Original Research Article

Effects of Cattle Dung Decomposition on Soil Carbon, Nitrogen, and Enzyme Activities in Pasture during Cold Season in Karst Mountain Areas of Guizhou, China

Xuedong Yang [1,†], *Qing Dou* [1,2,†][*Corresponding Author], *Bin Luo* [1], *Xianyi Liang* [1], *Li Li* [3][*Corresponding Author]

1 Guizhou Province Grassland Technology Experiment and Extension Station, Guiyang 550025, China; xdyang08@163.com (X.Y.); 19316688414@163.com (B.L.);

2 Corn Research Institute, Sichuan Agricultural University, Chengdu 625014, China; dqkyzh@163.com (Q.D.);

3 Guizhou Vocational College of Agriculture, Guiyang 551400, Guizhou, China; lilihnmping@163.com (L.L.).

[†]These authors contributed equally to this work.

Abstract: This study investigated beef cattle dung decomposition characteristics and their effects on soil carbon, nitrogen, and enzyme activities in typical pasture of karst mountain areas in Guizhou, during the winter-spring season. The results demonstrated that the degradation rate of dung was faster during 0-30 days than during 30-100 days. Compared with initial values, both dry matter and fresh weight of dung decreased significantly ($p < 0.05$) at experimental termination, while soil organic carbon and total nitrogen increased significantly ($p < 0.05$). Soil nitrate-N content showed an initial decrease followed by an increase. Soil urease and invertase activities exhibited positive correlations with soil organic carbon, total nitrogen, ammonium-N, and nitrate-N ($p < 0.05$). In conclusion, beef cattle dung increased soil carbon and nitrogen content while regulating urease and invertase activities in the short term, though these effects varied considerably across experimental sites.

Keywords: Karst; Cattle manure decomposition; Soil carbon and nitrogen; Soil enzyme activity

Introduction

Livestock dung provides abundant nutrients to soil through natural decomposition, serving as the primary source of soil carbon and nitrogen in grazing grasslands [1,2]. Carbon and nitrogen in dung can be returned to grassland soil through pathways such as organic matter decomposition and leaching of inherent mineral nutrients [3,4]. In temperate grasslands, 10%–16% of carbon from dung infiltrates the soil within 60 days [5], becoming available for plant uptake to promote growth and development [6,7]. Simultaneously, dung indirectly regulates elemental cycling processes in soil by altering physicochemical properties such as soil moisture content and pH [8].

The decomposition of livestock dung and soil nutrient cycling rely on soil enzyme activity [9]. Dung stimulates microbial growth and enhances enzymatic activities in soil [10]. Current research on dung decomposition patterns and their impacts on grasslands primarily focuses on northern China’s steppes and alpine meadow regions [4,9,10], with relatively fewer studies examining artificial grasslands in southern karst mountainous areas.

This study simulates beef cattle dung deposition and decomposition in Guizhou Province to analyze decomposition patterns across different regions. We investigate dung decomposition effects on soil carbon, nitrogen, and enzyme activities in grasslands. The findings will provide scientific references for pasture management practices in Guizhou.

Materials and Methods

Study site

This study conducted experiments in grasslands at Dushan (107°30′ E, 25°10′ N, altitude 980 m) and Dafang (105°52′08″ E, 27°22′37″ N, altitude 1810 m). The annual average temperatures in Dushan and Dafang were 15°C and 11.8°C, with annual rainfall of 1400 mm and 1150 mm, frost-free period of 290 days and 257 days, and both of yellow soil. The pasture in Dushan was an annual pasture with 93% coverage, dominated by *Lolium multiflorum* L. in winter. The pasture in Dafang was a perennial pasture established for 10 years, with 67% coverage, dominated by *Dactylis glomerata* L., associated with *Trifolium repens* L., *Lolium perenne* L., *Poa pratensis* L. and other weeds.

Experimental design

Sample plots with the same pasture composition, terrain conditions and soil were selected in Dafang and Dushan in December 2021. Fencing was constructed and grazing was prohibited for 6 months. Two weeks before the start of the experiment, remove all vegetation from the sample plots, with the mowing stubble height approximately 5 cm. 30 dung pats were uniformly distributed across the sample plots. Each dung pat contained a subsurface nylon mesh (4 mm aperture) for residue collection. Standardized pats (20 cm diameter, 1.2 kg fresh weight) were spaced 5 m apart.

Sampling and analyses

Samples were collected at 0, 7, 15, 30, 60, and 100 days post dung pat deployment.Dung pats (n=5/timepoint) and underlying soils (0-5 cm depth) were collected under cryopreservation. All biochemical analyses followed standardized protocols: SOC via dichromate oxidation-external heating method [12], TN by Kjeldahl digestion, nitrate-N by alkaline hydrolysis diffusion method, ammonium-N by colorimetric determination after KCl extraction [13], with soil urease and invertase activities quantified using colorimetric determination assays[14].

Statistical analysis

Initial data curation was executed in Microsoft Excel 2016. Differences between means (ANOVA) were analyzed followed by the least significant difference (LSD) test using IBM SPSS Statistics 17.0. Graphical representations were implemented in OriginPro 2024b (OriginLab Corporation, Northampton, MA).

Results

Characteristics of dung weight and nutrients changes

Dung weight progressively decreased over time. Significant mass loss occurred primarily within the initial decomposition phase (0-30 days), evidenced by 37.84% and 35.54% dry matter degradation at Dafang and Dushan respectively. Cumulative reduction at termination reached 44.93% (Dafang) and 49.27% (Dushan).

Organic carbon (OC), total nitrogen (TN), and ammonium-N content in dung decreased significantly over the decomposition period, while nitrate-N exhibited an initial decline followed by an increase. Nutrient change rates differed between two study areas. By the experimental endpoint compared to Day 0, OC declined by 31.12% (Dafang) and 49.27% (Dushan), TN declined 41.08% (Dafang) and 31.27% (Dushan), Ammonium-N declined 99.99% at both sites. Nitrate-N reached minimum concentrations at 0.89 g/kg on Day 30 (Dafang) and 0.82 g/kg on Day 15 (Dushan), subsequently rebound to >1.6 g/kg at both sites by Day 100.

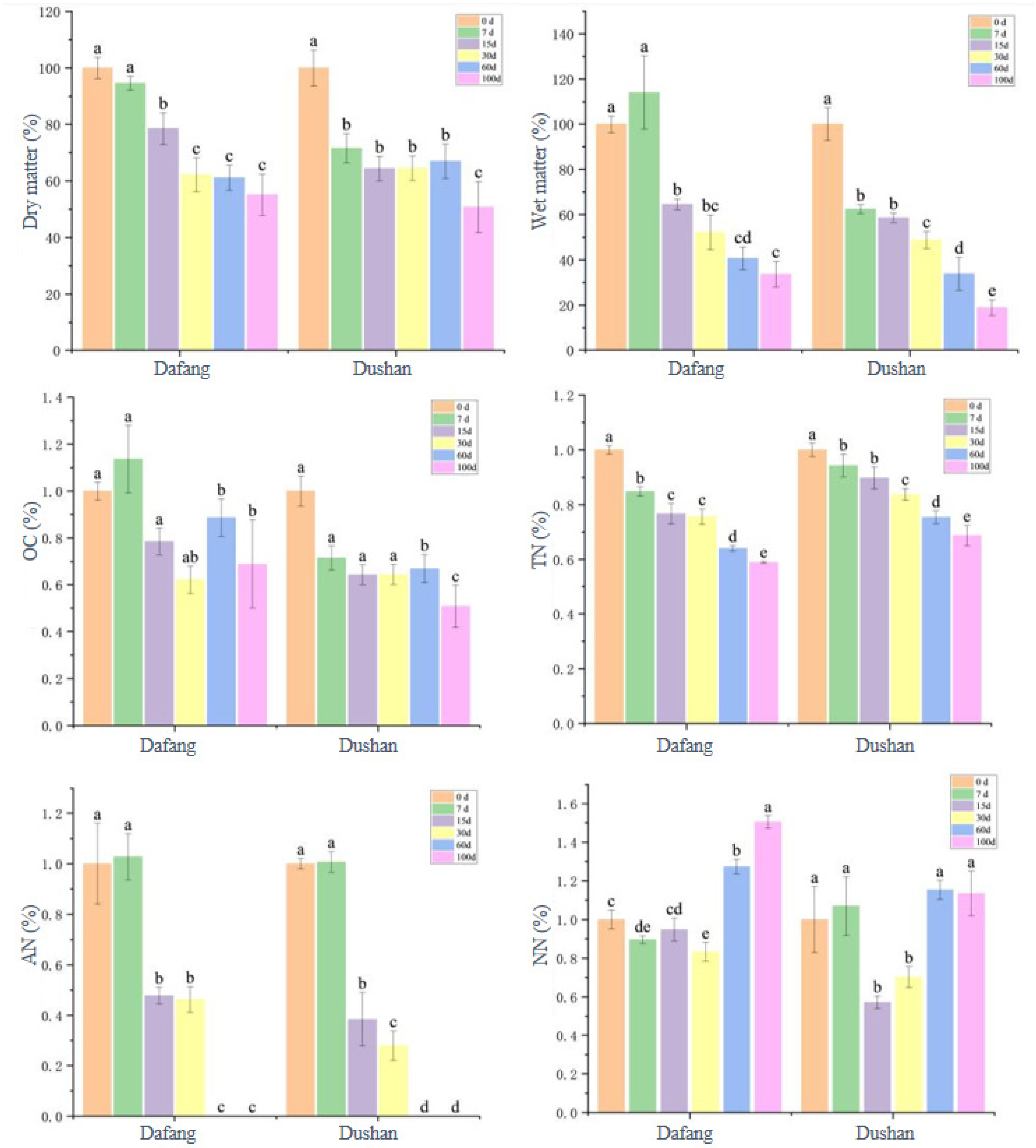

Figure 1. The changes of weight and nutrients compared to the initial values in cattle dung

Note: Different lowercase letters indicate significant differences (*P* <0.05).

Characteristics of soil nutrients and enzyme activity changes

The contents of soil organic carbon (SOC), total nitrogen (TN), and ammonium-N at the Dafang initially increased before declining over time, but a significant increased of Dushan. Soil nitrate-N content of both sites significantly decreased at the experimental endpoint.

Urease and invertase activities of Dafang exhibited a progressive decline throughout the experimental period. Both enzymes of Dushan demonstrated minor fluctuations in , showing no consistent increasing or decreasing trend.

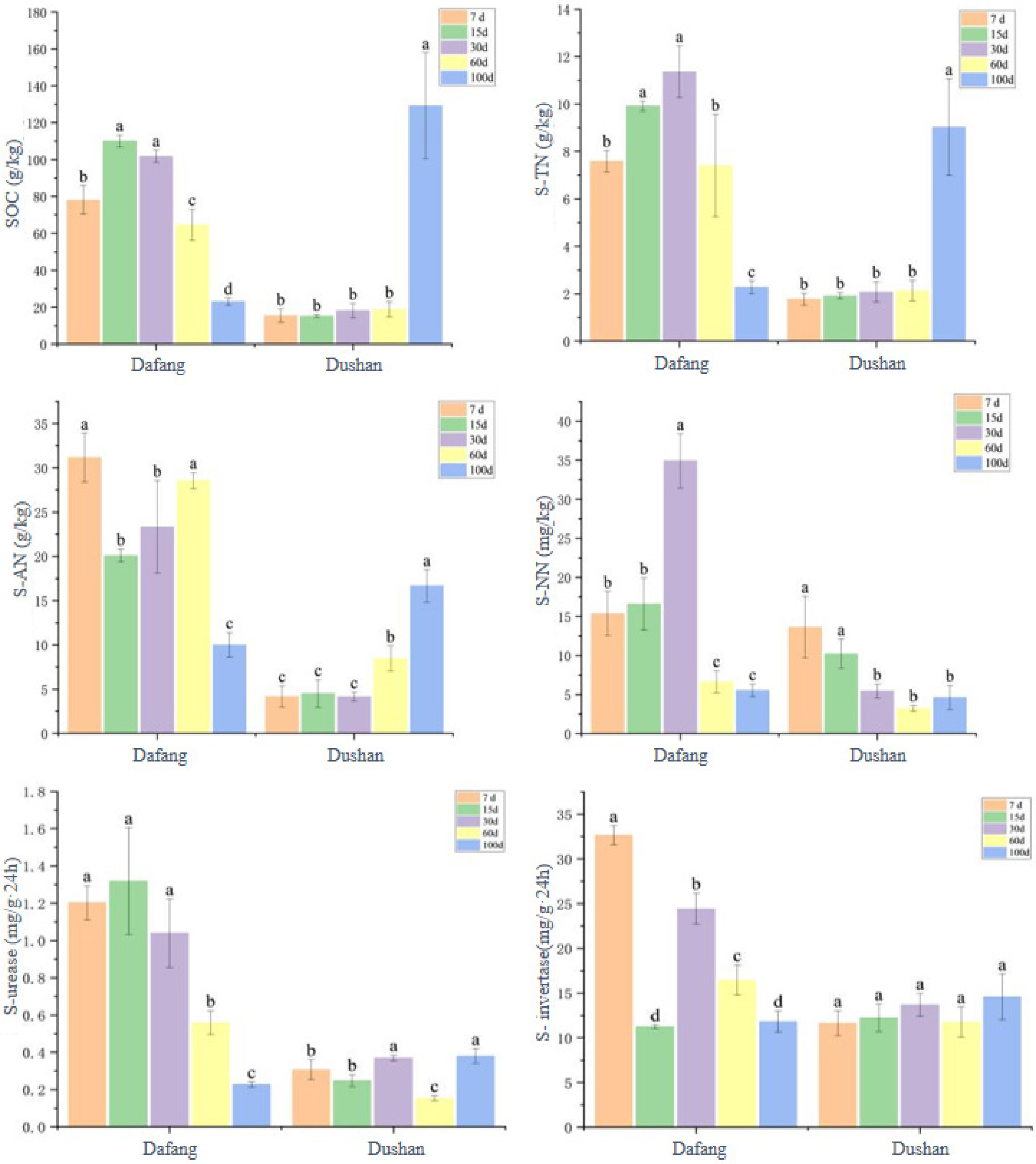

Figure 2. The changes of soil nutrients and enzyme activities

Note: Different lowercase letters indicate significant differences (*P* <0.05).

Relationships between dung nutrients and soil properties

Dung organic carbon (DOC) showed significant positive correlations (P < 0.05) with soil organic carbon (SOC), total nitrogen (TN), ammonium-N, nitrate-N, urease (URE) and invertase (INV). Dung total nitrogen (DTN) showed significant positive correlations (P < 0.05) with soil ammonium-N, URE and INV. Dung ammonium-N (DAN) showed significant negative correlations (P < 0.05) with SOC, TN and soil ammonium-N. Dung nitrate-N (DNN) showed significant negative correlations (P < 0.05) with SOC,STN, ammonium-N and URE.

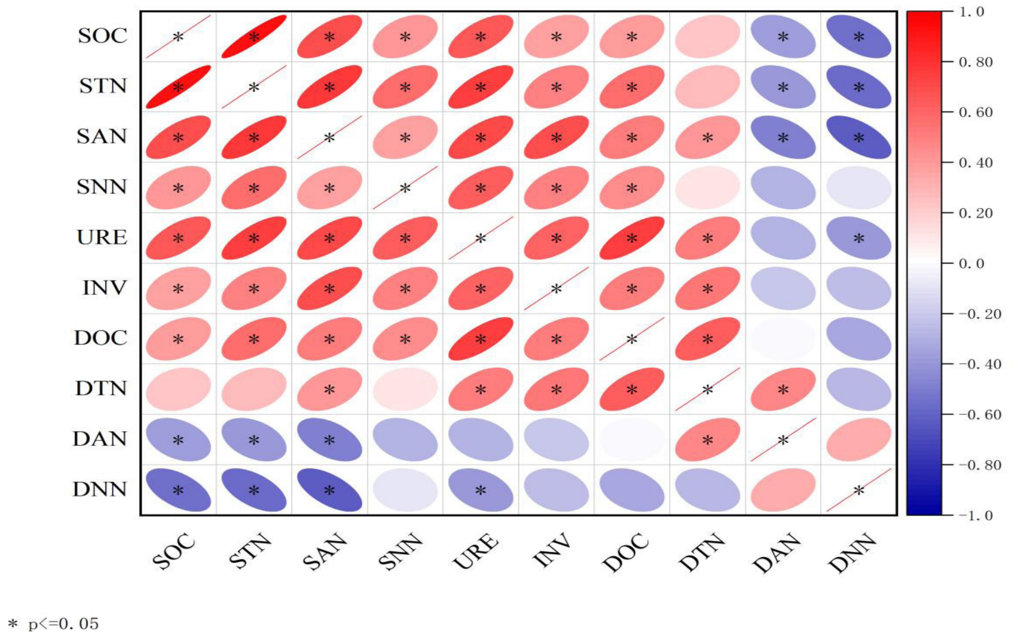

Figure 3. Correlation of fecal nutrients, soil nutrients and soil enzyme activities in dung decomposition of cattle

Note: "*" indicate significant differences (*P* <0.05).

Discussion

Effects of cattle dung decomposition on grassland soil nutrients in Karst mountain areas

Soil organic carbon (SOC) and total nitrogen (TN) contents significantly increase as dung decomposes, aligning with findings from most studies [15,16]. It this study, SOC and TN in Dafang were notably higher during the initial phase than in later stages, while SOC and TN accumulation primarily occurred toward the end of the trial in Dushan. This divergence may relate to differences in temperature, humidity, and dung beetle populations between the two sites. Temperature and humidity directly regulate microbial activity, thereby influencing soil nutrient transformation [17]. During the study, dung plots in Dushan exhibited rapid surface moisture loss, prone to crust formation, coupled with fewer dung beetles. These factors likely hindered dung incorporation into the soil. Cattle dung elevates soil ammonium-N and nitrate-N contents [18]. Organic nitrogen compounds in dung were converted to ammonium-N via microbial decomposition, which was further transformed into nitrate-N by nitrifying bacteria [19]. In Dushan soil, ammonium-N and nitrate-N displayed inverse trends, suggesting potentially insufficient activity of nitrifying bacteria in this area.

Effects of cattle dung decomposition on grassland soil enzyme activities in Karst mountain areas

Soil enzyme activities were influenced by multiple factors including temperature, moisture, and nutrient availability [20]. Dafang Soil urease and invertase activities in Dafang progressively declined during dung decomposition, but consistently low with minimal fluctuations in Dushan. This disparity likely stems from reduced soil nutrients input in Dushan. Organic matter inputs typically stimulate soil enzyme activity by enhancing microbial processes. Soil urease activity directly correlates with soil nitrogen levels [21], and governs nitrogen cycling efficiency and transformation dynamics [22]. Invertase critically regulates organic carbon decomposition and nutrient release [23]. The scarcity of soil fauna in Dushan might reduced dung-derived nutrient input , thereby impaired enzyme activities and nutrient cycling efficiency. This limitation undermines grassland grazing system sustainability in the region.

Conclusion

Through simulated cattle grazing processes, this study investigated dung decomposition characteristics and their impacts on grassland soil nutrients and enzyme activities in Karst mountainous areas. Cattle dung substantially increased soil carbon and nitrogen content while modulating urease and invertase activities. Decomposition rates exhibited significant site-specific variations, with Dafang showed faster decomposition than Dushan. Slow dung decomposition constrained soil nutrient accrual and limited influence on enzymatic activity. Therefore, to optimize nutrient cycling in Karst mountain grazing systems, some measures should be recommended to accelerate dung decomposition and enhance dung-derived nutrient flux into soils, exemplified by soil fauna augmentation and mechanical dung fragmentation.

Author Contributions

X.Y. and Q.D. designed the experiments and wrote the manuscript. Q.D., X.L. and B.L. performed the data analysis. L.L. contributed to the grammar and language revision of the paper. All authors have read and agreed to the published version of the manuscript.

Funding

The Guizhou Province Key Research and Development Program of China (Qiankehezhicheng[2021]Yiban143).

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Jaramillo V. J., Detling J. K. Small-scale heterogeneity in a semi-arid north American grassland. I. Tillering, N uptake and retranslocation in simulated urine patches[J]. The Journal of Applied Ecology, 1992, 29(1): 1-8.
[2] He Y., Sun G., Luo P., Wu N. Effects of dung deposition on grassland ecosystem: A review[J]. Chinese Journal of Ecology, 2009, 28(2):322-328.
[3] Gifford G. F., Hawkins R. H. Hydrologic impact of grazing on infiltration: A critical review[J]. Water Resources Research, 1978, 14: 305-313.
[4] Zhang Z. Y., Zhang S. T. Effects of yak dung deposition on soil enzyme activities in an alpine meadow in the Tibetan Plateau[J]. Pratacultural Science, 2021, 38(5): 803-811.
[5] Bol R., Amelung W., Friedrich C., Ostle N. Tracing dung-derived carbon in temperate grassland using ^{13}C natural abundance measurements[J]. Soil Biology & Biochemistry, 2000, 32(10): 1337-1343.

[6] Lovell R. D. , Jarvis S. C. Effect of cattle dung on soil microbial biomass C and N in a permanent pasture soil[J]. Soil Biology & Biochemistry, 1996, 28(3): 291-299.
[7] Yoshitake S., Soutome H., Koizumi H. Deposition and decomposition of cattle dung and its impact on soil properties and plant growth in a cool-temperate pasture[J]. Ecological Research, 2014, 29(4): 673-684.
[8] Cheng Y., Wang J., Mary B., Zhang J. B., Cai Z. C., Chang S. X. Soil pH has contrasting effects on gross and net nitrogen mineralizations in adjacent forest and grassland soils in central Alberta, Canada[J]. Soil Biology & Biochemistry, 2013, 57: 848-857.
[9] Saiyaremu·Halifu, Aikebaier·Yilahong, Song R. Q., Abudousaimaiti·Naihemaiti, Mirenisha·Maimaitiming, Diliduer·Aili. Correlation between soil enzyme activities and soil physical chemical properties in Chabuchar grassland[J]. Acta Prataculturae Sinica, 2018, 27(3): 116-125.
[10] Ruess R. W., Seagle S. W. Landscape patterns in soil microbial processes in the serengeti national park, Tanzania[J]. Ecology, 1994, 75(4): 892-904.
[11] Wang B., Sun G., Luo P., Wang M., Wu N. Labile and recalcitrant carbon and nitrogen pools of an alpine meadow soil fromthe eastern Qinghai-Tibetan Plateau subjected to experimental warming and grazing[J]. Acta Ecologica Sinica, 2011, 31(06): 1506-1514.
[12] Tiessen H., Cuevas E., Chacon P. The role of soil organic matter in sustaining soil fertility[J]. Nature, 1994, 371(6495): 783-785.
[13] Solórzano L., Jonathan H. S. Determination of total dissolved nitrogen in natural waters[J]. Limnology & Oceanography, 1980, 25(4): 751-754.
[14] Zhang L., Wu F. Z., Xu Z. F., Tan B., Liu Y., Yang Y. L., Wang A., Yang W. Q. Responses of soil invertase and urease activities in an alpine forest of western Sichuan to simulated climate warming at different critical periods[J]. Acta Ecologica Sinica, 2017, 37(16): 5352-5360
[15] Guimaraes B. C., Fernanda D. K. G., Homem B. G. C., de Lima I. B. G., Spasiani P. P., Boddey R. M., Alves B. J. R., Casagrande D. R. Emissions of N_2O and NH_3 from cattle excreta in grass pastures fertilized with N or mixed with a forage legume[J]. Nutrient Cycling in Agroecosystems, 2022, 122: 325-346.
[16] Tully K. L., Abwanda S., Thiong'O M., Mutuo P. M., Rosenstock T. S. Nitrous oxide and methane fluxes from urine and dung deposited on Kenyan pastures[J]. Journal of Environmental Quality, 2017, 46: 921-929.
[17] Williams P. H., Haynes R. J. Effect of sheep, deer and cattle dung on herbage production and soil nutrient content[J]. Grass & Forage Science, 2010, 50(3): 263-271.
[18] André S., Jeferson D., Cimélio B., Márcio A. A., Jonatas T. P., Josiléia A. Z., Michely T., Carla M. R., Anibal de M. Nitrous oxide emission factors for urine and dung patches in a subtropical Brazilian pastureland[J]. Agriculture Ecosystems & Environment, 2014, 190: 94-103.
[19] Gilliam F. S., Yurish B. M., Adams M. B. Temporal and spatial variation of nitrogen transformations in nitrogen-saturated soils of a central Appalachian hardwood forest[J]. Canadian Journal of Forest Research, 2001, 31: 1768-1785.
[20] Wang Q. L., Cao G. M., Wang C. T. The impact of grazing on the activities of soil enzymes and soil environmental factors in alpine *Kobresia pygmaea* meadow[J]. Plant Nutrition & Fertilizer Science, 2007, 13(5): 856-864.
[21] Haynes R. J. Effects of ammonium ions on the growth of plants: A review[J]. Journal of Plant Nutrition, 1986, 9(2): 173-190.
[22] Štursová M., Bárta J., Šantrůčková H., Baldrian P. Small-scale spatial heterogeneity of ecosystem properties, microbial biomass, and enzyme activity in a temperate mountain forest soil[J]. FEMS microbiology ecology, 2016, 92: 12.
[23] Syers J. K., Sharpley A. N., Keeney D. R. Cycling of nitrogen by surface-casting earthworms in a pasture ecosystem[J]. Soil Biology and Biochemistry, 1979, 11(2): 181-185.