height of common vetch + barley mixture, stated that nitrogen fertilization significantly increased the height of common vetch and barley plants. Investigating the effect of sewage sludge on turf grass, Celebi et al. (2010) found that sewage sludge application in many features including plant height caused an increase.

Table 4. Means of plant height and botanical composition of vetch and barley for applications

	Plant height (cm)					
	Vetch			Barley		
	2015	2016	Mean	2015	2016	Mean
Control	101	69	85.1 bc*	83	89	86.1 c
10 t ha ⁻¹ TSS	104	74	89.1 ab	97	99	97.7 b
20 t ha ⁻¹ TSS	107	83	94.8 a	103	113	107.9 a
30 t ha ⁻¹ TSS	115	87	101.1 a	109	119	113.8 a
Mineral fertilizer	106	71	88.6 b	96	104	99.9 b
Mean	106.8 a	76.7 b		97.4	104.7	
LSD (0.05)	12.6		7.25			6
	Botanical composition (%)					
	Vetch			Barley		
	2015	2016	Mean	2015	2016	Mean
Control	72.45	49.09	60.77 a	27.55	50.91	39.23 b
10 t ha ⁻¹ TSS	55.92	29.40	42.66 b	44.08	70.60	57.34 a
20 t ha ⁻¹ TSS	52.97	34.68	43.82 b	47.03	65.32	56.17 a
30 t ha ⁻¹ TSS	57.97	29.90	43.93 b	42.04	70.11	56.07 a
Mineral fertilizer	67.53	47.12	57.32 a	32.47	52.88	42.67 b
Mean	61.36 a	38.03 b		38.63b	61.96 a	
LSD (0.05)	7.71		9.25	7.71		9.25

* Denotes significant differences at $p \leq 0.05$

Botanical composition

While the botanical composition rate of vetch was 61.36% in the first year, botanical composition rate of 38.03% was obtained in the second year. In terms of fertilizer applications, the highest vetch botanical composition rates were obtained from control and mineral fertilizer applications with 60.77% and 57.32% respectively, while the all sewage sludge applications gave lower botanical composition rates. While a low botanical composition rate of 38.63% was obtained in the first year for barley, a higher botanical composition rate of 61.96% was obtained in the second year. In terms of fertilizer applications, the highest botanical composition rates were obtained from sewage sludge applications varying between 56.07-57.34%, while the lowest composition rates were obtained from control and mineral fertilizer applications with 39.23 and 42.67%, respectively (Table 4). Karaca and Cimrin (2002) found that nitrogen and phosphorus fertilization had no statistical effect on the botanical composition of the vetch + barley mixture based on fresh weight. While the researchers determined the rate of common vetch as 54.6% in control plots, they emphasized that this rate decreased to 50.8% at 60 kg ha⁻¹ nitrogen dose. The researchers commented that this may be related to the need of barley to nitrogen and thus the increased competitiveness of barley. Plant height naturally affects the total weight of the plant and therefore the botanical composition rate. Second year planting was done with a delay of a few days due to climate and soil conditions. In December of the second year and in the

following few months, the air temperature remained well below the first year. In addition, in January 2017, following the second year of sowing, a very high rainfall of 237.6 kg was observed. It can be said that the rapid emergence of barley and its rapid development affected the vetch plants and therefore the botanical composition rates of the vetch remain low.

Fresh herbage yield, dry matter rate and dry matter yield

In the first year 48.04 t ha⁻¹ fresh herbage yield was obtained, while in the second year a lower fresh herbage yield (24.41 t ha⁻¹) was obtained. Considering the applications, the highest yield was obtained from 30 t ha⁻¹ sewage sludge application as 34.63 t ha⁻¹, while all other applications were in the same group and gave lower fresh herbage yield. The highest dry matter rate (28.58%) was obtained from second year applications. The dry matter rate of the first year (24.16%) was lower than the second year. Dry matter rates varied between 26.02% and 26.63% according to fertilizer applications and there was no statistical difference between them. Year effect is also important on dry matter yield, and the highest dry matter yield was obtained from first year cultivation as 11.50 t ha⁻¹. The second year gave lower dry matter yield (6.98 t ha⁻¹). In terms of fertilizer applications, on dry matter yield, it is seen that the highest yields were obtained from 30 and 20 t ha⁻¹ sewage sludge applications as 10.59 t ha⁻¹ and 9.28 t ha⁻¹, respectively (Table 5).

Table 5. Means of fresh herbage yield, dry matter rate and dry matter yield of vetch + barley mixture for applications

	Fresh herbage yield (t ha ⁻¹)			Dry matter rate (%)			Dry matter yield (t ha ⁻¹)		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
Control	45.60	21.00	33.30 b*	24.54	28.71	26.63	11.20	6.05	8.62 b
10 t ha ⁻¹ TSS	47.72	23.05	35.38 b	25.03	28.00	26.52	11.36	6.52	8.94 ab
20 t ha ⁻¹ TSS	46.67	26.80	36.73 b	23.57	28.48	26.02	10.99	7.57	9.28 a
30 t ha ⁻¹ TSS	52.55	29.60	41.08 a	23.75	29.21	26.48	12.52	8.65	10.59 a
Mineral fertilizer	47.67	21.60	34.63 b	23.94	28.49	26.21	11.41	6.10	8.76 b
Mean	48.04 a	24.41b		24.16 b	28.6 a		11.50 a	7 b	
LSD (0.05)	3.25		3.5	1.56			0.98		1.31

* Denotes significant differences at $p \leq 0.05$.

There are many studies showing that sewage sludge increases efficiency (Binder et al., 2002; Hirel et al., 2007; Cocarta et al., 2017; Delibacak et al., 2016). Cimrin et al. (2001) found that nitrogen and phosphorus fertilization increased the fresh matter yield of the mixture and emphasized that 60 kg N ha⁻¹ application gave good results. Keskin et al. (2012) investigated the effect of sewage sludge application on leguminous + gramineous mixtures and reported that sewage sludge leads to an yield increase. Researchers stated that sewage sludge can be used as a nitrogen source in such mixtures. As for the low yields in the second year, it may be possible to interpret this difference in terms of plant height and botanical composition values. When Table 4 is examined, it will be seen that the second year vetch plant height and botanical composition rates are quite low compared to the first year. This, ultimately affected the fresh herbage yield and lower yields were obtained in the second year. The year differences on dry matter rates can be attributed to the differences in the botanical composition of the plants, as explained above. Yüksek dozda arıtma çamuru uygulamasıyla baklagil+buğdaygil karışımını kuru madde veriminin arttığını birçok araştırmacı belirtmiştir (Ayub et al., 2008; Karaca and Cimrin, 2002; Keskin et al., 2012).

Crude ash rate and yield

The highest crude ash rate (8.82%) was obtained with 10 t ha⁻¹ application in the first year of the study. The lowest crude ash content was obtained as 6.75% in the first year. In the second year, the highest crude ash rate was obtained as 7.61% with 20 t ha⁻¹ sludge application, while the lowest crude ash content was obtained with 30 t ha⁻¹ sludge application as 6.66% (Table 6). Bozkurt et al. (2001) reported that the amount of P, Fe, Mn and Cu increased in plants by using sewage sludge in barley. Karaca and Cimrin (2002) emphasized that nitrogen increased the P amount in common vetch + barley mixture. As a result, we can say that since these elements form the crude ash content, the sludge application increased the crude ash rate. Although there was a slight decrease in the botanical composition rate of the vetch with sewage sludge applications (Table 4) the higher crude ash rate compared to the control can be attributed to the presence of many other nutrients other than nitrogen in the content of the sludge.

Regarding the crude ash yield, the highest crude ash yield (0.91 t ha⁻¹) was obtained in the first year, while a lower ash yield was obtained as 0.50 t ha⁻¹ in the second year (Table 6). The mean of the applications varied among 0.65 and 0.80 t ha⁻¹. Although there was no significant difference in the rate of crude ash between years, we can attribute the year difference in ash yield to the use of dry matter yield in the calculation of crude ash yield. Because there was a significant difference in dry matter yield between years. Crude ash yield was found by multiplying the dry matter yield with the crude ash rate. The fact that there was no difference in ash yield with sludge application in our study can be attributed to the difference in soil conditions in which the experiment was established.

Crude protein rate and crude protein yield

Regarding the crude protein contents, there were no significant differences and 13.90% and 12.38% values were obtained from the first and second years, respectively. In terms of applications, crude protein rates ranged among 12.52 and 13.84% (Table 6). Karaca and Cimrin (2002) determined that nitrogen fertilization increased the crude protein rate of common vetch + barley mixture. Although there was no statistically significant difference in protein rate in applications, numerically higher crude protein contents were obtained in sludge and mineral fertilizer applications than control. Therefore, it can be said that our results are compatible with the results of other researchers.

While a higher protein yield was obtained as 1.60 t ha⁻¹ in the first year, a lower yield (0.87 t ha⁻¹) was obtained in the second year. Regarding the applications, protein yields ranged among 1.10 and 1.38 t ha⁻¹. Karaca and Cimrin. (2002) stated that nitrogen fertilizer in the vetch + barley mixture increased the fresh herbage yield and the crude protein rates, thus the protein yield increased. Although the applications had no significant effect on protein yield, sludge and mineral fertilizer applications gave better results than control numerically in our study, too.

Table 6. Means of crude ash content, crude protein content, crude ash yield and crude protein yield of vetch + barley mixture for applications

	Crude ash rate (%)			Crude ash yield (t ha ⁻¹)		
	2015	2016	Mean	2015	2016	Mean
Control	8.21 ab*	7.33 bc	7.77	0.91	0.44	0.68
10 t Ha ⁻¹ TSS	8.82 a	7.48 bc	8.15	1.00	0.49	0.75
20 t Ha ⁻¹ TSS	6.75 c	7.61 abc	7.18	0.74	0.55	0.65
30 t Ha ⁻¹ TSS	8.12 ab	6.66 c	7.39	1.01	0.58	0.80
Mineral fertilizer	7.97 ab	7.60 bc	7.79	0.91	0.46	0.68
Mean	7.97	7.34		0.91a*	0.50 b	
LSD (0.05)	A x Y:1.05			0.11		

	Crude protein rate (%)			Crude protein yield (t ha ⁻¹)		
	2015	2016	Mean	2015	2016	Mean
Control	13.19	11.86	12.52	1.47	0.72	1.10
10 t Ha ⁻¹ TSS	14.70	12.21	13.45	1.67	0.81	1.24
20 t Ha ⁻¹ TSS	13.06	13.08	13.07	1.43	0.99	1.21
30 t Ha ⁻¹ TSS	13.70	11.91	12.80	1.73	1.03	1.38
Mineral fertilizer	14.85	12.84	13.84	1.70	0.78	1.24
Mean	13.90	12.38		1.60 a	0.87 b	
LSD (0.05)				0.22		

* Denotes significant differences at $p \leq 0.05$.

NDF and ADF rates

The highest NDF rate was obtained in the second year as 49.00 %. NDF rate was 43.90 % for first year. Applications had no significant effect on NDF rate and values changed among 46.02 and 47.05 %. ADF rates varied between 29.98% and 31.56% according to the applications (Table 7). Aesen et al. (2004) reported that increasing the legume rate resulted in lower NDF and ADF concentrations for legume-grass. Carr et al. (2004) found that ADF values of barley-pea and oat-pea mixtures were 34.4 % and 36.5 %, respectively. Strydhorst et al. (2008) found ADF rates between 28.1 and 26.9 % and

NDF rates varying between 43.5 and 41.8 % in various legume-wheatgrass mixtures such as broad bean-barley, lupen-barley and pea-barley. Based on many studies, Van Soest (1996) reported that legumes and grasses differ from each other in terms of intake and digestibility, and that legumes have low NDF under similar growth conditions than grasses. The low NDF rates in our study, especially in the first year, can be attributed to the high rate of legumes in the botanical composition in the first year, and this is consistent with the findings of many researchers.

Table 7. Means of Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) contents of vetch + barley mixture for applications

	NDF (%)			ADF (%)		
	2015	2016	Mean	2015	2016	Mean
Control	44.06	48.68	46.37	30.38	31.62	31.00
10 t Ha ⁻¹ TSS	42.67	49.36	46.02	29.70	31.93	30.81
20 t Ha ⁻¹ TSS	44.19	48.61	46.40	29.37	30.59	29.98
30 t Ha ⁻¹ TSS	45.75	48.34	47.05	31.05	32.07	31.56
Mineral fertilizer	42.84	50.04	46.44	31.87	31.11	31.48
Mean	43.90 b	49.00 a*		30.47	31.46	
LSD (0.05)	2.75					

* Denotes significant differences at $p \leq 0.05$.

CONCLUSION

For the sustainable use of agricultural areas, the amount of organic matter should be increased. For this, the necessary amount of organic matter should be mixed with the soil to improve the physical and chemical properties of the soil. It is accepted by many researchers that sewage sludge can be used in agricultural activities due to the high organic matter they contain. In addition to high organic matter content, it is accepted by many researchers that sewage sludge contains macro and micro nutrients in sufficient amount to meet the nutrient needs of

plants. However, in addition to these beneficial aspects, many studies have shown that sewage sludge can contain different amounts of heavy metals depending on the region and process of production.

In the light of this information, in this study that the effect of different amounts of sewage sludge applications and mineral fertilizer on the yield and quality of vetch + barley mixture was investigated, it was understood that sewage sludge affected the yield, plant heights and botanical composition. On the other hand, dry matter rate, crude ash rate and yield, protein rate and yield, NDF and

ADF rates were not affected by the applications. When the results are evaluated in general, it is concluded that 20 or 30 t ha⁻¹ sewage sludge can easily be used in vetch + barley mixtures.

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