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Changes in Carbon, Nitrogen and Phosphorus Stoichiometry of Leaf-Litter-Soil in Differently Stands Under 'Plain Afforestation Program' in China

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ABSTRACT

Changes in land use might affect the combined C, N, and P stoichiometry in soil. The Plain Afforestation Program, which converts low-yield croplands or abandoned lands into forest, shrub, and/or grassland, was a famous land reforestation project in Beijing. To clarify the spatial distribution, stoichiometric characteristics, and controlling factors of carbon (C), nitrogen (N), and phosphorus (P), four typical Plain Afforestation forests including *Robinia pseudoacacia*, *Pinus tabuliformis*, *Ailanthus altissima*, and *Salix matsudana* plantations were selected in Yongding River plain afforestation area, Beijing. Leaf, litter, and soil C, N, and P concentrations and their stoichiometric relationships were analyzed. The results showed that the concentrations of N and P in the four plantations were in order of *R. pseudoacacia*>*A. altissima*>*S. matsudana* >*P. tabuliformis* in leaf and litter. Compared with leaves, the concentrations of C for *P. tabuliformis* were highest. The concentrations of N and P, as well as N:P for R. pseudoacacia plantation, were significantly higher than those for the other plantations. C and N concentrations were the highest in surface soil (0-10 cm), and C:N and C:P both demonstrated the trend of litter>soil in the plantations with the exception of *S. matsudana*. The total N concentration of leaf was positively correlated with that of litter in the four plantations. Overall, our findings suggested the growth of *R. pseudoacacia*, *P. tabuliformis*, and *S. matsudana* was mainly restricted by P, while that of *A. altissima* was constrained by N. In addition, it is a feasible method that uses nitrogen fertilizer when tending the artificial forest in the plain area.

INTRODUCTION

Stoichiometry is a science that studies the balance of multiple chemical substances in biological systems and ecological processes in the context of ecology (Drenovsky et al. 2019). Elser et al. (2007) have extensively explored the causes and consequences of these constraints under the terminology of ecological stoichiometry. The study of the Stoichiometry measurement ratio of vegetation carbon (C), nitrogen (N), phosphorus (P), and the level of community nutrient supply can reveal the relationship between nutrient supply characteristics and vegetation development in various regions (Agren 2004). The ratio of nitrogen and phosphorus is a very important indicator of the absorption ability of N and P elements by plants (Cleveland & Liptzin 2007). There is considerable empirical evidence that the change of C, N, and P in the soil can feed back the effectiveness of soil nutrients, and the change of C, N, and P in leaf also affects soil nutrients (Elser et al. 2003, Güsewell et al. 2006, Brant et al. 2015). Ecological stoichiometry has provided an integrative solution to measure changes in C, N, and P within a plant at a time (Makino et al. 2003). Changes in C:N and C:P influence C fixation and exhaustion in diverse ecosystems, thus making both ratios important indices to assess N or P use efficiency. Previous research has highlighted a diverse set of geochemical and ecological factors that can influence the identity and nature of C:N:P stoichiometry in particular ecosystems (Tessier & Raynal 2003). It is reasonable that the ratios of nutrients in the plant tend to be constant finally in a specific situation and may vary as the environment changes (Fanin et al. 2013). In monoculture plantation environments, stand age is key because of nutrient transformations from leaves, litter, and soil over time scales of 10-20 years. At present, most knowledge about the change in the ecological stoichiometry of elements is derived from studies across space, while only a few are touched. Many studies demonstrated the interactions between the season, vegetation type, and structure (See et al. 2015). Soil nitrogen affects phosphorus recycling: foliar resorption and plant-soil feedbacks in a northern hardwood forest. Ecology 96: 2488-2498), and soil properties affect microbial nutrient immobilization under a Mediterranean-type climate to influence the biogeochemical cycles for C, N, and P in Mediterranean forest ecosystems (Wright et al. 2010). To date, studies on the soil C, N, and P stoichiometry at different scales are lacking, and information about their influences on the global or regional scale is scarce, particularly in China.

In China, widespread ecological degradation has constrained sustainable socio-economic development in recent decades, particularly before the end of the 20th century (Fu et al. 2002). Since the 1950s (Uchida et al. 2009, Zhao et al. 2014), the Chinese government has made great efforts to afforestation and restore ecosystems (Chang et al. 2011, Bui & Henderson 2013). More than 9.27 million ha of cropland and abandoned land have been afforested in China through the "Plain Afforestation Program" (PAP). The afforestation area in the afforestation Plain of north China lacks available phosphorus, and the rapid development of industrialization and urbanization in this area leads to the phenomenon of high nitrogen deposition (Lü 2012, Cui et al. 2015). The status and ratio characteristics of nitrogen and phosphorus in vegetation and soil need to be further studied. Although the initial goal of the PAP was to control soil erosion, the program strongly affects the C, N, and P cycling in soil. However, few studies have reported the soil C, N, and P stoichiometries under PAP. To clarify the spatial distribution, stoichiometric characteristics, and controlling factors of carbon (C), nitrogen (N), and phosphorus (P), four typical forests including *Robinia pseudoacacia* (*R. pseudoacacia*)*, Pinus tabuliformis* (*P. tabuliformis*)*, Ailanthus altissima* (*A. altissima*), and *Salix matsudana* (*S. matsudana*) plantations were selected in Yongding River plain afforestation area, Beijing. This study aims to accomplish the following: a) illustrate the distribution of the soil C:N, C:P, N:P values under the PAP; b) establish the changes in the soil C:N, C:P, N:P values after the change in land use; and c) study the factors driving the changes in the C:N, C:P, N:P ratios.

MATERIALS AND METHODS

Study Area

The study area is located in Beijing (39°30′13.99″ N, 116°15′26.54″ E). It features 30-45 m above sea level. The climate of this area belongs to a warm temperate semi-arid continental monsoon climate. The annual average temperature is 11.5°C, the precipitation is 568.9 mm, the rainfall is mainly concentrated in July and September, and the annual average humidity is 63%-68%. Before the implementation of the plain forest construction, the study area was the sand wasteland, the lotus root land of potholes, and the land for conversion of farmland to forest. Its own land force is relatively weak compared with the natural forest, mainly distributed in light loamy brown tide soil and sandy loam soil, and the pH value is 8.8-9.1. The forests are all same age(6a), including *R. pseudoacacia*, *P. tabuliformis*, *A. altissima*, *S.matsudana*, *Ginkgo biloba*, *Acer truncatum*, and *Ulmus pumila* (Table 1).

Plant Sampling

Each tree in the selected quadrat was measured to measure the altitude, longitude, latitude, soil thickness, planting density, average tree height, and average crown in August 2019. Three standard trees were randomly selected in each standard quadrat. Each standard tree was collected from four directions of the upper, middle, and lower three levels of the crown with a high branch as a sample, the mature leaves with healthy growth were used. According to the five-point method of plum blossom, a representative 100 cm × 100 cm litter quadrat is set under each quadrat to collect litter. At the end of September, two layers of soil (0-30 cm due to the shallow soil layer in the study area) are collected at the place where litter samples are collected). After the soil sample is fully mixed, the soil sample of the afforestation site is collected outside the afforestation area according to the same method.

Measurement and Calculation

The litter in the samples was harvested using the harvest method, weighed after being mixed, marked for drying in an oven at 8^{o}C, and the leaves and litter were crushed by a plant crusher. The mixed soil sample of topsoil (0-10 cm) was taken from the sample of litter using the soil drilling method. After the soil sample was air-dried, stones, roots, and other impurities were removed, and ground using a 0.16 mm mesh screen. Organic C was measured by the potassium dichromate / sulphuric acid mixture titration method. Total N was measured by using the semi-micro Kjeldahl method with a Kjeldahl Auto-analyser (KDN-102C, Shanghai, China). Total P was measured by using the HNO3 digest-Mo-Sb antispetrophotography method with a spectrophotometer (UV-2102 PCS, Shanghai, China) (Table 2). The ecological

Table 1: Basic status of sampling sites.

Plantation type	Altitude [m]	Average DBH [cm]	Average tree height [m]	Canopy density
R. pseudoacacia	40	13.6	5.8	0.78
A. altissima	41	13.3	6.9	0.85
P. tabllaeformis	38	11.1	5.1	0.65
S. matsudana	36	17.1	11.1	0.80

stoichiometric ratios of C, N, and P were calculated as organic C vs. total N (C:N), organic C vs total P (C:P), and total N vs. total P (N:P).

Statistical Analysis

Excel 2016 was used for mapping, SPSS 19.0 was used for one-way variance analysis and Pearson correlation analysis, Duncan's test method was used for LSD multiple comparisons of relevant indexes, and the differences in stoichiometric ratios among stands and between cuts were analyzed using One-Way ANOVAs. Where there were no significant effects, the average was compared using a One-Way ANOVA. and $P = 0.05$ was used as the benchmark for a significant difference.

RESULTS

Contents and Stoichiometric Ratio of C, N, and P in Leaves of Different Forests

Fig. 1 shows that the content of C in leaves of *R. pseudoacacia, P. tabuliformis, A. altissima, and S.matsudan* forest were 354.19, 331.67, 393.23, and 411.21 g.kg^{-1}, respectively. The leaf N content of *R. pseudoacacia* forest, *Ailanthus altissima* forest, *P. tabulaeformis* forest, and *S. matsudana* forest showed the change of *R. pseudoacacia* forest (22.82 g.kg^{-1}) > *Ailanthus altissima* forest (17.24 g.kg^{-1}) > *S. matsudana* (16.97 g.kg^{-1}) > *P. tabulaeformis* forest (11.3 g.kg^{-1}). The leaf P content was the highest in *A. altissima* forest (1.61 g.kg^{-1}), and the lowest in *P. tabulaeformis* forest (0.76 g.kg^{-1}).

Contents and Stoichiometric Ratio of C, N, and P in Litters of Different Forests

The highest litter C content was 427.11 g.kg^{-1}, and the highest litter N content was 20.12 g.kg^{-1}, followed by *A. altissima* forest (15.91 g.kg^{-1}), *S. matsudana* forest (13.88 g.kg^{-1}), *P. tabulaeformis* forest (7.24 g.kg^{-1}), and the lowest litter P content was 1.51 g.kg^{-1}, 1.13 g.kg^{-1}, 0.89 g.kg^{-1}, and 0.40 g.kg^{-1}. The litter C: P and C: N of the four industrial forests in the study area were all in the form of *P. tabulaeformis* forest, *S. matsudana* forest, *A. altissima* forest, and *R. pseudoacacia* forest, and the difference between them was significant are shown in Fig. 1 ($P < 0.05$). Compared with the *Robinia* forest with the lowest metering ratio, the C: P of the highest *P. tabulaeformis* forest was 41.2% higher and the C: N was 32.7% higher. N: P was significantly higher in the *R. pseudoacacia* forest (14.14) than in other forest types.

Contents and Stoichiometric Ratio of C, N and P in the Soil of Different Forests

The soil C content of the artificial forest in the study area showed that *R. pseudoacacia* (15.23 g.kg^{-1}) > *A. altissima* (11.04 g.kg-1) > *S. matsudana* (8.21 g.kg^{-1}) > *P. tabulaeformis* forest (7.33 g.kg^{-1}), and the difference between the two was significant ($P < 0.05$) (Fig. 1). The content of soil N was 0.79, 0.68, 0.57 and 0.67 g.kg^{-1} in *R. pseudoacacia* forest, *A. altissima* forest, *S. matsudana* forest, and *P. tabulaeformis* forest, with significant difference ($P < 0.05$). The highest soil P content was *S. matsudana* forest (0.77 g .kg^{-1}), followed by *Ailanthus altissima* forest (0.74 g.kg^{-1}), significantly higher than *Robinia pseudoacacia* forest and *Pinus tabulaeformis* forest. The average C:N value of the soil was 13.73, and there was a significant difference between the two trees ($P < 0.05$). The C: P value showed that *R.pseudoacacia* forest > *A. altissima* forest > *P. tabulaeformis* forest > *S. matsudana*forest, and there was a significant difference between *P. tabulaeformis* forest and *Robinia pseudoacacia* forest ($P < 0.05$). The N: P value of soil showed that *P. tabulaeformis* forest > *R. pseudoacacia* forest > *S. psammophila* forest > *A. altissima* forest. There was a significant difference between *P. tabulaeformis* forest, *R. pseudoacacia* forest, and *S. psammophila* forest. The results of the stoichiometric ratio of soil in different depths of the same stand show that (Fig. 2), with the increase of soil depth, the content of C and N gradually decreases, the content of P does not change significantly, and the content of all elements in the soil without afforestation is the smallest, which shows that afforestation has an obvious effect on the improvement of the regional land force.

Table 2: Soil properties of the 0-10 cm layer of three different shrub sample plots.

Plantation type	SOC content [g.kg^{-1}]	TN content [g.kg^{-1}]	TP content [g.kg^{-1}]	AN content [mg.kg^{-1}]	AP content [mg.kg^{-1}]
R. pseudoacacia	37.57 ± 10.03a	1.72 ± 0.58a	1.09 ± 0.05a	214.93 ± 31.68a	47.51 ± 17.73a
A. altissima	23.14 ± 7.15a	1.53 ± 0.52a	1.64 ± 0.02a	113.87 ± 40.01a	29.41 ± 20.83a
P. tabllaeformis	31.12 ± 4.16a	2.15 ± 0.52b	1.12 ± 0.04a	201 ± 42.58b	37.51 ± 11.61a
S. matsudana	22.92 ± 4.06a	1.95 ± 0.52a	1.07 ± 0.03a	101 ± 32.18a	24.11 ± 14.53a

Note: SOC, soil organic carbon; TN, total nitrogen; TP, total phosphorus; AN, alkali-hydrolyzable nitrogen; AP, available phosphorus. Different lowercase letters in the same column indicate significant differences at the $P < 0.05$ level. The same is below.

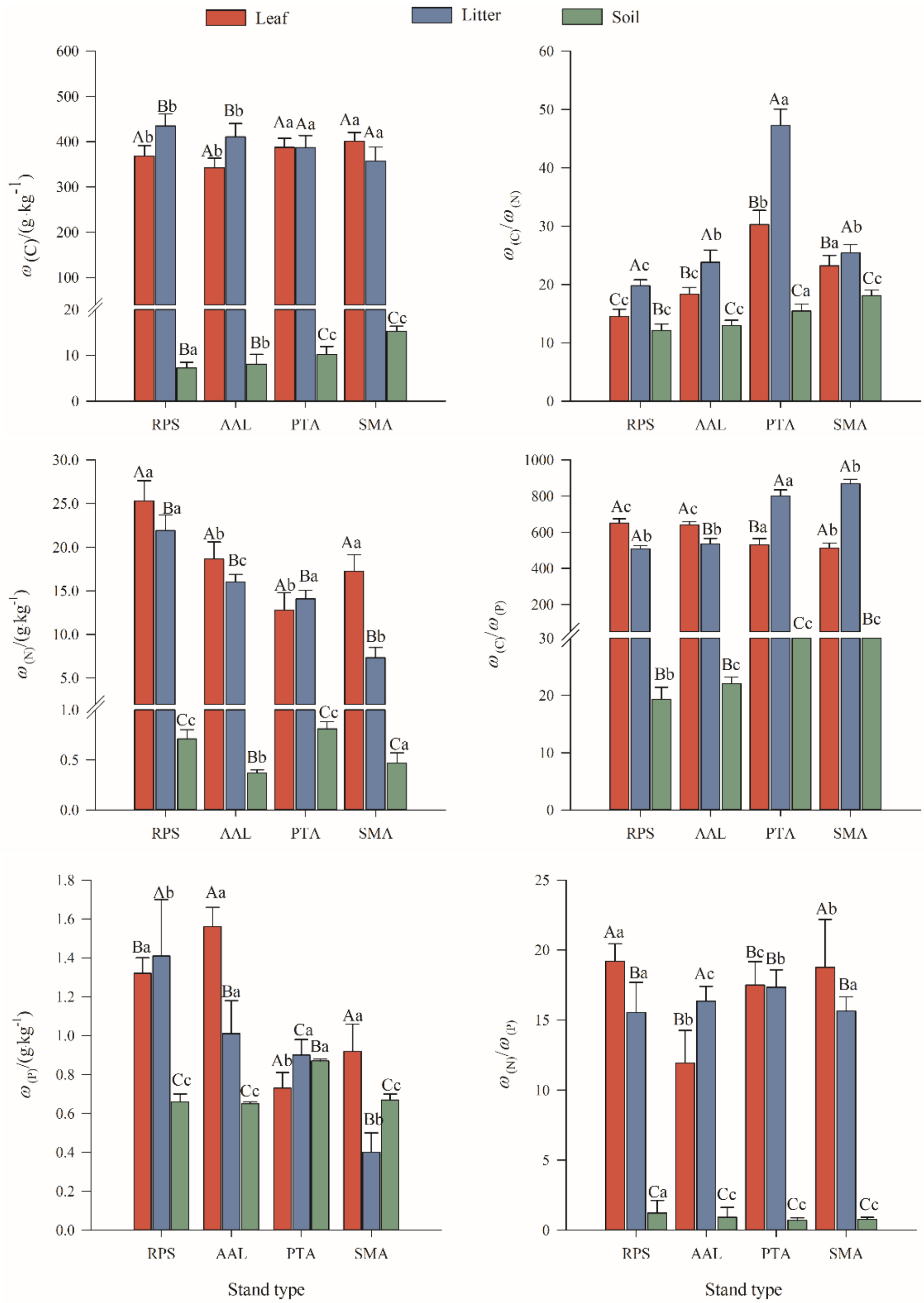

Fig. 1: Distribution characteristics of Carbon, nitrogen, phosphorus contents, C: N, C: P, and N: P of different components in the plantations.

Note: RPS, PTA, AAL, and SMA respectively represent *Robinia pseudoacacia*, *Pinus tabuliformis*, *Ailanthus altissima*, and *Salix matsudana*, Different small letters in the same component meant significant differences among different species, and different capital letters in the same species meant significant difference among different components at 0.05 level.

Correlation Analysis of the Content and Ratios of C, N and P

Pearson correlation analysis on nutrient concentration and stoichiometric characteristics of leaf litter soil showed that the correlation was close between C, N, and P of three broad-leaved trees (Table 3), N value of *R. pseudoacacia* was a significantly positive correlation between leaf and litter ($P < 0.05$), N value of *A. altissima* forest and *S. matsudanaforest* was a significantly positive correlation between soil and litter ($P < 0.05$). As shown in Table 4, N: P of *R. pseudoacacia* and P of *A. altissima* have a significant negative correlation between litter and soil, N and P content of *R. pseudoacacia* leaves and litter has a significant correlation, C, N, P and the stoichiometric characteristic ratio of *P. tabulaeformis* have no significant correlation between leaves and litter, leaves and soil, litter and soil. On the whole, N content was positively correlated between leaves and litter, and the ratios of C:N, C:P, and N: P in the litter layer were not significantly correlated with the ratios of C:N, C:P and N:P in the soil layer. In this study, soil C: N, C : P, and N:P had a very significant correlation with the content of SOC and TN ($P < 0.01$) (Table 5), which indicated that the content of SOC and TN was a factor affecting the stoichiometric ratio of C, N, and P, and there was a coupling among C:N, C:P, and N:P.

DISCUSSION

Changes of C:N, C:P, and N:P in the Leaf-Litter-Soil in Differently Stands

C. N and P are essential nutrients for plant growth and development, and their contents can affect plant growth (Güsewell 2004). In this study, *P. tabulaeformis* forest and *S. matsudana* forest are significantly higher than *R. pseudoacacia* forest and *A. altissima* forest. The results show that the average C content of each organ of the coniferous tree is 1.6% - 3.4% higher than that of a broad-leaved tree (Ma et al. 2002). The results of this study are consistent with that of this study. The N content of *R. pseudoacacia* is rich because of its biological characteristics of nitrogen fixation. In addition, the N and P content of *R. pseudoacacia* leaves and litter are also higher than that of *Pinus tabulaeformis*. The content of N and P in leaves showed a significant positive correlation, which was affected by their own properties and biological characteristics of tree species, indicating that there was a coupling between N and P of different tree species (Elser et al. 2003). Plants absorbed the nutrient elements needed for their growth from the soil and synthesized organic compounds continuously through the photosynthesis of leaves, and the leaves withered to the ground in the form of litter after completing

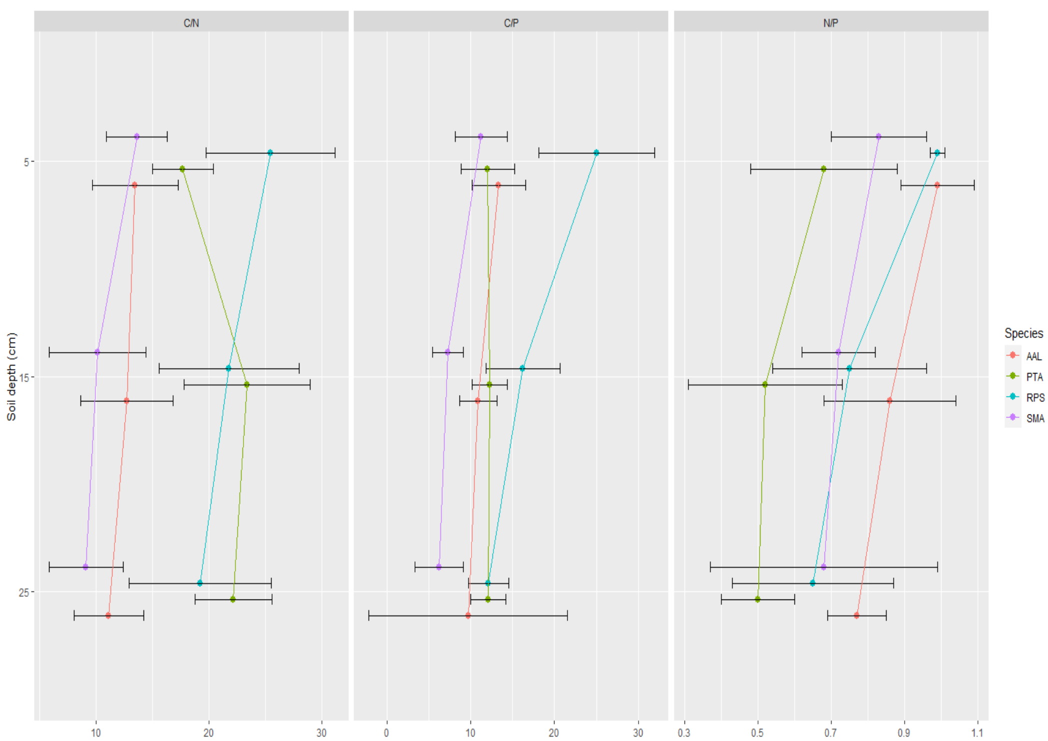

Fig. 2: C, N, P stoichiometric ratio at the different soil depths in the various stand types.

Table 3: Correlation coefficients between C, N, and P of different forests.

Element	Composition	RPS	AAL	PTA	SMA	Overall
	Leaf and litter	0.53	–0.14	0.46	–0.56	–0.31
C	Leaf and soil	0.22	0.22	0.51	0.68	0.47
	Litter and soil	0.57	0.16	–0.21	–0.47	0.14
	Leaf and litter	0.87*	0.68	0.57	0.13	0.76**
N	Leaf and soil	0.42	0.13	0.69	0.32	0.29
	Litter and soil	0.56	0.79*	0.38	0.59*	0.39
	Leaf and litter	0.79*	0.17	0.59	–0.31	0.22
P	Leaf and soil	–0.23	0.32	0.41	0.68	0.38
	Litter and soil	–0.69	–0.69	–0.23	0.44	–0.45

Note: * indicates significantly related, $P < 0.05$; **indicates highly significantly related, $P <$:0.01.

Table 4: Correlation coefficients between the stoichiometric ratio of C, N, and P of different forests.

Element	Composition	RPS	AAL	PTA	SMA	Overall
	Leaf and litter	0.89**	0.57	0.55	–0.63	0.11
C:N	Leaf and soil	0.73**	0.46	–0.61*	–0.52	0.29
	Litter and soil	0.56	0.31	0.44	0.63	0.34
	Leaf and litter	0.49	–0.16	–0.72	0.81*	0.27
C:P	Leaf and soil	0.52	0.15	0.68	0.62	0.55
	Litter and soil	0.66	0.19	0.56	0.53	0.61
	Leaf and litter	0.47	0.34	0.45	–0.18	0.33
N:P	Leaf and soil	–0.60	0.44	0.72	–0.38	0.38
	Litter and soil	–0.59*	0.31	–0.17	0.45	–0.58

Note: * indicates significantly related, P:< 0.05; **indicates highly significantly related, $P <$:0.01.

the biological life cycle (Koerselman & Meuleman 1996, Clinton et al. 2002).

In this study, the content of litter C, N, and P in *R. pseudoacacia* forest was the highest, while that in *P. tabulaeformis* forest was the highest, which was consistent with the content of N and P in leaves. The correlation analysis showed that there was a significant positive correlation between the content of litter N and P in leaves, and there were significant differences in the release patterns of P elements in different tree species (Huang et al. 2007), In addition, N: P ratio of litter in *Ailanthus altissima* plantation was the lowest among the four tree species, which might be beneficial to nutrient storage due to its small leaf type and easy decomposition and return to the soil (Knecht 2004). The average content of N and P in the plain plantation soil in the study area is lower than the national average content of 1.88 $g.kg^{-1}$ and 0.78 $g.kg^{-1}$ (Ren et al. 2018), which is generally in the lack of total nitrogen, which is consistent with the research results of Zheng et al. (2018). The lowest value of *Pinus tabulaeformis* is 0.47 $g.kg^{-1}$, which indicates that the ability of soil nutrient storage is poor, which is related to the characteristics of coniferous tree species of *P. tabulaeformis*. Because the leaf life of the evergreen coniferous forest is longer than that of the deciduous broad-leaved forest, the amount of leaf litter is less in the same years, and the acid environment formed by the decomposition of coniferous litter will inhibit the activity of soil microorganisms, which is not conducive to soil N, P accumulation (Bao et al. 2018). Soil C and N contents of different types of forests decrease with the increase of soil depth, and the content of 0-10 cm in the soil surface is the highest, showing the phenomenon of "surface accumulation", which is related to the high microbial activity in the soil surface (Su et al. 2016), and the nutrients returned by litter are mainly concentrated in the surface soil. As Fig. 3 shows, C:N is higher than the Chinese forest soil average, and C:P and N:P are lower than the Chinese average, which further verifies the lack of soil phosphorus, indicating that the content of soil SOC and TN is the factor affecting the stoichiometric

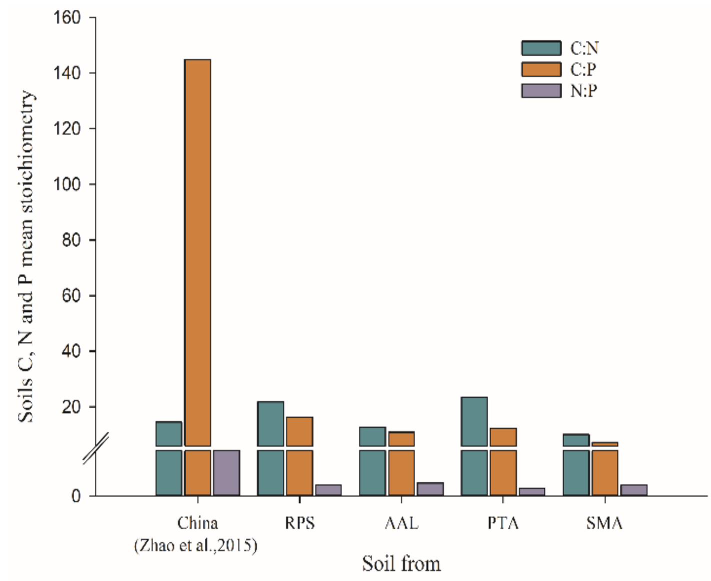

Fig. 3: Soils C, N, and P stoichiometry for this study compared with Chinese forest soil average (reference Zhao et al. 2015) level.

ratio of soil C, N, and P. There is no correlation between the stoichiometric ratio of the litter layer and the stoichiometric ratio of the soil layer, which indicates that simply increasing the quantity and quality of litter does not necessarily improve the soil nutrients, so it is very important to change the quality of litter layer in forest management.

Correlations of Stoichiometric Ratios with Concentrations or Ratios of C, N, and P

In this study, N: P of different components of *R. pseudoacacia* forest is the largest of four tree species, in which N: P of leaves and litter is significantly higher than that of soil, C: N and C: P of *R. pseudoacacia*, *A. altissima,* and *P. tabulaeformis* litter are higher than that of leaves. Plants absorb N and P from the soil and re-absorb N and P through the nutrient reabsorption process before leaves fall. In this study, we found that the total N content of plantation was a significantly positive correlation between leaves and litter, which indicated that plants fixed organic matter by photosynthesis and returned nutrient elements to the soil in the form of litter after completing their life cycle (Hobbie 1992, Liu et al. 2010, Sardans et al. 2011). As an important physiological

Table 5: Multi-Factor Analysis of Variance between its stoichiometric ratio and soil factors.

Species	Variables	pH	MC	SOC	TN	TP
	Soil C:N	0.14	0.10	0.63	-0.78**	0.40
RPS	Soil C:P	0.27	0.08	0.72*	0.49	0.51
	Soil N:P	0.22	0.11	0.53	0.53	0.63*
	Soil C:N	0.31	0.24	0.74*	-0.55*	0.24
AAL	Soil C:P	0.25	0.21	0.69	0.43	0.54
	Soil N:P	0.24	0.24	0.58	0.83	0.51
	Soil C:N	0.27	0.19	0.81**	-0.61**	0.22
PTA	Soil C:P	0.32	0.22	0.74*	0.37	0.62
	Soil N:P	0.64	0.17	0.46	0.75	0.48
	Soil C:N	0.13	0.31	0.66*	0.12	0.17
SMA	Soil C:P	0.35	0.24	0.71	0.44	0.31
	Soil N:P	0.33	0.16	0.69	0.57*	0.58

Notes: * indicates significantly related, $P < 0.05$; ** indicates highly significantly related, $P <:0.01$. MC, Moisture content; SOC, soil organic carbon; TN, total nitrogen; TP, total phosphorus; AN, alkali-hydrolyzable.

index, C: N and C: P can reflect the growth rate of plants. Generally speaking, the plant growth rate characterized by low C: N and C: P is faster (Elser et al. 2003). Generally, the higher the C: N ratio, the slower the mineralization of soil organic matter. On the other hand, the ratio can be used to estimate the balance of soil C and N nutrition (Van de Waal et al. 2010). The C: N and C: P values of the leaves of *P. tabulaeformis* are higher than those of other tree species, indicating that the growth rate of *P. tabulaeformis* is lower. *P. tabulaeformis* is suitable for an acid and neutral soil environment, but if there is a lot of construction waste in the soil, not excluding the lime component will have a bad impact on *Pinus tabulaeformis*. According to the judgment standard that when N:P> 16 represents the P limit, N:P < 14 represents the n limit (Tessier et al. 2003), the growth of *R. pseudoacacia*, *P. tabulaeformis,* and *S. mandshurica* plantation in this study is limited by P, and the growth of *A. altissima* is limited by N. As an evergreen coniferous forest plant, *P. tabulaeformis* has poor decomposition capacity of plant residues and different root distribution characteristics from other broad-leaved trees (Liu et al. 2010), so the correlation between leaves and litter of *P. tabulaeformis* and soil nutrient elements is relatively small. In addition, the number of dead branches and leaves of conifers is relatively small, decomposition is slow, and the return of nutrient elements to the soil is less (An et al. 2010, Tian et al. 2010). The coordination of stoichiometry among index variables of different components can facilitate the interpretation of the coupling process among nutrients.

CONCLUSIONS

The cycle of C, N, and P in a forest ecosystem is the mutual transformation among plants, litter, and soil, which indicates that there is mutual transportation and transfer of N and P between leaves, litter, and soil in a plantation ecosystem. Although C, N, and P stoichiometry have proved useful in studies of nutrient limitation, our objective is to better understand nutrient controlling factors of plant-soil interaction and reveal interactions of N and P to provide insight and theoretical fundamentals for forest environmental governance. Based on the study, the following conclusions may be drawn:

1. The N content in leaves, litter, and soil of *R. pseudoacacia* forest is significantly higher than that of the other three tree species. In contrast, *R. pseudoacacia* is the most suitable tree species for afforestation in the Beijing plain. The C, N content and stoichiometric ratio of plantation soil were 0-10 cm) the highest, and their significant difference decreases with the increase of soil depth. There is no significant correlation between litter and soil stoichiometric ratio.
2. In terms of nutrient limitation, since one nutrient that is more stable and less sensitive to environmental gradients would be more easily a limiting factor to plant growth, the growth of *R. pseudoacacia* forest, *P. tabulaeformis* forest, and *S. matsudana*forest is limited by P, while that of *A. altissima* forest is limited by N.
3. To ensure that the artificial forest can play its ecological function, we should pay attention to the use of nitrogen fertilizer when tending the artificial forest in the plain area. First, combine the nutrient concentration and stoichiometry ratio of the leaves of each tree species to analyze, with the help of long-term monitoring, to reveal the influence of tree species on the soil nutrient and the dynamic transformation of nutrients between the soil litter leaves under the forest in the plain area. Second, ensure the healthy growth of ecological trees in the plain, increase the return of soil organic matter, and promote nutrient cycling. Third, strengthen the supervision of plain ecological forest land, prohibit dumping and stacking construction and domestic garbage in the forest land, and prevent the variation of soil structure, texture, and chemical properties. Finally, we should consider reducing "clearing forest", pay attention to the protection of the dead branches and leaves of forest land to return the soil and undergrowth vegetation, and increase the accumulation of litter properly, which is conducive to the accumulation of C and N.

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