EFFECTS OF NITROGEN ADDITION ON SOIL NUTRIENTS AND STOICHIOMETRY IN THE DESERT STEPPE OF NORTHERN CHINA

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Abstract. Desert grasslands are a vital part of Inner Mongolia's ecosystem but are increasingly degraded by adverse weather and human activities. The effects of fertilization on soil nutrients and stoichiometry in desert steppe were studied in order to screen out the optimal combination of forage fertilization concentration in this area, and provide theoretical basis for the improvement of degraded grassland in this area. This study focused on the Short-flowered Stipa Desert Grassland. Using a randomized block design, four treatments were applied: control, low-concentration nitrogen fertilization, medium-concentration nitrogen fertilization, and high-concentration nitrogen fertilization. The aim was to study the effects of fertilizer application on soil nutrients and stoichiometry. The results showed that: (1) low-concentration nitrogen fertilization (75 kg/ha) increased soil total carbon and total nitrogen content, while higher low-concentration nitrogen fertilization (225 kg/ha) increased soil available potassium content; (2) changes in soil stoichiometry were primarily influenced by soil total carbon and total phosphorus. Moderate fertilization could increase soil nutrients content, but might lead to an imbalance in soil carbon and nitrogen ratio. The impact of different fertilization methods on soil carbon and nitrogen varies, and it was necessary to choose the appropriate fertilization method based on the actual situation of desert grasslands. In our study, the effectiveness of precipitation appears to be greater than the fertilization effect, resulting in poor soil nitrogen uptake and utilization, which will be a consideration in future research.
Keywords: *desert grassland, fertilization, soil nutrients, stoichiometry*

Introduction

The desert steppe is a transitional ecosystem between grassland and desert. It is a critical ecosystem globally and a key feature of arid and semi-arid regions (Bardgett et al., 2021). Its distinct environmental conditions and resource allocation patterns shape its ecosystem structure and function (Gao et al., 2020; Dong et al., 2020). The desert steppe is vital for animal husbandry in China, despite its barren soil and arid climate, which limit plant growth (Liu et al., 2020). In recent years, human and natural factors have accelerated desertification in grassland areas, limiting the desert steppe's self-regulation capacity and depleting grassland resources (Liu et al., 2020). Because desert grassland is characterized by low-growing vegetation dominated by grass species,

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grazing directly alters physical and chemical properties such as soil compactness and bulk density, disrupting the nutrient cycle that grassland ecosystems provide to soil. Grazing has essentially become the only way to utilize such grasslands (Dong et al., 2020). The properties of grassland plants and soil vary significantly, and their sensitivity to disturbances often falls below the recovery threshold. Soil nutrient is one of the important factors for the growth of desert steppe plants (Zhou et al., 2018). Xilin Gol grassland is one of the most widely spread grasslands in Inner Mongolia. Due to unreasonable human collection, soil element content is reduced. The change of land use mode, the disturbance of human factors, the difference of climate regions, etc., all further promote this nutrient cycle to play a further role in the soil with a certain spatial heterogeneity, so that the soil remains relatively immobile (Liu et al., 2020).

Changes in soil nutrient content are affected by the types and concentrations of fertilizers, among which soil phosphorus is the most susceptible, followed by soil nitrogen (Liang et al., 2022). The traditional view is that most terrestrial ecosystems are more limited by nitrogen than phosphorus (Cui et al., 2022; Liu et al., 2021). The addition of soil nitrogen usually affects the change of soil available phosphorus content, and the addition of nitrogen will cause soil acidification to a certain extent, and then slow down the flow of soil phosphorus (Gallego et al., 2022). Nitrogen addition affects soil root phosphatase and rhizosphere microorganisms, which indirectly affects the availability of soil phosphorus. In recent years, fertilization has become a widespread and efficient restoration measure for degraded grassland in ecological management (Qi et al., 2024; Liu et al., 2017). Reasonable fertilization system to actively promote the healthy and sustainable development of grassland soil nutrient balance is an important guarantee for the sustainable management of grassland, but also the foundation of ecosystem services and functions (Yue et al., 2020). Ecological stoichiometry provides a new comprehensive method for studying the interactions between plants and soil and the cycles of nitrogen, phosphorus and potassium (Bai et al., 2010; Li et al., 2010). The availability of soil nutrients directly affects the utilization and stoichiometric ratio balance of C, N and P content in soil by fine roots. It reflects soil quality and nutrient limitation (Zhao et al., 2024; Gao et al., 2020). Long-term fertilization affects the stoichiometric characteristics of plant and soil growth in desert steppe (Zhang et al., 2023; Li et al., 2022). At present, researches on plant ecological stoichiometry pay more attention to plant N: P and soil C: N, which mainly detect the mineralization capacity of soil nitrogen and reflect the influence degree of soil N by exogenous nitrogen input (Liu et al., 2021). It can also reflect the characteristics of its potential biochemical distribution and life history countermeasures (Chen et al., 2022). Generally, the research of soil ecological stoichiometry mainly includes the following aspects: the lower N: P indicates the soil nitrogen limit, and the higher N: P indicates the soil phosphorus limit (Li et al., 2023; Sun et al., 2020).

Desert grassland is an arid and biochemical grassland ecosystem in transition from grassland to desert, and it is a green ecological barrier in northern of China. It has special plant species composition, community type and structural function, and high ecological vulnerability (Gao et al., 2020). The study on the changes of soil nutrients and C, N and P ecological stoichiometric characteristics of desert grassland under different fertilization treatments can provide scientific basis for ecological restoration and soil nutrient management of grassland ecosystem in northern China. This study was designed to address the following three questions: (i) How does short-term N addition affect soil nutrients in desert steppe, Northern China? (ii) How does N addition affect the soil C: N: P stoichiometry and the relationship with soil nutrients?

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Materials and methods

Study sites and experimental design

The experiment was conducted in Zhurihe Town (112°47’11.2” E, 42°15’48.7” N), Sunite Right Banner, Xilin Gol League, Inner Mongolia, China. The region has a flat terrain with obvious calcium deposits, mainly distributed in 10-35 cm. The soil is light chestnut soil, and the humus layer is 5-10 cm thick. The average annual precipitation is 177.2 mm, and 60%-80% of the precipitation is concentrated in July to September, the peak season for pasture growth. The zonal vegetation in the test area was desert steppe with *Stipa breviflora* as the group species and *Cleistogenes songorica* as the dominant species. The main associated species are *Carex duriuscula*, *Caragana stenophylla*, *Asparagus gobicus*, *Kochia prostrata* and *Allium polyrhizum*, *Convolvulus ammannii*, *Artemisia capillaries*, *Heteropappus altaicus*, *Astragalus gulactites*, etc.

The site was selected in 2013 at a number of permanent plots within an enclosure in order to prevent grazing (*Fig. 1*). The experiment was carried out as a completely randomized block with four treatments and three replicates. With consideration of local traditional fertilization practices to select four nitrogen fertilizer rates: CK, F1, F2 and F3 were 0, 75 kg/hm^2, 150 kg/hm^2 and 225 kg/hm^2, plots were randomly placed on the site with an average separation distance of about 2 m. Nitrogen fertilizer was organic urea (CON_2H_4, total nitrogen content ≥ 46.4%) and fertilizer was beginning in May 2013, and no fertilizer was applied after that.

Figure 1. *The photo of fertilization test*

Sampling method

Samples are collected in early August each year. Three 1 m × 1 m random sampling parties were set up in each sample plot. Soil samples of 0-10 cm, 10-20 cm and 20-30 cm were randomly taken at three points using a soil drill with a diameter of 5 cm. After soil collection, the samples were brought back to the sample preparation room for air drying, the debris was removed by a ball mill, and then ground, and sent to the test room for soil physical and chemical indexes. The content of total carbon and total nitrogen in soil were determined by element analyzer. The content of total phosphorus and available phosphorus in soil was determined by molybdenum antimony heteropoly acid method. The content of total potassium and available

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potassium in soil was determined by flame photometric method. The content of soil available nitrogen was determined by alkaline hydrolysis diffusion separation acid - base titration method.

Statistical analysis

One-way analysis and T test of variance (ANOVA) were used SPSS 20.0 software (SPSS statistical package, Chicago, IL, United States). Statistical analyses were conducted on the soil nutrients of the three treatments for each quadrat in the field experiment. Significant differences in soil nutrients and stoichiometry between the four nitrogen fertilizer treatments were evaluated by one-way analysis of variance (ANOVA) procedures. Significant differences in soil nutrients and stoichiometry between the years were evaluated by T-test.

A principal component analysis (PCA) was performed to determine relationships among soil nutrients, stoichiometry and the effect of nitrogen fertilizer on these. Before analysis, we centered and normalized all variables with their standard deviations, and the importance of a trait in a given component is indicated by its relative loading on a component. Statistical graphs were prepared using Excel 2010.

Results

Soil total nutrients under different nitrogen fertilizer treatments

The soil total carbon content of 10-20 cm layer in 2013 and 2014 had a significant difference, and the soil total carbon content in 2013 under different treatments was significantly higher than that in 2014 ($P < 0.05$, *Table 1*). In 2013 and 2014, the soil total carbon content of 0-10 cm, 10-20 cm and 20-30 cm under control treatment was significantly higher than that under medium and high-concentration fertilization treatment ($P < 0.05$, *Fig. 2*), and the total carbon content of 0-10 cm and 10-20 cm soil under low-concentration fertilization treatment was not significantly different from that under control treatment ($P > 0.05$).

Compared with the control, soil total nitrogen content in 0-10 cm, 10-20 cm and 20-30 cm layers under different fertilization treatments did not increase significantly in 2013, but significantly decreased under partial fertilization treatments ($P < 0.05$). Compared with 2013, the soil total nitrogen content of 0-10 cm, 10-20 cm and 20-30 cm layers under low-concentration fertilization in 2014 was significantly increased, and the soil total nitrogen content of 0-10 cm layer under low-concentration fertilization was significantly higher than that under high-concentration fertilization ($P < 0.05$).

The soil total phosphorus content in different soil layers in 2013 and 2014 had significant differences, and the soil total phosphorus content in 2014 under different treatments was significantly higher than that in 2013 ($P < 0.05$, *Table 1*). Compared with the control, the soil total phosphorus content of 0-10 cm and 20-30 cm layers under high-concentration fertilization treatment in 2013 was significantly higher ($P < 0.05$). Compared with 2013, the total phosphorus content of soil 0-10 cm, 10-20 cm and 20-30 cm layers under different fertilization treatments increased significantly in 2014, among which the soil total phosphorus content of soil 10-20 cm layer under high-concentration fertilization treatment was significantly higher than that under other treatments, and the soil total phosphorus content of 20-30 cm layer under low-concentration fertilization treatment was significantly higher ($P < 0.05$).

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Table 1. *T test for the effects of fertilizer on soil total nutrients*

Source of variance	0-10 cm				10-20 cm				20-30 cm			
	TC	**TN**	**TP**	**TK**	**TC**	**TN**	**TP**	**TK**	**TC**	**TN**	**TP**	**TK**
t value	3.10	-5.19	-12.13	-1.088	1.318	5.716	11.39	3.50	1.98	6.09	16.60	1.24
P value	0.07	0.60	0.00001	0.656	0.045	0.743	0.0001	0.10	0.16	0.36	0.001	0.001

TC = soil total carbon; TN = soil total nitrogen; TP = soil total phosphorus; TK = soil total potassium

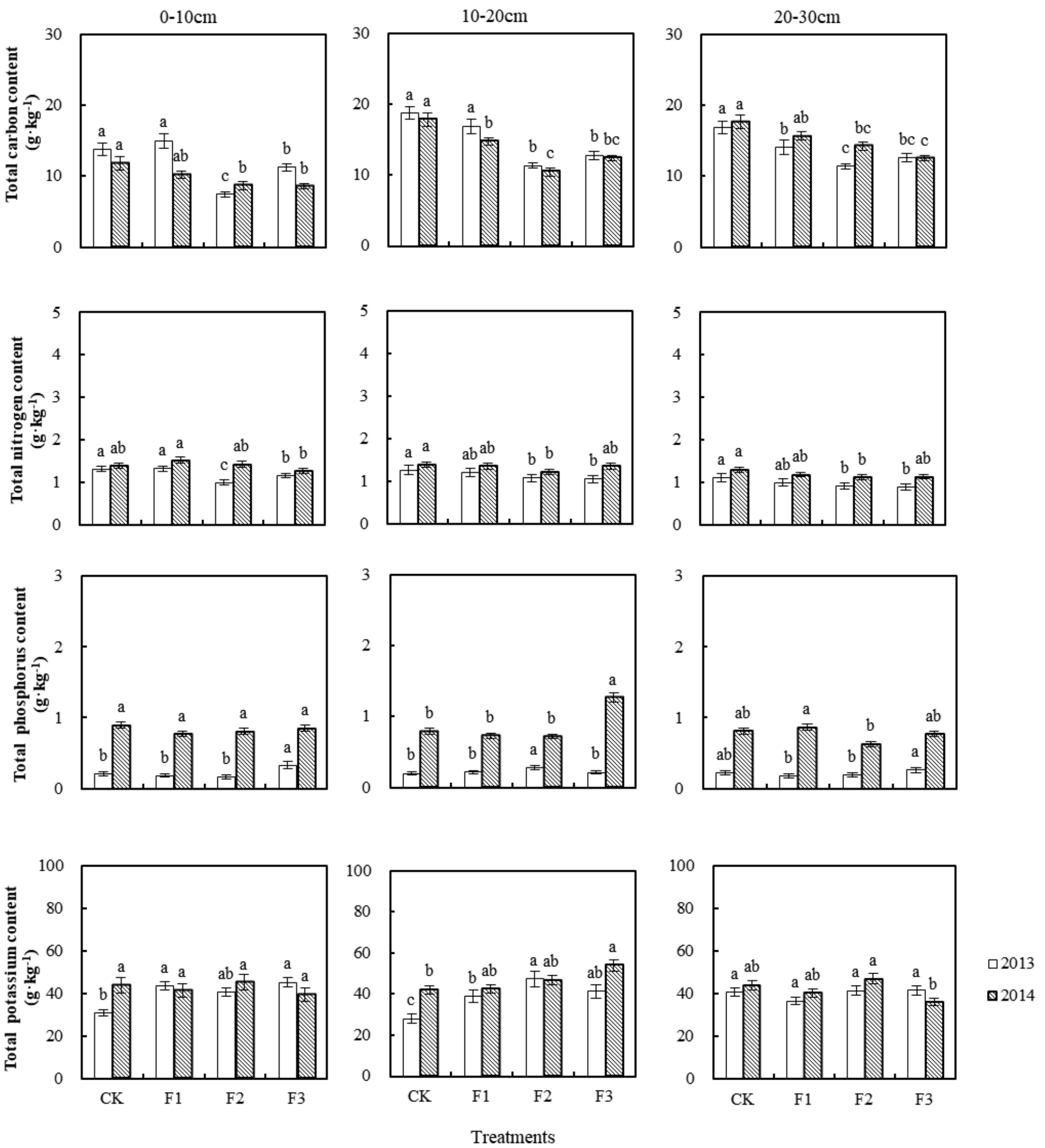

Figure 2. *Changes of total nutrient content in soil under different fertilization treatments. Lowercase letters represent significant differences between P < 0.05 treatments*

There was a significant difference in the soil total potassium content of 20-30 cm layer between 2013 and 2014. The soil total potassium content under high-concentration fertilization treatment in 2014 was significantly lower than that in 2013, while that under other treatments was higher than that in 2013 ($P < 0.05$, *Table 1*). Compared with

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the control, the soil total potassium content of 0-10 cm and 10-20 cm layers under different fertilization treatments in 2013 was significantly lower (*P < 0.05*). Compared to 2013, the soil total potassium content of 10-20 cm layer under high-concentration fertilization in 2014 was significantly higher than that of the control, while the soil total potassium content of soil 20-30 cm under high-concentration fertilization in 2014 was significantly lower than that of the control (*P < 0.05*).

Soil available nutrients under different nitrogen fertilizer treatments

The soil available nitrogen in different soil layers in 2014 was significantly higher than that in 2013, and soil available phosphorus in different soil layers in 2013 and 2014 had a significant difference, and the change trend was not obvious (*P < 0.05*, *Table 2*). The soil available potassium of 10-20 cm and 20-30 cm layers in 2014 were significantly higher than that in 2013.

Table 2. *T test for the effects of fertilizer on soil available nutrients*

Source of variance	0-10 cm			10-20 cm			20-30 cm		
	AN	AP	AK	AN	AP	AK	AN	AP	AK
t value	-3.35	-0.28	-3.45	-2.81	-0.87	-7.00	-4.89	-0.90	-5.54
P value	0.009	0.005	0.445	0.003	0.036	0.0001	0.0001	0.0001	0.0001

AN = soil available nitrogen; AP = soil available phosphorus; AK = soil available potassium

In 2013, soil available nitrogen content in 10-20 cm layer under low-concentration fertilization treatment was significantly higher than that in other treatments, and soil available nitrogen content in 20-30 cm layers control treatment was significantly higher (*P < 0.05*, *Fig. 3*). In 2014, the soil available nitrogen content of 10-20 cm layers under high-concentration fertilization treatment was the highest (*P < 0.05*); In 2013, the soil available phosphorus content of 20-30 cm layer was the highest under mid-concentration fertilization treatment (*P < 0.05*). In 2014, the soil available phosphorus content of 0-10 cm and 20-30 cm layers was the highest in mid-concentration fertilization treatment (*P < 0.05*); In 2013, the soil available phosphorus content of 10-20 cm layer under control treatment was the highest, and that in 20-30 cm soil under high-concentration treatment was the highest (*P < 0.05*). In 2014, the soil available phosphorus content of 0-10 cm, 10-20 cm and 20-30 cm layers were significantly higher under mid-concentration fertilization treatment (*P < 0.05*).

Soil stoichiometry under different nitrogen fertilizer treatments

The soil C: N in 0-10 cm in 2014 was significantly lower than that in 2013, the soil C: P and N: P in different soil layers in 2014 were significantly lower than that in 2013 (*P < 0.05*, *Table 3*). In 2013, soil C: N in 0-10 cm, 10-20 cm and 20-30 cm was significantly lowest under mid-concentration fertilization treatment (*P < 0.05*, *Fig. 4*). In 2014, the soil C: N of 0-10 cm and 10-20 cm layers under low, medium and high-concentration fertilization treatment were significantly lower than that in control treatment, and the soil C: N of 20-30 cm layer under high-concentration fertilization treatment was significantly lower than that in control treatment (*P < 0.05*). In 2013, the soil C: P of 0-10 cm, 10-20 cm and 20-30 cm were significantly lower than that of control under high-concentration fertilization treatment (*P < 0.05*). In 2014, the soil C:

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P of 20-30 cm layer under high-concentration fertilization treatment was significantly lower than that under control treatment ($P < 0.05$). In 2013, the soil N: P of 0-10 cm and 20-30 cm layers under mid-concentration fertilization treatment were significantly lower than that of the control, and the N: P of 10-20 cm soil under high-concentration fertilization treatment was significantly lower than that of the control ($P < 0.05$). In 2014, the soil N:P of 10-20 cm layer under high-concentration fertilization treatment was significantly lower than that under control treatment ($P < 0.05$).

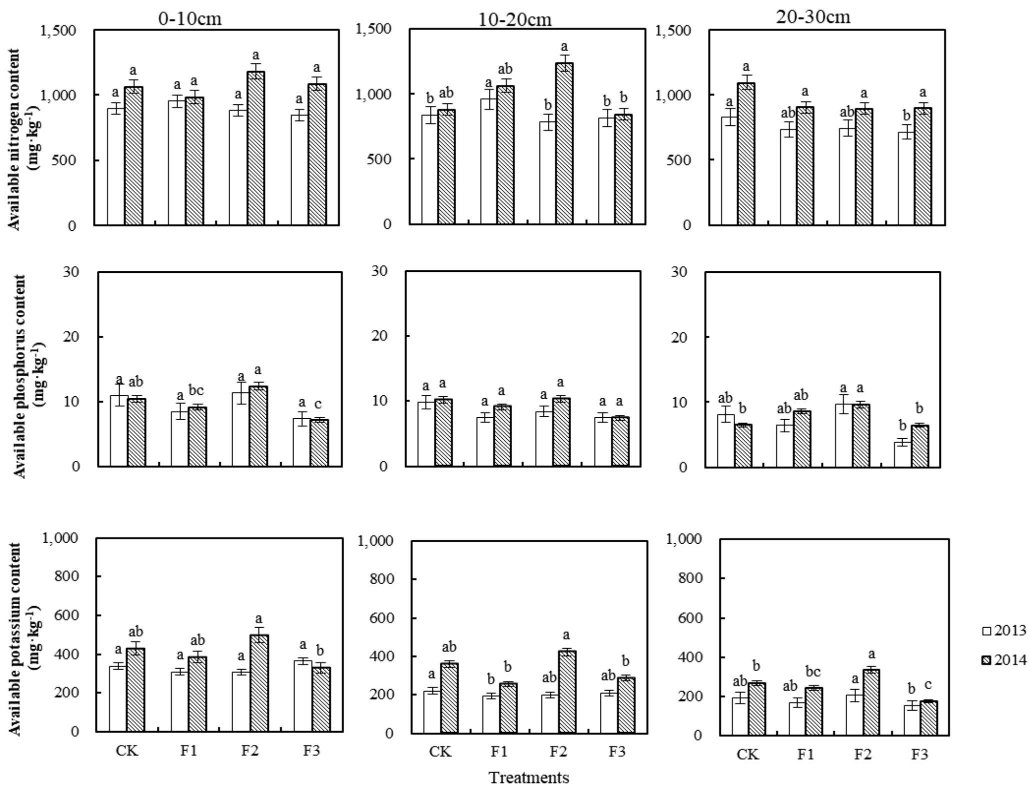

Figure 3. *Changes of available nutrient content in soil under different fertilization treatments. Lowercase letters represent significant differences between P < 0.05 treatments*

Table 3. *T test for the effects of fertilizer on soil stoichiometry*

Source of variance	0-10 cm			10-20 cm			20-30 cm		
	CN	**CP**	**NP**	**CN**	**CP**	**NP**	**CN**	**CP**	**NP**
t value	7.14	9.97	9.36	4.36	11.39	11.61	2.55	13.92	13.35
P value	0.013	0.0001	0.008	0.231	0.0001	0.008	0.14	0.0001	0.0001

CN = soil C: N; CP = soil C: P; NP = soil N: P

The evaluation indexes of soil nutrients and stoichiometric ratios under different treatments were standardized and the correlation analysis was carried out (*Fig. 5*). In 0-10 cm of soil, the soil total carbon was a moderate positive correlation with the soil C: N (0.86), and with the soil C: P (0.61). The soil total phosphorus had a moderate negative correlation with soil N: P (-0.80), and with soil C: P (-0.73). There was a moderate positive correlation between soil total carbon and soil C: N in 10-20 cm

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(0.86). The soil total phosphorus had a moderate negative correlation with soil N: P (-0.82), and with the soil C: P (-0.78). In 20-30 cm of soil, there was a moderate positive correlation between the soil total carbon and the soil C: N (0.64), and with the soil total nitrogen (0.55). The soil total phosphorus had a moderate negative correlation with soil N: P (-0.86), and with the soil C: P (-0.86). Comprehensive analysis showed that the change of soil stoichiometric ratio was mainly influenced by the soil total carbon and the soil total phosphorus, and other elements had little effect on the stoichiometric ratio.

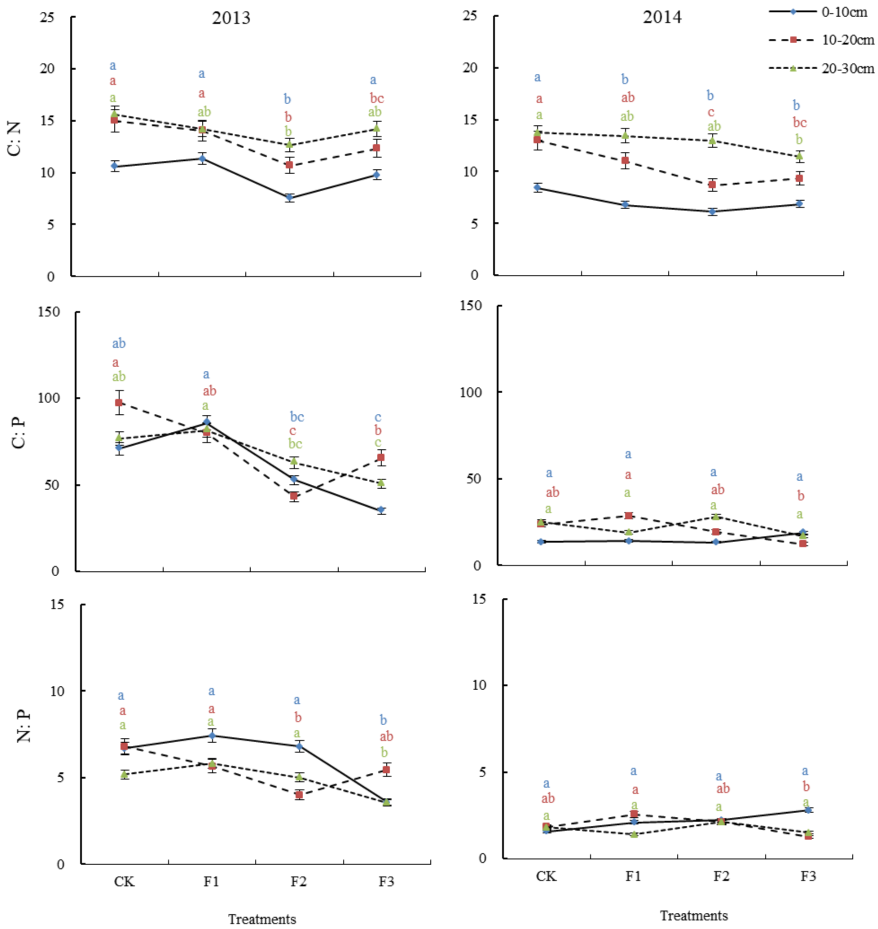

Figure 4. *Changes of soil stoichiometry under different fertilization treatments. Lowercase letters represent significant differences between P < 0.05 treatments*

Discussion

Effects of N addition on soil nutrients content

Fertilization changes soil nutrient content, plant productivity and subsurface carbon distribution, which in turn affects soil carbon dynamics in ecosystems (Zhao et al., 2019). There are two viewpoints on the research results of fertilization on soil total carbon. The short-term fertilization has no significant effect on soil total carbon content, which is consistent with the results of this study (Chen et al., 2020; Muhammad et al., 2019). The catalytic effect of fertilization on soil total carbon is more obvious, and the way to obtain soil total carbon mainly relies on animal and plant residues, root exudates and microbial carbon sequestration, and the effect is far greater than that of fertilization

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(Liu et al., 2019; Bento et al., 2021). This phenomenon can be explained by the cost-benefit hypothesis, which states that due to the increase in available nitrogen in the soil, plants allocate more carbon above ground rather than below ground, and plants do not need to increase the number and length of their roots to obtain available nitrogen to meet their needs (Liang et al., 2022).

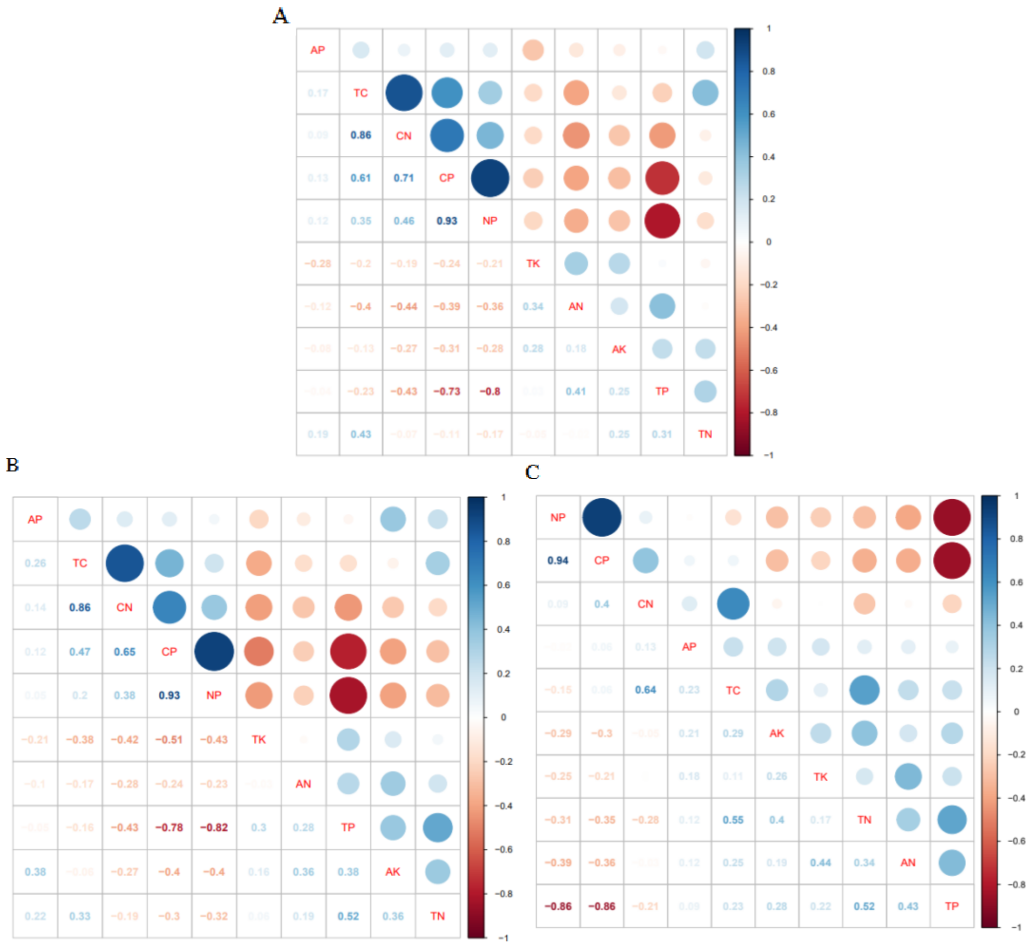

Figure 5. *Correlations between soil total nutrients, soil available nutrients and soil stoichiometry of 0-10 cm (A), 10-20 cm (B), and 20-30 cm (C). TC = soil total carbon; TN = soil total nitrogen; TP = soil total phosphorus; TK = soil total potassium; AN = soil available nitrogen; AP = soil available phosphorus; AK = soil available potassium; CN = soil C: N; CP = soil C: P; NP = soil N: P. Blue numbers represent significant positive correlation, yellow numbers represent significant negative correlations. The darker the color, the stronger the correlation*

As a base fertilizer, an appropriate increase in the application amount or concentration of nitrogen fertilizer will promote the increase of soil nitrogen, but excessive use of nitrogen fertilizer will affect the absorption of total nitrogen content in soil by plants (Gao et al., 2019; Dai et al., 2020). Low nitrogen addition can promote plant growth, thereby increasing soil carbon input (Yuan et al., 2020). The results of this study showed that the addition of nitrogen fertilizer did not significantly increase the soil total nitrogen content, but the soil available nitrogen content increased significantly in 2014. Nitrogen is one of the main elements absorbed by plants, and most of its

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changes are dominated by available nutrients (Chen et al., 2022). During the study period, the precipitation was mainly concentrated in the growing season from June to August, and the area was located in desert steppe. The years of drought and low rainfall resulted in the effective entry of medium and high-concentration nitrogen fertilizer into soil, which affected the absorption of nitrogen fertilizer and soil nitrogen by grassland plants (Wang et al., 2015). In water-limited ecosystems, infiltration rate is a power function of surface biomass. But there was no correlation between aboveground biomass and infiltration in wet area (Gallego et al., 2022). Precipitation changes may have interactive effects on soil water and nitrogen availability (Zhang et al., 2015). On the one hand, precipitation plays an important role in soil N leaching and mineralization. On the other hand, alleviating nitrogen restriction can stimulate plant growth and increase photosynthesis and transpiration, which in turn affects soil moisture (Ji et al., 2023). Studies have shown that when the irrigation amount was about 40% of field capacity and 900 $kg \cdot hm^{-2}$ pure nitrogen was applied, the contents of alkali-hydrolyzed nitrogen, available phosphorus and available potassium in 0-20 cm soil were significantly increased by 25.52%, 39.70% and 34.67%, respectively, compared with the control group (Fan et al., 2022).

Nitrogen addition has become an important factor affecting soil phosphorus cycle and dynamic changes of phosphorus components (Khorshid et al., 2019). On the one hand, nitrogen addition may alter soil phosphatase and microbial activity by reducing soil pH (Widdig et al., 2020), leading to a redistribution of soil inorganic phosphorus components (Zhao et al., 2019). On the other hand, nitrogen enrichment may increase the microbial demand for phosphorus, thereby indirectly increasing soil phosphatase activity, and promoting soil organic phosphate mineralization into soil available phosphorus. Nitrogen addition reduces soil pH and thus inhibits soil phosphatase activity (Zi et al., 2022), while increased water availability alleviates this limitation (Widdig et al., 2020). The studies have shown that fertilization is conducive to the increase of soil total phosphorus with enough rainfall. Different from previous studies, the amount of precipitation in this study is not directly related to the content of total phosphorus in soil (Li et al., 2010; Liu et al., 2011). The soil phosphorus content is mainly available phosphorus, and the total phosphorus content in soil cannot directly indicate the actual phosphorus utilization in soil (Shah et al., 2020). In this study, the soil total phosphorus content increased year by year, which may be due to the relative shortage of phosphorus in the soil of the experimental site, the lack and uneven distribution of precipitation during the experimental period, the restriction of soil nutrient absorption by vegetation, the increase of soil adsorption strength and adsorption capacity of phosphorus by fertilization, the existence of inorganic phosphorus in the soil, and the content of available phosphorus increased.

Effects of N addition on soil stoichiometry

The soil elements have independent effects, and there are complex relationships among them, which are the key factors affecting the stability of grassland ecosystem (Chen et al., 2022). The stoichiometric ratio of soil elements can be used as an important index to test the changes of soil limiting elements and fertility (Tian et al., 2022). In this study, the changes of soil stoichiometry in 2014 did not change significantly in response to different concentrations of nitrogen addition, but the different ratios in 2014 were significantly lower than that in 2013. The soil total carbon was positively correlated with the soil C: N and C: P. The reason may be that the study

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area is desert grassland with relatively scarce precipitation, the relationship between soil nutrients and plant utilization is weakened, more elements in fertilizer are stored in the soil, and the effect of fertilization is more reflected in the soil level, which is an important factor affecting the research results (Li et al., 2023).

The average values of C: N, C: P, and N: P in terrestrial soil in China are 11.9, 61.0, and 5.2 (Sun et al., 2020; Zhang et al., 2023). In this study, the average values of C: N, C: P, and N: P in soil were 12.32, 66.91, and 5.49 respectively, which were the general level of hydrothermal conditions. The studies have shown that soil C: N can reflect the degree of decomposition of organic matter. When C: N ranges from 12 to 16, organic matter can be decomposed well by microorganisms, and soil C: N is inversely proportional to the available nitrogen released by the decomposition process of organic matter. The greater the potential of organic matter to release available nitrogen during the decomposition process what soil C: N is smaller. In this study, the average value of C: N in the fertilized soil was 10.14, indicating that the decomposition of soil organic matter and the release of available nitrogen had great potential (Tian et al., 2022). The soil C: P is related to the organic phosphate mineralization ability. The C: P is less than 200, it means that the organic phosphorus net mineralization. The C: P is between 200 and 300, which means that soluble phosphorus almost no change. The C: P is greater than 300 indicates that the organic phosphorus net fixation. In this study, the average soil value C: P was 66.91, indicating that the overall net organophosphorus mineralization in the study area was high (Sun et al., 2020). However, the soil C: P and N: P in the second year of fertilization were significantly lower than those in the first year, while soil total phosphorus in the second year of fertilization was generally higher than that in the first year, indicating that there was soil phosphorus restriction after fertilization. This may be due to insufficient rainfall in the test site, weak leaching of soil phosphorus, strong weathering, and easy accumulation of phosphorus (Li et al., 2023).

Conclusion

The effects of fertilization on soil nutrients and stoichiometry in desert steppe in northern China were studied. The results showed that low-concentration fertilization (75 kg/hm^2) was beneficial to the increase of soil total carbon and soil total nitrogen content, and low-concentration fertilization (225 kg/hm^2) was beneficial to the increase of soil available potassium content. The changes of the soil stoichiometry were mainly influenced by soil total carbon and total phosphorus, and the influence of other elements on the soil stoichiometry was relatively small. As one of the main driving factors of climate change, nitrogen deposition rate increases year by year, and nitrogen and phosphorus deposition rates are unbalanced. Therefore, it is of great significance to study the effects of nutrient addition on soil nutrients and stoichiometry in desert steppe. Soil nutrient and stoichiometric characteristics are sensitive to nutrient addition, and short-term experiments can be concluded. Soil structure and ecosystem carbon and water processes are long-term processes that need long-term experiments to verify.

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