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Research article

The effect of sheep manure application rates on the yield, quality and macro element content of rangeland

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Abstract

This study was conducted during 2021 and 2022 in Bingöl Province (Türkiye) to determine the effects of different doses of sheep manure on forage yield, forage quality, and macroelement contents in natural rangeland areas. The study used a randomized block design with six different doses of sheep manure (0, 5, 10, 15, 20, and 25 t ha^{-1}) applied to the rangeland areas. According to the two-year average results, green forage yield ranged from 3.80 to 10.60 t ha^{-1}, dry matter yield from 1.50 to 4.04 t ha^{-1}, and crude protein yield from 0.216 to 0.633 t ha^{-1}. The highest green forage yield (10.60 t ha^{-1}) was obtained at the 25 t ha^{-1} rate, the highest dry matter yield (3.57, 3.93 and 4.04 t ha^{-1}) at the 15, 20, and 25 t ha^{-1} rates, and the highest crude protein yield (0.603, 0.555, 0.633 and 0.610 t ha^{-1}) at the 10, 15, 20, and 25 t ha^{-1} rates. In terms of forage quality, the highest crude protein content (18.1%) and the lowest NDF (44.0%) and ADF (30.3%) values were obtained at the 10 t ha^{-1} application rate. The macro element contents (P, K, Ca, and Mg) were not significantly affected by the application rates. Yield parameters were higher in the second year, while quality parameters were higher in the first year. The study inferred that the application of 10 t ha^{-1} of sheep manure is the ideal rate for optimizing the yield and quality of rangeland forage.

Keywords: Forage quality, Forage yield, Rangeland, Sheep manure

Introduction

Rangelands are areas that serve as the primary forage source for ruminant animals worldwide and hold strategic importance for ecosystems. However, low productivity and quality losses are major issues, particularly in arid and semi-arid rangelands (Gokkus, 2014). In these areas, the decline in soil organic matter and nutrient deficiencies are among the key factors limiting the sustainability of rangelands.

The application of organic fertilizers, especially manure, plays a significant role in increasing soil organic matter. Sheep manure is a material rich in organic matter and macronutrients (Ca, Mg, P, K) (Fijahi *et al*., 2025) and is considered an alternative nutrient source that could reduce the potential environmental risks associated with chemical fertilizers (Akpinar, 2020; Zha *et al*., 2024). Additionally, the slower decomposition rate of sheep manure compared to cattle manure (Zhu *et al*., 2020) offers advantages, particularly in the gradual release of nutrients over time in rangeland areas. This can contribute to more efficient nutrient utilization by plants by reducing leaching losses, especially under semi-arid conditions. Proper utilization of manure produced in regions with intensive small ruminant farming holds significant potential for both reducing environmental pollution and improving rangeland conditions (Gulcubuk and Aluftekin Baykal, 2004; Polat *et al*., 2012).

It has been reported that sheep manure has positive effects on botanical composition, crude protein content, and forage yield (Ayan *et al*., 2010; Mut *et al*., 2010; Paredes *et al*., 2024). Additionally, studies conducted in various ecosystems indicate that sheep manure improves soil properties, thereby supporting plant growth, and in some cases may limit heavy metal uptake (Han *et al*., 2022). Similarly, it has been reported that the application of sheep manure increases yields in rice and tea production

(Liu *et al*., 2010; Jia *et al*., 2023), and these findings indicate that organic manure has positive effects in various agro-ecosystems.

This study was conducted to determine the effects of different doses of sheep manure on forage yield, forage quality, and macro-element content in natural rangeland areas; it was hypothesized that increasing manure doses would improve the yield and quality of rangeland forage.

Materials and Methods

Plant materials and study site: The study was conducted in 2021 and 2022 in a rangeland area located on the grounds of the Bingöl University Agricultural Application and Research Center (Bingöl, Türkiye). This rangeland area is located approximately 15 km from the center of Bingöl Province, at coordinates 38°48'39" N and 40°31'58" E, with an average elevation of 1,085 m above sea level. The study area is a natural rangeland, and the vegetation consists primarily of grasses (Poaceae). Previous studies in the same area determined that grasses account for approximately 60-70% of the vegetation, while legumes and plants from other families are present in relatively low proportions (Cacan *et al*., 2016; Cacan and Kokten, 2019).

Soil and climatic characteristics: In Bingöl Province, where the study was conducted, the long-term annual average temperature is 12.3°C. Average temperatures in January and February fall below freezing, while July and August are the hottest months. In 2021, the average temperature was 14.2°C, and in 2022, it was 13.4°C. The long-term average annual total precipitation in Bingöl Province is 932 mm. The highest precipitation occurs during the winter months. July and August are the months with the least precipitation. In 2021, the average annual precipitation was 668 mm, and in 2022, it was 830 mm. It was observed that 2021 and 2022 were warmer and drier than the long-term average (Fig 1).

Soil analysis of samples taken from the study area revealed loamy texture, a pH close to neutral (7.25), non-saline composition (0.195%), low calcium carbonate (0.84%), low organic matter (1.27%), low available phosphorus (4.85 kg ha^{-1}), and sufficient available potassium (27.3 kg ha^{-1}) (Sezen, 1995; Karaman, 2012).

Experimental design and laboratory analysis: The study was conducted on March 19, 2021, using a randomized block design with three replications. In the study, each plot was 3 m × 3 m (9 m²) in size, with 1 m spacing left between each plot. In the study, six different rates of sheep manure were applied: 0 (control), 5, 10, 15, 20, and 25 t ha^{-1}. The weighed sheep manure for each plot was applied evenly to the soil surface by hand broadcasting on March 19, 2021, when the experiment was established. The total rangeland area is 52.7 ha, and the experimental area was 288 m².

Harvesting was conducted during the full flowering stage of the dominant plants in the rangeland area on May 28, 2021, (first year), and on May 30, 2022, (second year). During harvesting, a 1 m² area was harvested from each plot. After harvesting, the plants were weighed under field conditions to calculate the green forage yield per hectare. A 500-g sample of green forage was dried at 70°C for 48 hours, and the dry matter content was determined; the dry matter yield was calculated using this value (MAF, 2019). The forage samples were then ground using a hand mill, sieved, and then analyzed using an NIRS (near-infrared spectroscopy) device and the #IC-0904FE calibration set to determine crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg). The crude protein content obtained was multiplied by the dry matter yield to calculate the crude protein yield per hectare (Cacan and Kokten, 2019; Yildiz and Cacan, 2023).

Moisture content of the sheep manure was determined according to the AOAC 960.01 method (AOAC, 2005). Total nitrogen content was analyzed using the elemental analysis method in accordance with the TS EN 13878 (2004) standard. The total boron (B), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), and phosphorus (P) contents of the sheep manure were

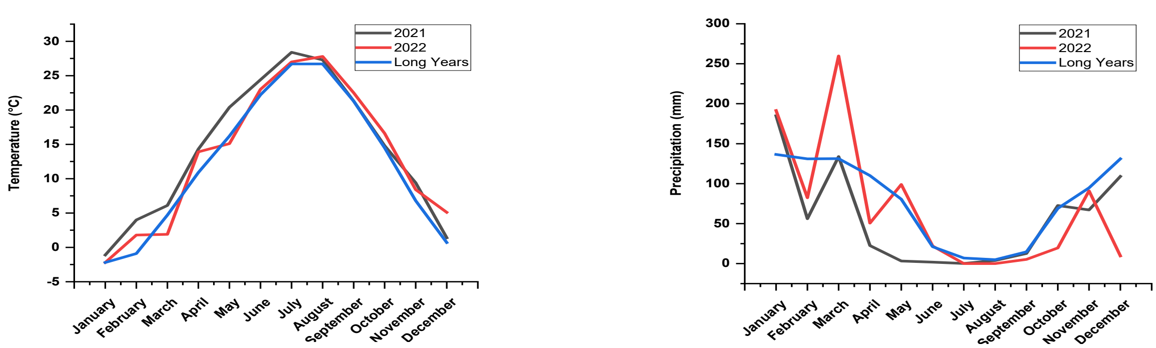

Fig 1. Average temperature and precipitation values for the years during the study

determined using inductively coupled plasma-optical emission spectrometry (ICP-OES). Microwave digestion procedures were performed using the CEM Mars-6 Microwave Technology system (CEM Corporation, 2018). The pH and electrical conductivity (EC) values of the sheep manure were measured in suspensions prepared at a 1:10 (manure: distilled water) ratio, at 20 °C, using deionized water.

Statistical analysis: A homogeneity test was applied to the data obtained in the study, followed by an analysis of variance (ANOVA) appropriate for the randomized block experimental design. Differences between means were compared at the 0.05 significance level using the Tukey test (Yurtsever, 1984) using the JMP statistical software package.

Results and Discussion

Chemical composition of sheep manure: Chemical analyses of the sheep manure are presented in Table 1. According to Table 1, sheep manure has moderate nitrogen content (1.70%) and high organic matter content (38.43%). Sheep manure has the potential to contribute to soil organic matter enrichment and improve soil structure. A pH of 7.74 indicates that the manure has a slightly alkaline character and may act as a buffering agent in acidic soils. An EC value of 1.75 dS m^{-1} indicates that the manure has a relatively low salt content and is unlikely to pose a salinity risk at the applied rates. It was observed that the manure contains sufficient levels of macronutrients (P, K, Ca, and Mg) and micronutrients (Fe, Mn, Zn, Cu, and B) (Sezen, 1995; Karaman, 2012).

Forage yield and quality: Table 2 presents the values for forage yield and quality obtained from rangeland following the application of sheep manure at different rates. The differences in green forage yield, dry matter yield, crude protein content (except for the year × dose interaction), crude protein yield, and NDF and ADF contents resulting from different doses of sheep manure, as well as year and year × dose interaction effects, were statistically significant.

Table 1. Mineral and chemical composition of sheep manure

N (%)	1.70	Ca (ppm)	19132
P (ppm)	3461	Mg (ppm)	6192
K (ppm)	12900	Fe (ppm)	17616
C (%)	22.29	Mn (ppm)	462
pH	7.74	Zn (ppm)	66.60
EC (ds m^{-1})	1.75	Cu (ppm)	31.30
Organic matter (%)	38.43	B (ppm)	27.43

The average yields over the years and doses were 7.89 t ha^{-1}for green forage and 3.26 t ha^{-1} for dry matter. The highest green forage yield was achieved with a 25 t ha^{-1} application rate, and the highest dry matter yield was achieved with a 15 t ha^{-1} application rate. Additionally, the 20 and 25 t ha^{-1} application rates were also found to be among the groups yielding the highest dry matter yields. In the second year, green forage and dry matter yields were higher compared to the first year. When interactions were examined, it was observed that high-dose applications yielded higher green forage in both years, while for dry matter, high-dose applications in the second year showed higher values (Table 2).

While green forage yield was 3.80 t ha^{-1} in the control group, it increased by approximately 70% with the 5 t ha^{-1} dose application, reaching 6.55 t ha^{-1}. It continued to increase with higher doses, reaching its highest value at the 25 t ha^{-1} dose, with an increase of approximately 180%. Similarly, dry matter yield in the control group was 1.50 t ha^{-1}, increased by approximately 110% with the 5 t ha^{-1} dose application to reach 3.12 t ha^{-1}, and reached its highest value of 3.57 t ha^{-1} with the 15 t ha^{-1} dose application, representing an increase of approximately 140%. The 20 t ha^{-1} and 25 t ha^{-1} doses were in the same statistical group as the 15 t ha^{-1} dose. Thus, increasing sheep manure doses resulted in a proportional increase in both green forage and dry matter yields (Table 2).

An average crude protein content of 16.0% was obtained across all doses and years. The highest crude protein content was obtained from the 5 and 10 t ha^{-1} dose treatments. The 15, 20, and 25 t ha^{-1} dose treatments showed similarity among themselves and formed the second group. The crude protein content obtained in the first year was higher than that in the second year. The year × dose interaction was non-significant for crude protein content. An average crude protein yield of 0.521 t ha^{-1} was obtained across doses and years. The highest crude protein yield was obtained with the 10 t ha^{-1} dose application, and the 15, 20, and 25 t ha^{-1} dose applications were also included in the group yielding the statistically highest values. The crude protein yield obtained in the first year was lower than that in the second year. In terms of interaction, higher values were obtained in the second year for all doses except the control group (Table 2).

The average NDF and ADF values across all doses and years were 46.2 and 31.8%, respectively. The lowest NDF and ADF values were obtained from the 10 t ha^{-1} dose application. The other dose applications, excluding 10 t ha^{-1}, constituted the group yielding higher values. It was observed that the NDF and ADF values obtained in the second year were higher than those in the first year. When interactions were examined, it was observed that the 10 and 20 t ha^{-1} dose applications, particularly in the first year, yielded lower NDF and ADF values (Table 2).

Table 2. Effect of sheep manure application rates on the yield and quality characteristics of rangeland

	Green forage yield (t ha^{-1})			**Dry matter yield (t ha^{-1})**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	3.90 d	3.70 d	3.80 E	1.40 e	1.60 de	1.50 D
5 t ha^{-1}	5.50 c	7.60 b	6.55 D	2.23 cde	4.00 ab	3.12 C
10 t ha^{-1}	8.00 b	8.70 b	8.35 C	2.49 cd	4.30 a	3.40 BC
15 t ha^{-1}	8.50 b	8.70 b	8.60 C	2.84 c	4.30 a	3.57 ABC
20 t ha^{-1}	8.60 b	10.30 a	9.45 B	2.96 c	4.90 a	3.93 AB
25 t ha^{-1}	10.50 a	10.70 a	10.60 A	3.18 bc	4.90 a	4.04 A
Mean	7.50 B	8.28 A	7.89	2.52 B	4.00 A	3.26
	CV (%): 4.7, P(Year)<0.0001, P(Dose)<0.0001, P(Year x Dose)<0.0001			CV (%): 10.2, P(Year)<0.0001, P(Dose)<0.0001, P(Year x Dose): 0.0016		
	Crude protein content (%)			**Crude protein yield (t ha^{-1})**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	14.8	14.0	14.4 C	0.208 e	0.224 e	0.216 C
5 t ha^{-1}	17.3	15.9	16.6 AB	0.387 de	0.636 abc	0.511 B
10 t ha^{-1}	19.1	17.1	18.1 A	0.475 bcd	0.732 a	0.603 AB
15 t ha^{-1}	16.3	15.1	15.7 BC	0.461 cd	0.649 ab	0.555 AB
20 t ha^{-1}	16.4	15.9	16.2 BC	0.484 bcd	0.782 a	0.633 A
25 t ha^{-1}	15.7	14.7	15.2 BC	0.500 bcd	0.720 a	0.610 AB
Mean	16.6 A	15.5 B	16.0	0.419 B	0.624 A	0.521
	CV (%): 6.2, P(Year): 0.0023, P (Dose)<0.0001, P(Year x Dose): 0.8325			CV (%): 11.6, P(Year)<0.0001, P(Dose)<0.0001, P (Year x Dose): 0.0090		
	NDF (%)			**ADF (%)**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	48.1 ab	43.8 abc	46.0 AB	31.8 ab	30.0 ab	30.9 AB
5 t ha^{-1}	45.3 abc	46.3 abc	45.8 AB	30.5 ab	32.8 ab	31.6 AB
10 t ha^{-1}	41.1 c	46.9 abc	44.0 B	27.9 b	32.7 ab	30.3 B
15 t ha^{-1}	47.6 abc	49.1 a	48.4 A	32.1 ab	34.7 a	33.4 AB
20 t ha^{-1}	42.3 bc	48.4 ab	45.3 AB	28.0 b	33.7 a	30.9 AB
25 t ha^{-1}	47.8 ab	48.2 ab	48.0 AB	32.6 ab	35.2 a	33.9 A
Mean	45.4 B	47.1 A	46.2	30.5 B	33.2 A	31.8
	CV (%): 4.7, P(Year): 0.0268, P(Dose): 0.0217, P(Year x Dose): 0.0062			CV (%): 5.6, P(Year): 0.0002, P(Dose): 0.0082, P (Year x Dose): 0.0252		

Different letters within each column indicate significant differences at P ≤ 0.05 according to Tukey test.

While the crude protein content in the control group was 14.4%, it increased with the 5 t ha^{-1} dose application and reached its highest value with the 10 t ha^{-1} application. Following this dose, the crude protein content declined. Similarly, crude protein yield in the control group was 0.216 t ha^{-1}, began to increase with the 5 t ha^{-1} dose application, and reached its highest value with subsequent dose applications. In terms of crude protein yield, the 10 t ha^{-1} dose application showed an increase of approximately 180% compared to the control group. Although the variation in NDF and ADF contents among the doses was limited, the statistically lowest values were obtained from the 10 t ha^{-1} dose application (Table 2).

Green forage yield, dry matter yield, and crude protein yield increased in the second year compared to the first year. The probable reason is that the applied sheep manure began to show a greater effect in the second year. Zhu *et al*. (2020) reported that sheep manure decomposes more slowly than cattle manure in rangelands. This may explain why the effect of sheep manure on green forage and dry matter yield, and indirectly on crude protein yield, became more pronounced in the second year. The increase in green forage and dry matter yield can be attributed to greater dry matter accumulation in plant biomass. The higher dry matter accumulation in plant biomass in the second year increased NDF and ADF contents, while the crude protein content was relatively lower.

Chemical fertilizers can be rapidly taken up by plants and may exert effects on physiological activities within a short period of time (Sahin *et al*., 2024; Defar *et al*., 2025). However, organic manure applications also have significant positive effects on plant growth and soil fertility (Akpınar, 2020). There are also studies suggesting the combined use of chemical and organic manures to increase yield and quality in crop production (Kumar *et al*., 2024).

Table 3. Effect of sheep manure application rates on the yield and quality characteristics of rangeland

	P (%)			**K (%)**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	0.33	0.30	0.31	2.12	1.99	2.05
5 t ha^{-1}	0.33	0.30	0.31	2.12	1.85	1.98
10 t ha^{-1}	0.32	0.31	0.31	2.18	1.84	2.01
15 t ha^{-1}	0.33	0.30	0.31	2.19	1.85	2.02
20 t ha^{-1}	0.33	0.30	0.32	2.11	1.91	2.01
25 t ha^{-1}	0.32	0.30	0.31	2.17	1.91	2.04
Mean	0.33 A	0.30 B	0.31	2.15 A	1.89 B	2.02
	CV (%): 2.38, P(Yar) < 0.0001, P(Dose): 0.8553, P(Year x Dose): 0.1744			CV (%): 4.40, P(Year) < 0.0001, P(Dose): 0.7742, P (Year x Dose): 0.2913		
	Ca (%)			**Mg (%)**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	1.64	1.55	1.59	0.32	0.31	0.31
5 t ha^{-1}	1.62	1.58	1.60	0.34	0.30	0.32
10 t ha^{-1}	1.70	1.55	1.63	0.35	0.29	0.32
15 t ha^{-1}	1.61	1.53	1.57	0.34	0.30	0.32
20 t ha^{-1}	1.73	1.54	1.64	0.34	0.29	0.32
25 t ha^{-1}	1.62	1.52	1.57	0.34	0.30	0.32
Mean	1.65 A	1.54 B	1.60	0.34 A	0.30 B	0.32
	CV (%): 2.85, P(Year)< 0.0001, P(Dose): 0.0835, P (Year x Dose): 0.1047			CV (%): 3.61, P(Year)<0.0001, P(Dose): 0.8492, P(Year x Dose): 0.0803		
	Ca:P			**K:(Ca+Mg)**		
	2021	**2022**	**Mean**	**2021**	**2022**	**Mean**
Control	5.03 ab	5.10 ab	5.07	1.08	1.08	1.08
5 t ha^{-1}	4.87 b	5.33 a	5.10	1.09	0.98	1.03
10 t ha^{-1}	5.31 ab	5.07 ab	5.19	1.06	1.00	1.03
15 t ha^{-1}	4.94 ab	5.17 ab	5.06	1.12	1.01	1.07
20 t ha^{-1}	5.25 ab	5.11 ab	5.18	1.02	1.04	1.03
25 t ha^{-1}	5.02 ab	5.07 ab	5.05	1.11	1.05	1.08
Mean	5.07	5.14	5.11	1.08 A	1.03 B	1.05
	CV (%): 2.99, P(Year): 0.1571, P(Dose): 0.4139, P(Year x Dose): 0.0092			CV (%): 5.91, P(Year): 0.0186, P(Dose): 0.4735, P(Year x Dose): 0.3886		

Different letters within each column indicate significant differences at P ≤ 0.05 according to Tukey test.

Macro element contents: The P, K, Ca, Mg, Ca:P, and K:(Ca+Mg) ratios obtained from the rangeland area through the application of sheep manure at different doses are presented in Table 3.

The effect of sheep manure doses on P, K, Ca, Mg, Ca:P, and K:(Ca+Mg) ratios was statistically non-significant. The differences between years in terms of these characteristics, as well as the year × dose interaction only for the Ca:P ratio, were significant. The P, K, Ca, Mg and K:(Ca+Mg) contents obtained in the second year were lower compared to the first year. As the average across doses and years, P, K, Ca, Mg, Ca:P and K:(Ca+Mg) contents were 0.31, 2.02, 1.60, 0.32%, 5.11 and 1.05, respectively (Table 3).

As a result of applying different doses of sheep manure to the rangeland area, the P content obtained from rangeland forage ranged from 0.31 to 0.32%, K content from 1.98 to 2.05%, Ca content from 1.57 to 1.64%, Mg content from 0.31 to 0.32%, Ca:P ratios from 5.06 to 5.19, and K:(Ca+Mg) ratios from 1.03 to 1.08. While no statistically significant difference was observed between years in Ca:P ratio, the year × dose interaction was significant. In terms of interaction, the lowest value was obtained from the 5 t ha^{-1} application of the first year, whereas the highest values were obtained from the other treatments (Table 3). While different doses of sheep manure had positive effects on rangeland forage yield and quality (Table 2), they caused some changes in macronutrient contents; however, these changes were statistically non-significant (Table 3). The probable reason is that the P, K, Ca, and Mg contents of the rangeland soils were low. Manuring with sheep manure partially replenished these deficient elements in the soil, but they did not reach levels sufficient to significantly increase the macronutrient contents in plant tissue. This suggests that higher doses of manure application may be required to increase the macronutrient content of rangeland plants.

Studies conducted in rangeland ecosystems have reported that sheep manure positively affects rangeland yield, botanical composition, and forage quality. Paredes *et al.* (2024) reported that sheep manure is an effective organic matter source for the rehabilitation of degraded rangelands. Similarly, Mut *et al.* (2010) stated that sheep manure applications increased the protein content in rangelands, and the 75 kg N ha^{-1} dose was found appropriate in terms of yield and quality. Ayan *et al.* (2010) reported that sheep manure had positive effects on the quality characteristics and mineral contents of rangeland. Furthermore, studies conducted in arid and semi-arid regions indicate that sheep manure is a viable and economical method for the restoration of degraded rangelands (Liu *et al.*, 2023).

Conclusion

In conclusion, when yield and quality parameters were evaluated together, it was found that the highest crude protein yield was achieved with the 10 t ha^{-1} dose application, and that the lowest NDF and ADF values were also obtained with the same dose application. Therefore, it is recommended that sheep manure be applied at a dose of 10 t ha^{-1} to improve the forage yield and nutrient quality of rangelands.

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