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Postprint: Soil Fertility Quality Assessment of Qinghai Spruce Forests in the Middle Qilian Mountains

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Abstract

This study investigated the Qinghai spruce forest in the Pailugou watershed of the Qilian Mountains, examining the distribution characteristics and variation patterns of soil fertility factors along elevation gradients, and evaluated the soil fertility status using principal component analysis. The results showed that: (1) Soils in the study area were alkaline, with pH values all greater than 8.0; in high-altitude areas (3300 m), water content reached a supersaturated state, with water content in all soil layers exceeding 100%; with increasing elevation, total nitrogen content showed an increasing trend, total potassium content showed a decreasing trend, while total phosphorus content showed a trend of first decreasing then increasing; available phosphorus content did not differ significantly among different elevation gradients ($P>0.05$), while available potassium content at 3300 m elevation was significantly higher than at other elevations ($P<0.05$). (2) The contents of soil organic matter, total nitrogen, total phosphorus, total potassium, available phosphorus, and available potassium all showed obvious "surface accumulation effects" across different elevation gradients, among which organic matter content in the 0-10 cm soil layer at 3300 m reached as high as 325.93 g·kg-1, being 1.6-1.8 times that of other soil layers at the same elevation and 1.3-2.0 times that of the same soil layer at other elevations. (3) Soil fertility factors were closely related: soil water content was extremely significantly positively correlated with organic matter and total nitrogen, extremely significantly negatively correlated with soil bulk density, pH, and total potassium, and significant positive correlations of varying degrees existed among soil nutrient contents. (4) Soil fertility quality across different elevation gradients was ranked as: 3300 m > 3200 m > 3100 m > 3000 m > 2900 m.

Full Text

2. Soil Physical and Chemical Properties

2.1 Basic Soil Characteristics

The soils in the study area were alkaline, with pH values exceeding 8.0. In the high-altitude zone (3300 m), soil water content reached supersaturated conditions, with values exceeding 100% across all layers. With increasing altitude, total nitrogen content showed a gradual increasing trend, total potassium content gradually decreased, and total phosphorus content initially decreased then increased. Available phosphorus content showed no significant differences among altitudes ($P > 0.05$), whereas available potassium content at 3300 m was significantly higher than at other elevations ($P < 0.05$).

Soil organic matter, total nitrogen, total phosphorus, total potassium, available phosphorus, and available potassium all exhibited pronounced "surface accumulation effects" across the altitudinal gradient. At 3300 m, the organic matter content in the 0–10 cm soil layer reached 325.93 g·kg ¹, representing values 1.6–1.8 times higher than in deeper layers at the same altitude, and 1.3–2.0 times higher than the same layer at lower altitudes.

Soil fertility parameters demonstrated close intercorrelations. Soil water content was positively correlated with organic matter and total nitrogen, while showing negative correlations with bulk density, pH, and total potassium. Significant positive correlations existed among various soil nutrient contents.

The comprehensive soil fertility quality ranking across altitudes was: 3300 m > 3200 m > 3100 m > 3000 m > 2900 m.

[TABLE 2]

Table 2 Descriptive statistics of soil physico-chemical properties at different altitudes (0–60 cm)

Note: The original table contained extensive data on water content, bulk density, pH, organic matter, total nitrogen, total phosphorus, total potassium, available phosphorus, and available potassium across five altitudinal zones and four soil depths. Different lowercase letters denote significant differences among altitudes ($P < 0.05$).

2.2 Distribution Patterns

The vertical distribution patterns of soil water content and bulk density across altitudes are illustrated in [FIGURE 3]. [FIGURE 4] depicts the distribution characteristics of soil pH and organic matter, while [FIGURE 5] shows the distribution of soil phosphorus and potassium.

[FIGURE 3]

Fig. 3 Distribution characteristics of soil water content and bulk density in different soil layers at various altitudes

[FIGURE 4]

Fig. 4 Distribution characteristics of soil pH and organic matter in different soil layers at various altitudes

[FIGURE 5]

Fig. 5 Distribution characteristics of soil phosphorus and potassium in different soil layers at various altitudes

2.3 Soil Fertility Assessment

2.3.1 Principal Component Analysis Principal component analysis extracted three components, with the first component accounting for 87.671% of the total variance. The first principal component was primarily associated with soil water content, organic matter content, and pH.

[TABLE 4]

Table 4 Principal component loadings for soil fertility parameters

Parameter	PC1	PC2	PC3
Water Content	0.102	0.031	-0.267
Bulk Density	-0.259	0.083	-0.081
pH	0.142	-0.134	0.586
Organic Matter	0.276	-0.023	0.138
Total N	0.263	0.003	0.120
Total P	-0.210	0.528	-0.276
Total K	-0.300	0.173	-0.053
Available P	0.030	0.296	0.401
Available K	0.017	0.363	0.062

Note: Variables X through X represent water content, bulk density, pH, organic matter, total nitrogen, total phosphorus, total potassium, available phosphorus, and available potassium, respectively.

[TABLE 6]

Table 6 Comprehensive fertility quality scores for Picea crassifolia at different altitudes

Altitude (m)	Comprehensive Score	Rank
3300	2.254	1
3200	1.120	2
3100	0.398	3

Altitude (m)	Comprehensive Score	Rank
3000	-0.057	4
2900	-0.803	5

The principal component analysis revealed that soil fertility quality was highest at 3300 m, as evidenced by the maximum comprehensive score of 2.254.

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