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Ecological stoichiometric characteristics of nitrogen and phosphorus in leaves, stems and roots of Haloxylon ammodendron in southern Gurbantunggut Desert and their relationship with soil factors

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Abstract

In order to explore the stoichiometric characteristics of nitrogen (N) and phosphorus (P) of Haloxylon ammodendron on the south edge of Gurbantungut Desert, and to reveal the adaptability of desert plants to nutrient utilization in barren habitats, this study took the south edge of Gurbantungut Desert in Xinjiang as a typical area. The contents of N and P in leaves, stems and roots of H. ammodendron were measured and analyzed, and the correlation between the ecological stoichiometry of N and P in organs and soil factors was discussed, as well as the influence of the samples and organs. The results showed as follows: (1) There were significant differences in N content, P content and N:P among different organs of H. ammodendron, and the trend of each index was roughly the same. The general trend was higher in leaves, followed by stems and roots. (2) Correlation analysis showed that N content in all organs of H. ammodendron was positively correlated with soil total nitrogen. P content in leaves and roots was significantly positively correlated with soil total P, while P content in stems was significantly negatively correlated with soil total P. P content in all organs was negatively correlated with soil N:P. The contents of N, P and N:P in different organs were negatively correlated with soil pH and electrical conductivity. (3) General linear model analysis showed that organs had great influence on N content, P content and N:P of H. ammodendron.

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Abstract

In order to explore the stoichiometric characteristics of nitrogen (N) and phosphorus (P) of *Haloxylon ammodendron* on the south edge of Gurbantungut Desert, and to reveal the adaptability of desert plants to nutrient utilization in barren habitats, this study took the south edge of Gurbantungut Desert in Xinjiang as a typical area. The contents of N and P in leaves, stems and roots of *H. ammodendron* were measured and analyzed, and the correlation between the ecological stoichiometry of N and P in organs and soil factors was discussed, as well as the influence of the samples and organs. The results showed as follows: (1) There were significant differences in N content, P content and N:P among different organs of *H. ammodendron* , and the trend of each index was roughly the same. The general trend was higher in leaves, followed by stems and roots. (2) Correlation analysis showed that N content in all organs of *H. ammodendron* was positively correlated with soil total nitrogen. P content in leaves and roots was significantly positively correlated with soil total P, while P content in stems was significantly negatively correlated with soil total P. P content in all organs was negatively correlated with soil N:P. The contents of N, P and N:P in different organs were negatively correlated with soil pH and electrical conductivity. (3) General linear model analysis showed that organs had great influence on N content, P content and N:P of *H. ammodendron* .

Keywords: *Haloxylon ammodendron* ; Gurbantungut Desert; Ecological stoichiometry; Correlation analysis; Soil factor

Introduction

Ecological stoichiometry is a scientific theory to study the balance and relationship between the elements of ecosystem (especially N and P). This theory applies the methods and principles of chemistry, physics and other disciplines to study the content and ratio characteristics of organic elements and their changes with the environment at different scales and levels in the field of ecology (Hu et al., 2020; Niklas, 2006). The analysis of the relationship between the content and ratio of various chemical elements in plants and environmental factors is of great significance for us to understand the nutrient utilization and nutrient limitation of plants, the chemical cycle of bio-earth and the function of community or ecosystem (Niklas, 2006).

N and P are essential nutrients for plant growth, and N is an important element for plant protein and chlorophyll synthesis. P is an important element that constitutes nucleic acid and ATP, both of which affect the normal metabolism, growth and development, morphology and function of plants (Hu et al., 2020). The N and P stoichiometric characteristics of plants can reflect the growth rate, productivity level and the effectiveness of soil resources to a certain extent. The productivity of plants is often positively correlated with leaf N content, and the growth rate is positively correlated with leaf P content (Reich et al., 2009; Niklas & Cobb, 2005). The characteristics of N content, P content and stoichiometric ratio in different plant organs are different due to the difference of nutrient distribution, storage and function. Leaf is the organ of plant photosynthesis, stem is the nutrient organ between root and leaf, and root is an important organ for plant to absorb and transport water and nutrient elements underground. There are significant differences in N content and P content in plant leaves at different research levels, which are mainly determined by genetic factors and environmental factors (Chen et al., 2022). In general, the N content and P content of plant leaves with faster growth and shorter life are higher, and the N content and P content of plant leaves with slower growth and longer life are lower (Han et al., 2005). The lifespan of roots is shorter than that of leaves and stems, decomposes faster, and is greatly affected by soil nutrients (Jackson et al., 1997). The content of N and P elements in the leaves of Alashan desert plants is higher than that in stems and roots (He et al., 2016), which indicates that plants tend to invest more N and P into leaves, reduce the openness of stomata, and save water while improving the efficiency of photosynthesis (Liu et al., 2022; He et al., 2016). In addition, desert plants also adapt to the arid and barren environment in the desert by reabsorbing the nutrients of senescent leaves (He et al., 2015; Drenovsky et al., 2010).

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The available N and P contents in soil environment have profound effects on the ecological stoichiometric characteristics of N and P in plants. The soil in high latitudes is relatively young, and the ability of parent rock to release P is strong, but the content of N is low, so plant growth is usually limited by N element; The soil in low latitudes is ancient, the ability of parent rock to release P is weak, the content of N is high, and plant growth is usually limited by P element (Reich & Oleksyn, 2004). In addition, when the availability of nutrients in the soil changes, plants will enhance their ability to obtain external nutrient resources by changing external morphology and regulating internal physiological functions (Fransen & De Kroon, 2001; Jackson et al., 1996). When soil N supply is insufficient, plants allocate more biomass to the belowground part to expand root growth, which helps roots to obtain more N (Song & Hou, 2020). The soil conditions of different deserts in China are quite different, and the soil total nitrogen and total phosphorus are lower than the national level. Therefore, desert plants may be limited by both N and P elements. The N and P contents of leaves, roots and litters of northern desert plants were positively correlated with soil N and P contents, indicating that their N and P stoichiometric characteristics were affected by soil factors. Therefore, it is of great significance to study the characteristics of N content, P content and stoichiometric ratio of plant leaves, stems, roots and soil for understanding the distribution of nutrients in various organs during plant growth, the utilization efficiency of soil nutrients and revealing the adaptation mechanism of plants to the environment (Wen et al., 2021).

Through the review of domestic and foreign research, it is found that domestic and foreign scholars have done a lot of work on the study of plant ecological stoichiometry in various ecosystems, and have achieved extremely fruitful research results. At present, the research mainly focuses on the stoichiometric characteristics of plant leaves, less attention is paid to stems and fine roots, and the research on the relationship between ecological stoichiometry of plant leaves, stems and roots and soil factors in desert ecosystems needs to be further strengthened. Taking the southern margin of Gurbantunggut Desert as a typical sample area, this paper focuses on the stoichiometric characteristics of N and P in leaves, stems and roots of H. ammodendron in different places of the south edge of Gurbantunggut Desert, in order to enrich the research results of plant ecological stoichiometry in desert ecosystem.

Gurbantunggut Desert is located in the center of the Junggar Basin and has a unique climate-soil-vegetation type diversity. It has typical scientific value for studying the ecological geographical pattern of plant stoichiometry and its driving mechanism (Zhang et al., 2020).*H. ammodendron* is the main constructive species and one of the most distinctive landscape vegetation in the Gurbantunggut Desert (Liu et al., 2021) . It plays an important role in maintaining the local ecological balance and plant community composition (Li et al., 2014). However, for half a century, environmental degradation, deforestation and overgrazing have led to the decline and even death of a large area of *Haloxylon Bunge* , which seriously threatened the stability of ecosystem function in Gurbantunggut Desert. In this study, the south edge of the Gurbantunggut Desert was taken as the research area. The characteristics of N content, P content and stoichiometric ratio of different organs (leaves, stems and fine roots) and soil of typical plant *H. ammodendron* in this area were studied. The correlation between the stoichiometric characteristics of*H. ammodendron* and soil factors was discussed in order to provide a scientific basis for revealing how plants in desert ecosystems adapt to the environment.

Materials and Methods

2.1 Study area

Gurbantunggut Desert is located in the center of the Junggar Basin in northern Xinjiang (44°11'-46°20'N, 84°31'-91°00'E). It is the second largest desert in China and the largest fixed and semi-fixed desert in China (Tian et al., 2022).

The study area is located in the south edge of the Gurbantunggut Desert. The terrain in this area is high in the northeast and low in the southwest, with an altitude of 400-700 m. It belongs to a typical temperate continental climate. It is hot and dry in summer and cold and long in winter. The annual average temperature is 5-5.7 °C, the maximum temperature is above 40 °C, the minimum temperature is below -40 °C, the annual evaporation is 2000-2800 mm, the annual precipitation is 80-160 mm, and the winter snow depth is 10-30

cm (Tursun et al., 2022). Desert soil is mainly fixed, semi-fixed sandy soil (Zhao et al., 2019), loose matrix, nutrient-poor. The main vegetation is *H. ammodendron* ,*Ephedra przewalskii Stapf* , *Artemisiadesertorum Spreng. Syst. Veg* ,*Ceratoideslatens* (*J. F. Gmel.*) *Reveal et Holmgren* , etc (Tan et al., 2021).

From west to east, 5 samples of Karamay, Kuitun, Shihezi, Fukang and Qitai were selected in the south of Gurbantunggut Desert (Table 1).

Table 1 Basic Situation of Sample Plot

Plot name	longitude (°E)	Latitude (°N)	Elevation (m)	MAT ()	MAP (mm)
Kuitun	84.86	44.85	295	8.70	118
Karamay	85.03	45.29	270	8.89	114
FuKang	88.30	44.52	499	7.63	169
Qitai	90.06	44.81	563	8.68	109
Shi hezi	85.15	44.72	366	9.07	122

2.2 Sampling methods

The sampling time of this study was July 2019. A 20 m × 20 m quadrat was set up in 5 samples, and the plants in the quadrat were collected in individual units, 10 replicates were collected in each quadrat, and the fresh weight was not less than 5 g. Aboveground organs were collected by branch shear method, and underground organs were collected by excavation method. Put the collected samples into a marked envelope and bring them back to the laboratory to determine the element content of each organ.

While collecting plant samples, soil samples were collected by S-type multipoint sampling method. Ten sampling points were set up in each quadrat, and 0-50 cm soil was mixed. After removing the roots, stones and other litters of the mixed soil samples, about 1 kg of average samples were retained and sealed in a numbered plastic bag.

2.3 Methods of sample treatment

The plant samples were dried to constant weight at 65 °C in an oven, and the dry weight of the plant samples was recorded. Each organ of the sample was ground with a pulverizer and passed through an 80-mesh sieve, weighed, bagged and sealed for the determination of N and P contents in*H. ammodendron* and the calculation of N:P ratio. The total nitrogen content of each organ of *H. ammodendron* was determined by Kjeldahl method, and the total phosphorus content was determined by molybdenum antimony colorimetry. The results of N and P determination were expressed as nutrient content per unit mass (mg/g).

The collected soil samples were air-dried, the plant roots and stones in the soil samples were removed, ground through a 60-mesh sieve, and bagged for testing. Soil samples measured indicators include : pH, conductivity, total nitrogen, total phosphorus. The soil pH was determined by redox potentiometer, and the soil conductivity was determined by electrode method; Soil total nitrogen and total phosphorus determination methods are the same as plants. Longitude, latitude and altitude data are measured using GPS during sampling.

2.4 Statistic methods

Excel 2019 and SPSS 26.0 were used for data preprocessing, drawing and statistical analysis of the experimental data; One-way analysis of variance was used to test the stoichiometric characteristics of N and P in the leaves, stems and roots of *H. ammodendron* and the difference of soil factors. Duncan 's method was used for multiple comparisons, the significance level of difference was 0.05; The relationship between stoichiometric characteristics of *H. ammodendron* organs and soil factors was tested by Pearson correlation analysis; The effects of different samples and organs on the stoichiometric characteristics of N and P in *H. ammodendron* use the general linear model to analyze the main factor effects and interactions.

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Results and analysis

3.1 Ecological stoichiometric characteristics of N and P in *H. ammodendron*

3.1.1 Characteristics of N content, P content and stoichiometric ratio in different organs of *H. ammodendron*

The N content, P content and stoichiometric ratio of *H. ammodendron* in the study area were analyzed by classical statistics. The results are shown in Table 2.The overall N and P contents of*H. ammodendron* ranged from 30.93 to 68.35 mg/g and from 1.96 to 5.54 mg/g, with an average of 48.72 and 2.82 mg/g, respectively. The range was 37.42 and 3.58 mg / g, respectively. By further analyzing the stoichiometric ratio of N and P in *H. ammodendron* , it can be seen that the range of N:P is 7.67-26.56, with an average of 17.97.

Table 2 Statistical analysis of ecological N and P stoichiometry of spindle spindle

	Parameter	Mean (mg/g)	SD	Range (mg/g)	Min (mg/g)	Max (mg/g)	Bias angle	Peak	CV
Leaf	N	19.80	4.41	20.19	10.10	30.29	-0.12	-0.11	0.2
	P	1.07	0.21	1.09	0.54	1.63	-0.21	0.82	0.2
	N:P	18.97	4.85	19.15	9.00	28.15	0.13	-0.76	0.2
	N	16.68	5.06	20.91	7.90	28.81	0.59	0.29	0.3
Stem	P	0.96	0.57	2.72	0.51	3.23	3.28	10.53	0.5
	N:P	20.91	9.36	36.94	2.69	39.63	0.27	0.00	0.4
	N	12.25	4.95	20.41	4.76	25.17	1.29	1.82	0.4
Root	P	0.79	0.18	0.77	0.44	1.21	0.16	-0.56	0.2
	N:P	16.05	5.89	20.98	5.80	26.78	0.01	-0.88	0.3
	N	48.72	10.18	37.42	30.93	68.35	0.25	-0.98	0.2
Whole	P	2.82	0.70	3.58	1.96	5.54	2.79	8.23	0.2
	N:P	17.97	4.71	18.89	7.67	26.56	-0.25	-0.40	0.2

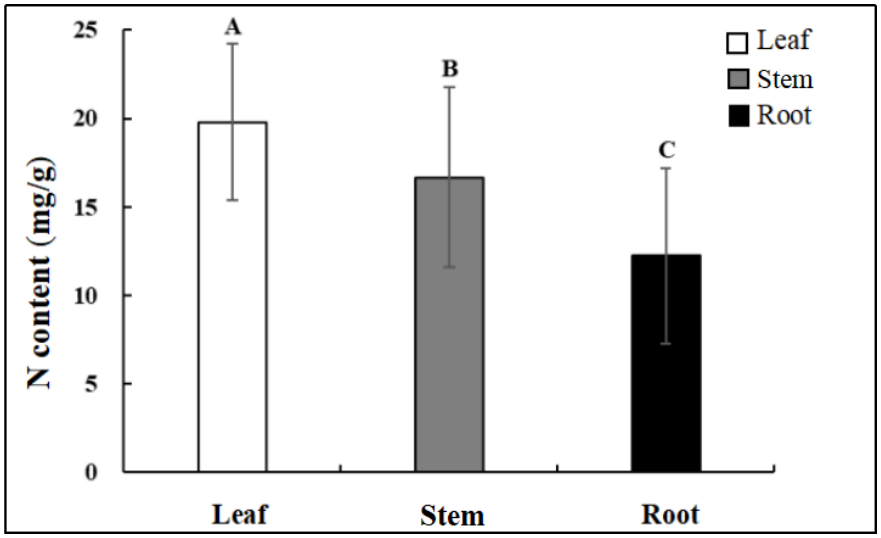
The N content, P content and stoichiometric ratio of *H. ammodendron* leaves in the study area were analyzed by classical statistics. The results are shown in Table 2. The variation range of N content and P content in *H. ammodendron* leaves were 10.10-30.29 mg/g, 0.54-1.63 mg/g, respectively. The average values were 19.80 mg/g and 1.07 mg/g, respectively. By further analyzing the stoichiometric ratio of N and P in leaves, it was found that the N:P ranged from 9.00 to 28.15, with an average of 18.97. The variation coefficients of N content, P content and N:P in *H. ammodendron* leaves were all greater than 0.1, which were moderate variation.

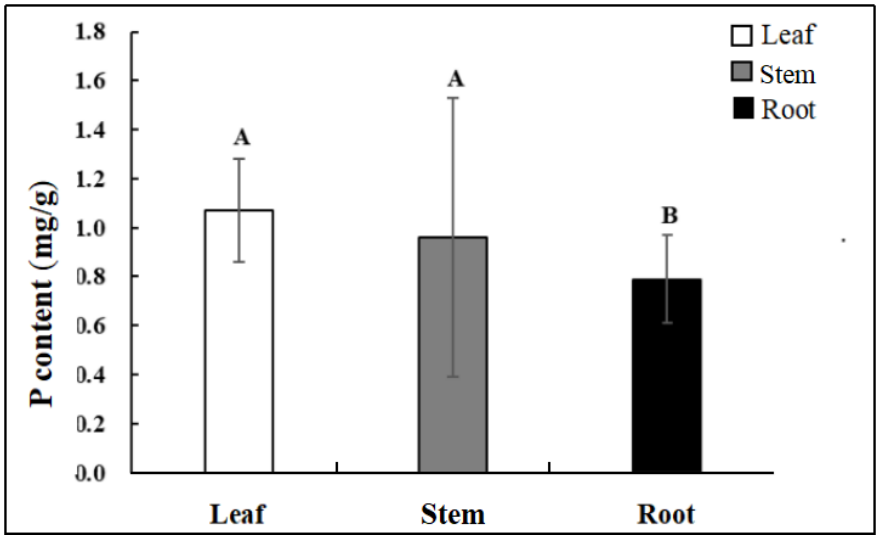
The N content, P content and stoichiometric ratio of *H. ammodendron* stems in the study area were analyzed by classical statistics. The results are shown in Table 2. The variation range of N content and P content in *H. ammodendron* stems were 7.90-28.81 mg/g, 0.51- 3.23 mg/g, respectively. The average values were 16.68 mg/g and 0.96 mg/g, respectively. By further analyzing the stoichiometric ratio of N and P in *H. ammodendron* stems, it can be seen that the range of N:P was 2.69-39.63, with an average of 20.91. The variation coefficients of N content, P content and N:P in *H. ammodendron*stems were all greater than 0.1, which were moderate variation.

The N content, P content and stoichiometric ratio of *H. ammodendron* roots in the study area were analyzed by classical statistics. The results are shown in Table 2. The variation range of N and P contents in *H. ammodendron* roots were 4.76-25.17 mg/g and 0.44-1.21 mg/g, respectively. The average values were 12.25 mg/g and 0.79 mg/g, respectively. By further analyzing the N and P stoichiometry of *H. ammodendron* roots, it can be seen that the N:P ratio ranged from 5.80 to 26.78, with an average of 16.05. The variation coefficients of N content, P content and N:P in *H. ammodendron* roots were all greater than 0.1, which were moderate variation.

The N content, P content and stoichiometric ratio of each organ of*H. ammodendron* were analyzed by one-way anova and multiple comparisons. The results are shown in Figure 1. There were differences in N content, P content and their stoichiometric ratios in different organs of *H. ammodendron.*

N content and P content showed the trend of leaves > stems > roots. The N content of leaves was significantly higher than in stems and roots (p >0.05), and the P content was significantly higher than in roots (p >0.05). The N and P contents in stems were significantly higher than in root (p >0.05). The N:P of leaves and stems was significantly higher than in roots (p >0.05), and the order was stems > leaves > roots.





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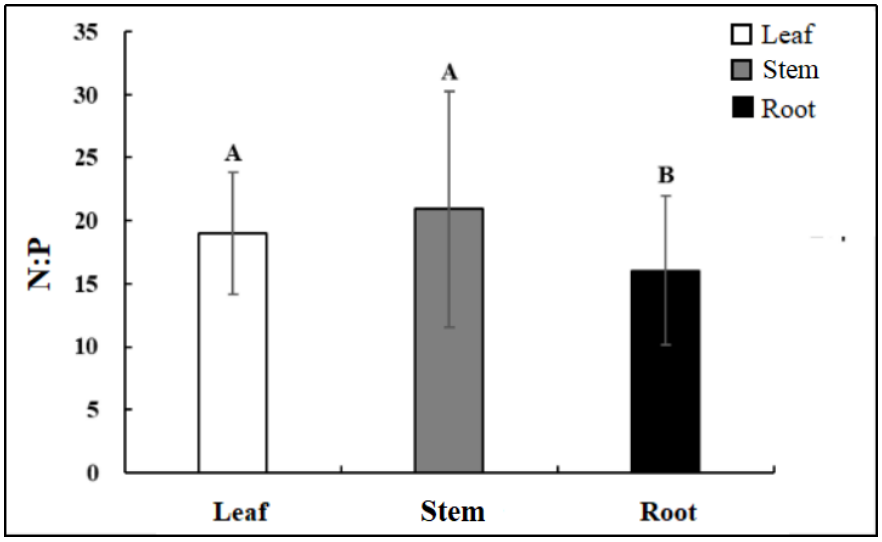


Figure 1 Stoichiometric Characteristics of N and P in Different Organs of *H. ammodendron*

Note: Different capital letters indicate significant differences between different organs of the same index($p<$ 0.05)

3.1.2 Ecological stoichiometric characteristics of N and P in different organs of *H. ammodendron*

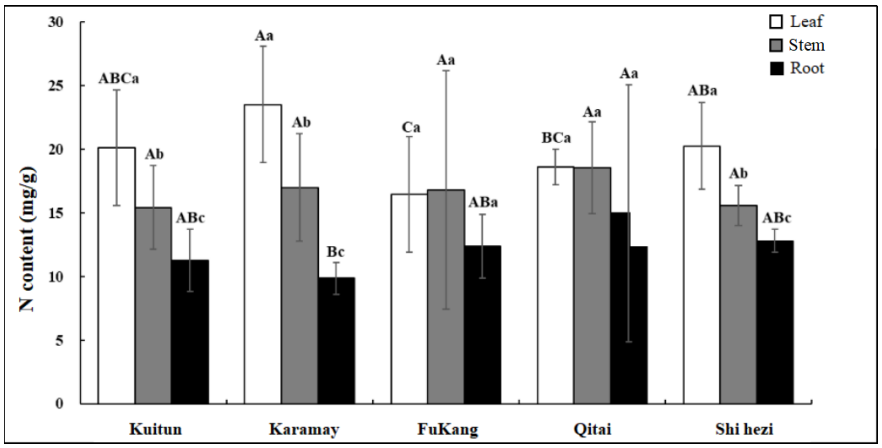
The N content, P content and stoichiometric ratio of different organs of*H. ammodendron* were analyzed by one-way anova and multiple comparisons. The results are shown in Figure 2. There were differences in N and P contents in different organs of *H. ammodendron.*

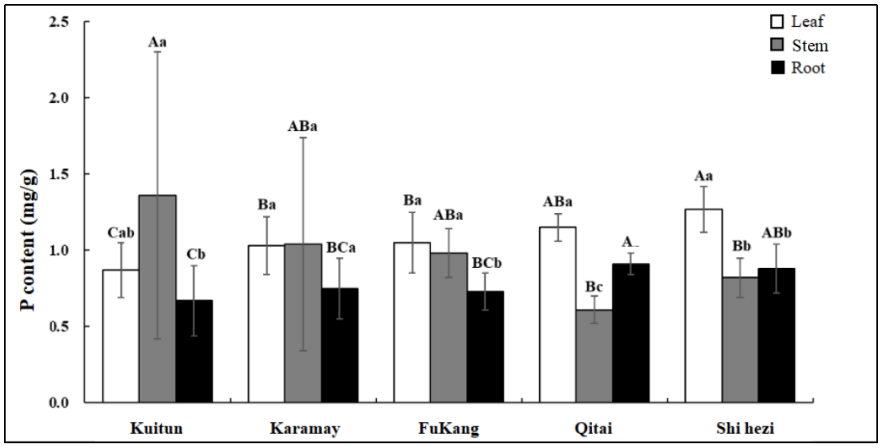
The N content of *H. ammodendron* in Kuitun, Karamay and Shihezi showed a trend of leaves > stems > roots. The N content of leaves was significantly higher than stems (p <0.05), and the N content of stems was significantly higher than roots. There was no significant difference in N content in different organs of *H. ammodendron* in Fukang and Qitai (p >0.05). The N content in Fukang was stems > leaves > roots, while that in Qitai was leaves > stems > roots. The N content of leaves in Karamay was significantly higher than in Fukang and Qitai (p <0.05). There was no significant difference in the N content of *H. ammodendron* stems among the 5 samples (p >0.05), and the N content of *H. ammodendron*roots in Qitai was significantly higher than in Karamay (p <0.05).

The P content of *H. ammodendron* in Kuitun and Karamay showed stems > leaves > roots, and the P content of*H. ammodendron* stems was significantly higher than that of roots (p >0.05). Qitai and Shihezi showed a trend of leaves > root s> stems. The P content of each organ of *H. ammodendron* in Qitai was significantly different ($p<0.05$), and the P content of leaves in Shihezi was significantly higher than that of stems and roots (p <0.05). The P content of Fukang was leaves > stems > roots, and the P content of leaves and stems was significantly higher than that of roots ($p<$ 0.05). In the 5 samples, the P content of leaves in Shihezi was significantly higher than in Fukang, Karamay and Kuitun, and the P content of leaves in Fukang and Karamay was significantly higher than in Kuitun (p <0.05).The P content in stems of kuitun was significantly higher than in Qitai and Shihezi (p <0.05). The P content of *H. ammodendron* roots in Qitai was significantly higher than in Kuitun, Karamay and Fukang, and the P content of *H. ammodendron* roots in Shihezi was significantly higher than in Kuitun (p <0.05).

The N:P of *H. ammodendron* in Qitai and Shihezi showed a trend of stems > leaves > roots, and the N:P of stems was significantly higher than that of leaves and roots (p <0.05). The N:P of leaves in Kuitun was significantly higher than that of stems, and leaves > roots > stems (p <0.05), The N:P of leaves and stems in Karamay was significantly higher than that of roots, and leaves > stems > roots (p <0.05). There was no

significant difference in N:P in different organs of*H. ammodendron* in Fukang, and stems > roots > leaves (p >0.05). Among the 5 samples, the N:P of leaves in Kuitun and Karamay was significantly higher than in Fukang, Qitai and Shihezi, and the N:P of stems in Qitai was significantly higher than in the other 4 samples ($p<0.05$). There was no significant difference in N:P of*H. ammodendron* roots in 5 samples (p >0.05).





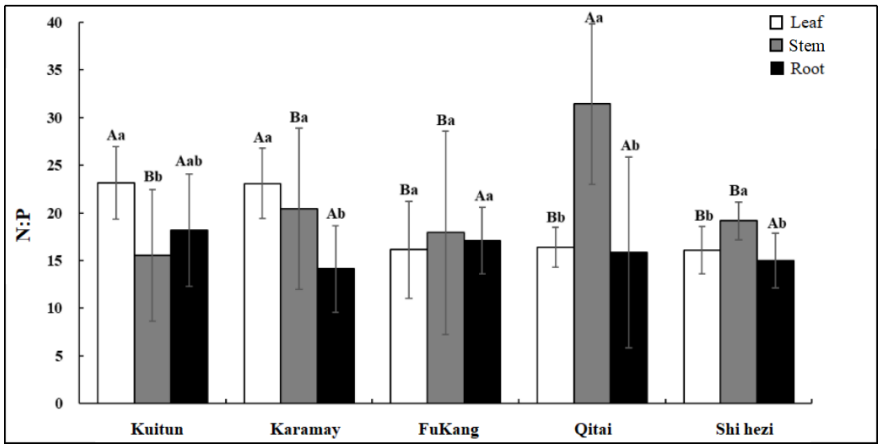


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Figure 2 Ecological Stoichiometric Characteristics of N and P in Different Organs of *H. ammodendron*

Note: Different capital letters indicate that the difference between the same organ is significant; different lowercase letters indicate significant differences between different organs in the same place($p< 0.05$)

3.2 Relationship between N, P stoichiometric characteristics of *H. ammodendron* and soil factors

3.2.1 Different soil factors

One-way anova analysis of variance and multiple comparisons were performed on soil factors in different samples. The results are shown in Table 3. There were significant differences in soil P content, N:P, pH and electrical conductivity among different samples (p >0.05). The soil P content in Qitai was significantly higher than in other samples (p <0.05), Fukang soil N:P was significantly higher than other samples (p <0.05), Karamay soil N:P was significantly higher than Kuitun, Qitai and Shihezi (p <0.05). The soil pH in Karamay and Qitai was significantly higher than in other samples (p <0.05). The soil electrical conductivity of Qitai was significantly higher than that of other samples, and that of Shihezi was significantly higher than that of Kuitun, Karamay and Fukang (p <0.05).

Table 3 One-way analysis of variance and multiple comparisons of soil factors in different sample plots

Plot	Index	TN	TP	N:P	pH	EC
Kuitun	Mean(mg/g)	0.82^{a}	0.46^{b}	1.80^{c}	8.71^{b}	0.96^{c}
	SD	0.57	0.32	0.50	0.53	0.54
Karamay	Mean(mg/g)	1.25^{a}	0.51^{b}	3.54^{b}	9.12^{a}	0.50^{c}
	SD	1.43	0.39	2.45	0.08	0.41
FuKang	Mean(mg/g)	2.16^{a}	0.42^{b}	5.19^{a}	8.46^{b}	0.85^{c}
	SD	2.56	0.49	2.12	0.19	0.43
Qitai	Mean(mg/g)	1.51^{a}	3.11^{a}	0.84^{c}	9.1^{a}	11.84^{a}
	SD	0.27	2.29	0.54	0.34	1.50
Shi hezi	Mean(mg/g)	2.10^{a}	1.38^{b}	1.55^{c}	8.68^{b}	4.45^{b}
	SD	0.56	0.46	0.11	0.13	6.38

Note: Different lowercase letters indicate significant differences between different plots for the same soil factor($p< 0.05$)

3.2.2 Relationship between N, P ecological stoichiometry in different organs of *H. ammodendron* and soil factors

The correlation analysis of N content, P content and N:P with soil factors in different organs is shown in Table 4. On the whole, the N content, P content and N:P of each organ were only significantly correlated with soil total nitrogen and total phosphorus (p <0.05), but not significantly correlated with soil N:P, pH and conductivity (p <0.05). The results showed that N content of leaves and P content of roots were significantly positively correlated with soil N content (p <0.05), and N content and N:P of stems were significantly positively correlated with soil N content (p <0.01). The P content of leaves and roots was significantly positively correlated with soil P content (p <0.05), the P content of stems and the N content of roots were significantly negatively correlated with soil P content (p<0.05), and the N:P of roots was significantly negatively correlated with soil P content (p <0.01).The P content of leaves was significantly negatively correlated with soil N:P (p <0.05), and the P content of roots was significantly negatively correlated with soil N:P (p <0.01).There was no significant correlation between N:P of leaves and soil N content, P content and N:P (p <0.05). There was no significant correlation between stem indexes and soil N:P and pH (p <0.05).There was no significant correlation between N content in each organ and soil pH (p <0.05). The N:P of leaves was significantly negatively correlated with soil pH (p <0.01), and the P content of roots was significantly positively correlated with soil pH (p <0.05). The P content of leaves was significantly positively correlated with soil electrical conductivity (p <0.05), N:P was significantly negatively correlated with soil

electrical conductivity ($p < 0.01$), and the N content of stems was significantly negatively correlated with soil electrical conductivity ($p < 0.05$). There was no significant correlation between root indexes and soil electrical conductivity (p <0.05).

Table 4 Pearson correlation analysis of N, P ecological stoichiometric characteristics in different organs of *H. ammodendron* and soil factors

Organ	Index	TN	TP	N:P	pH	EC
Leaf	N	0.35*	0.02	-0.28	-0.25	-0.18
	P	0.17	0.36*	-0.30*	0.23	0.34*
	N:P	0.16	-0.26	-0.02	-0.37**	-0.41**
Stem	N	0.78**	0.08	0.03	-0.04	-0.32*
	P	-0.23	-0.29*	0.02	-0.09	-0.05
	N:P	0.51**	0.26	-0.14	0.11	-0.27
Root	N	0.05	-0.35*	-0.09	0.03	-0.03
	P	0.30*	0.28*	-0.41**	0.41**	0.07
	N:P	-0.17	-0.56**	0.17	-0.26	-0.07

Note: *,p< 0.05;**,p ¡0.01。

3.3 Effects of samples and organs on the ecological stoichiometric characteristics of N and P in *H. ammodendron*

Through general linear model analysis, the effects of samples and organs on the ecological stoichiometric characteristics of N and P in *H. ammodendron* were quantified. The results are shown in Table 5. The effect of organs on the N content, P content and N:P of *H. ammodendron* was significant (p <0.01), and the samples only had significant effect on N:P (p< 0.05). The interaction between samples and organs had significant effects on N content (p< 0.05), and extremely significant effects on P content and N:P (p <0.01).

Table 5 General Linear Model Analysis of Effects of Organs and Sampling Areas on N and P Ecological Stoichiometry of *H. ammodendron*

Independent variable	Dependent variable	Quadratic sum	Freedom	Mean square	Statistic	Significance
Site	N	92.82	4.00	23.21	1.07	0.37
	P	0.19	4.00	0.05	0.43	0.79
	N:P	395.37	4.00	98.84	2.70	0.03*
Organ	N	1437.40	2.00	718.70	33.17	0.00**
	P	2.05	2.00	1.02	8.99	0.00**
	N:P	599.80	2.00	299.90	8.19	0.00**
Sitet×Organ	N	385.78	8.00	48.22	2.23	0.03*
	P	4.15	8.00	0.52	4.56	0.00**
	N:P	1799.08	8.00	224.89	6.14	0.00**

Note: *,p<*0.05* ;**,p ¡0.01。

4.Discussion

4.1 Changes of N and P stoichiometric characteristics in different organs of

H. ammodendron

The average content of N and P in the leaves of *H. ammodendron* in the study area (19.80 mg/g, 1.07 mg/g) was lower than the average level of N and P in the leaves of terrestrial plants (20.60 mg/g, 1.99 mg/g) (Tan et al., 2021), and the average level of N and P in the leaves of terrestrial plants in China (20.20 mg/g, 1.46

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mg/g) (Ding & Cong, 2021), indicating that the nutrient content of *H. ammodendron*leaves in this area is low. Leaves are organs for photosynthesis to produce organic matter. *H. ammodendron* grows rapidly in summer, requiring leaves to produce more organic matter to meet the needs of plant growth. Therefore, the absorption of N and P in leaves increased and the accumulation of N and P in leaves was generally higher than in stems and roots (Han et al., 2005; Wei, 2000; Elser et al., 2000). The metabolic activity of stems was stronger than that of roots, so the N and P contents of stems were lower than those of leaves, but higher than those of roots (Makino et al., 2003). The metabolic level of roots is low, and the absorbed nutrients are also supplied to other organs and parts while maintaining their own growth, so the N content and P content in roots are the lowest. N:P is closely related to plant growth rate and soil resource availability (Xiao et al., 2014; Makino et al., 2003; Qian et al., 2002). The precipitation in the study area is scarce, the soil is barren, and plants need to absorb water and nutrients from deep soil (Paige & Michaeleen, 2020; Sun et al., 2020; Chen et al., 2016). Plant N:P can be used to determine the nutrient supply of plant growth by the environment (Chen et al., 2016; Lv et al., 2015), N:P¡14,plant growth is mainly limited by N ; N:P¿16,Plant growth is mainly limited by P (Han et al., 2005; Elser et al., 2000). The N:P of *H. ammodendron*plants and organs in the study area was higher than 16, indicating that*H. ammodendron* in the study area was more limited by P than N (Nie et al., 2022; Li et al., 2019). In this study, the N:P in leaves and stems of *H. ammodendron* was significantly higher than in roots, which may be resulted from the higher utilization efficiency of N and P in aboveground parts (Kerkhoff et al., 2006).

4.2 The relationship between N, P stoichiometric characteristics of *H. ammodendron* organs and soil factors

Soil total nitrogen was significantly positively correlated with the N content of *H. ammodendron* leaves and extremely significantly positively correlated with the N content of stems, indicating that the N of *H. ammodendron* leaves and stems mainly came from soil total nitrogen. The growth and metabolism of these two organs were greatly affected by soil N , and the change of soil nutrient content had a greater impact on stems (Hogberg et al., 2006). Soil total phosphorus was significantly positively correlated with P content in leaves and roots of *H. ammodendron* , negatively correlated with P content in stems, indicating that soil P limited the growth of leaves and roots. Except for the P content in leaves and roots of *H. ammodendron* , there was no significant correlation between soil N:P and N, P ecological stoichiometry in different organs of *H. ammodendron* , indicating that soil nutrient stoichiometry had little direct effect on the organs of *H. ammodendron* , which may be due to the fact that*H. ammodendron* was limited by both water and nutrient elements, and formed unique ecological stoichiometry and physiological and ecological habits after long-term evolution (Liu & Wang, 2020). Soil pH affects the solubility of mineral salts, which in turn affects the effectiveness of soil nutrients (Bell et al., 2014). The soil in the study area is alkaline, which affects the release of N and P. Therefore, soil pH is generally negatively correlated with different indicators of various organs of *H. ammodendron* . Soil electrical conductivity reflects the salt content in soil (Bell et al., 2014; Matzek & Vitousek, 2009; Reich et al., 2009; Craine et al., 2008). When the soil salt content is high, the soil osmotic pressure increases, and it is more difficult for roots to absorb water and salt. Therefore, soil electrical conductivity is generally negatively correlated with N and P stoichiometric characteristics of leaves, stems and roots. The above showed that the ecological stoichiometric characteristics of N and P in*H. ammodendron* were affected by organs and soil factors.

4.3 Effects of samples and organs on ecological stoichiometric characteristics of N and P in *H. ammodendron*

In this study, the ecological stoichiometric characteristics of N and P in *H. ammodendron* were mainly affected by organs and the interaction between samples and organs. Samples only had a significant effect on N:P content of *H. ammodendron* . The effects of sampling sites on the ecological stoichiometric characteristics of N and P in*H. ammodendron* may be related to external environmental factors, such as topography and soil (Abbas et al., 2013; Agren & Weih, 2012; Sardans et al., 2012; Cuassolo et al., 2012). The effects of organs on the ecological stoichiometric characteristics of N and P in *H. ammodendron* may be related to its own structural characteristics and genetic characteristics. Studies have shown that plants respond to changing environments by regulating the nutrient content and proportion of each organ (Sun et al., 2020). Therefore, the effect of organs on N content, P content and N:P of *H. ammodendron* was significant, but the effect of

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samples on N:P was also significant, which indicated that the ecological stoichiometric characteristics of N and P of *H. ammodendron* in this study were affected by the single factor of samples and organs and the interaction of two factors.

5.Conclusion and prospect

5.1 Conclusions

In this paper, *H. ammodendron* in five areas of Gurbantunggut Desert was selected as the research object. Combined with mathematical statistics method, the N content, P content and N:P characteristics of*H. ammodendron* leaves, stems and roots were calculated and compared. The relationship between N, P ecological stoichiometry characteristics of *H. ammodendron* organs and soil factors was analyzed. It was found that the differences of N, P content and N:P in different organs of *H. ammodendron* were significant, and the trend of each index was roughly the same. The overall trend was that the leaves were relatively high, followed by the stems, and the roots was generally low. The N content of each organ of *H. ammodendron* was significantly positively correlated with soil total nitrogen. The P content of leaves and roots was significantly positively correlated with soil total phosphorus, and the P content of stems was significantly negatively correlated with soil total phosphorus. P content in different organs was negatively correlated with soil N:P. The N content, P content and N:P in different organs generally showed a certain negative correlation with soil pH and electrical conductivity, and the organs had a greater impact on the N content, P content and N:P of *H. ammodendron.*

5.2 Limitations and prospects

The time period of this study is short, and only the *H. ammodendron* in the southern margin of the Gurbantunggut Desert was studied. The spatial and temporal distribution of the overall ecological stoichiometric characteristics of desert plants in the region was not studied in depth. The research on the ecological stoichiometric characteristics of various elements in various organs of desert plants can reveal the distribution characteristics of ecological stoichiometric characteristics of desert plants and the adaptability of desert plants to the environment in more detail, and the follow-up work needs to be further refined. In addition, this study only combines some soil factors (soil N, P content, pH, conductivity). In the later study, more environmental factors (such as annual rainfall and annual average temperature) need to be combined.

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