EFFECTS OF SHORT-TERM NITROGEN AND PHOSPHORUS ADDITION ON ROOT BIOMASS AND MORPHOLOGICAL CHARACTERISTICS OF *LIGUSTRUM LUCIDUM AIT* IN NEW RECLAMATION COASTAL FIELD

WANG, Z.^{1,2} – LIU, X.² – ZHANG, L.^{1,2} – JIANG, H.⁴ – DU, H.⁵ – YANG, D.^{6,7} – WU, H.³ – LIANG, J.^{3**} – CAI, Y.^{1,2*}

¹*Shanghai Key Lab for Urban Ecological Processes and Eco-Restoration
Shanghai 200241, China*

²*School of Ecological and Environmental Sciences, East China Normal University
Shanghai 200241, China*

³*Shanghai Academy of Landscape Architecture Science and Planning, Shanghai 200232, China*

⁴*Ecological Engineering College, Guizhou University of Engineering Science
Bijie 551700, Guizhou, China*

⁵*Shanghai Academy of Social sciences, Shanghai 200020, China*

⁶*School of Geographic Sciences, East China Normal University, Shanghai 200241, China*

⁷*Henan Key Laboratory of Integrative Air Pollution Prevention and Ecological Security,
College of Environment and Planning, Henan University, Kaifeng 475004, China*

**Corresponding authors
e-mail: ylcai@geo.ecnu.edu.cn*

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Abstract. Root system plays an important role in plant's nutrient acquisition and ecosystem carbon cycle. Nitrogen (N) and phosphorus (P) work significantly in promoting root system growth. To reveal the influence of N and P application on landscaping plants' root morphology characteristics, Ingrowth soil core fertilization method was applied in the coastal reclaimed soil (196.25 cm³) where *Ligustrum lucidum ait* grew from June to August in 2018. We set 11 processing gradients, including 0, 1, 3, 5, 7, 9, 11, 13, 15, 17, 20 g, and explored the influence of different N and P addition types on *Ligustrum lucidum ait* root morphology, biomass and other indicators. The results showed that compared with the control group, 3 g N application increased length of root by 62.39%, surface area by 120.87%, volume by 169.97%, biomass by 102.75%, root length density by 59.19% and root surface area density by 106.99%. 3 g P application increased those indexes by 77.37%, 111.15%, 147.50%, 98.05%, 73.87%, and 97.88%. The study indicated that compared with the control group, the application of 3 g N and P into 196.25 cm³ soil made significant differences on total length, diameter, surface area, volume, biomass, root length density, and root surface area density ($P < 0.05$).

Keywords: *root system, plant's nutrient acquisition, biomass, root morphology, Ligustrum lucidum ait*

Introduction

Most of the new coastal reclamation areas are the new land which forms through the sediment's being dredging from the seabed into the coastal tidal flat. After many years of natural desalination, salt washing and land abandonment for soil salinity reducing, they have gradually got suitable for the growth of green vegetation. However, this type of soil

is extremely deficient in nutrients, such as nitrogen and phosphorus, which is the key factor that restricts the growth of plants. The lack of nitrogen and phosphorus in soil will slow the growth of vegetation, which will affect the artificial afforestation and ecological restoration in the reclamation area. The problem of artificial afforestation and ecological restoration in the new coastal reclamation area is urgent to be solved.

The survival of artificial afforestation is determined by plant roots. Root system is the interface between plants and soil, and is an important organ that absorbs nutrients and water. Nutrient content in soil directly affects plant growth. The addition of nitrogen and phosphorus to soil can change the influence of soil environment, and then affect the characteristics of plant root system. Roots often adapt to the environmental changes by adjusting the characteristics of root system, such as morphology, surface area, volume and biomass, showing high plasticity (Pregitzer et al., 1993; Eissenstat and Yanai, 1997; Eissenstat et al., 2000; Robinson, 2010; Wurzbürger and Wright, 2016). Studies have shown that, under the condition of poor soil nutrients, the application of nutrient elements can help the root system grow rapidly enough to adapt to the changes in the environment (Schiefelbein and Benfey, 1991; Pregitzer et al., 1993; Bates and Lynch, 1996; Pregitzer et al., 1997, 2002; Wells et al., 2010; Robinson, 2010). For example, increased availability of soil nitrogen can lead to an increased fine root length, higher biomass and coarser diameters (Lynch, 1995; Messier, 2002; Pregitzer et al., 2002). It has also been found that N application increases root surface area and total length (King et al., 1997). It can also significantly affect the diameter, root length and specific root length of lower root order (Fitter and Stickland, 1991). Root plasticity has the same response to phosphorus (Fitter et al., 2010). For example, with the increase of soil phosphorus availability, *Larix gmelinii* increased root length to enhance the absorption of P, leading to the significant differences in root volume and lateral root tillers of *Pinus massoniana* in different species (Lynch, 1995).

However, most previous studies focused on the good soil environment and indoor experiments. The researches on phosphorus content in the wild arid field are very few. Then, the soil's nitrogen and phosphorus adding referred to be the surface spraying method, which was easily affected by weather (rain, snow), thus causing errors in the experiment results. Meanwhile, the way of adding nitrogen and phosphorus to soil was to apply fertilizer to the existing roots. The sampled roots included both old roots and new roots which grew right after the nutrient adding, so it's impossible to determine its specific influence on the characteristics of old roots or new roots. Ingrowth soil core avoids the above problems and can help master the growth characteristics of new root under different treatment conditions. And it can also contribute to clarifying the relationship between new root characteristics and soil nutrients (Peterjohn et al., 1999; Mcgrath et al., 2001).

Therefore, this study chose *Ligustrum lucidum* ait which grew on Shanghai coastal reclaimed soil with poor nitrogen and phosphorus content as the research object, applied ingrowth soil core to carry out short-term experiment of nitrogen and phosphorus adding to investigate the response of *Ligustrum lucidum* ait root morphology, biomass and other characteristics to soil's short-term nitrogen and phosphorus addition, so as to provide basic reference materials for the study on the relationship between root morphology and soil resource effectiveness as well as the construction and ecological restoration of artificial forests.

Materials and methods

Study area

The field site (30 ° 52 '54" N, 121 ° 54 '24 "E) was located in Lingang new Urban area in Shanghai (Fig. 1). It was damp, windy, warm, humid with abundant rainfall as well as with abundant sunshine in the region with four distinct seasons. And the annual average temperature in 2018 was 15°C to 15.8°C, with the lowest temperature (3.3°C) in January, the highest temperature in August (38°C). The annual total sunshine was 2000-2200 h, the annual precipitation was 900-1050 mm and the monthly average evaporation is 91.9 mm, which was a typical subtropical maritime climate. Soil was that of saline and alkaline sandy soil. Soil with a pH value greater than 8.5 took up 97.5%, and the organic matter content was less than 20 g/kg. The groundwater level was between 0.5 and 2.5 m. In order to solve the problem of barren soil vegetation, different vegetation planting experiments were carried out. Vegetation planting began in February 2010 and was completed in April 2010. The test site was 1200 m long, 20 m wide and 24000 m² for total area. All the plants in the site were native species. Representative plant *Ligustrum lucidum* ait was selected as the experimental sample.

Figure 1. Map of the study area

Plot design

In the privet plantation (8 years old), a fixed standard plots of 20×30 m were set, and the privet with the same chest diameter, crown width and tree height were selected as samples in the sample plot (Table 1). The field within 1 m from the tree trunk was fertilized. A total of three groups were designed. I for nitrogen treatment, ten fertilizing gradients were set as: 1, 3, 5, 7, 9, 11, 13, 15, 17, 20 g; II for phosphorus processing, the gradients were set the same as those of nitrogen; III no treatment was done as a control.

Plant root sampler (l=10 cm, φ=5 cm, h=10 cm) was used. Most root system evenly distributed in surface area (Wang, 2004; Jiang, 2016), and the sampling depth was 10 cm. Then with the trunk as the center, 1 m from the center of trunk as the radius for sampling, 9 soil column samples were taken at the same distance around each tree, and 3 privet samples were taken as a treatment (Fig. 2). There was a total of 63 samples of *Ligustrum*

lucidum ait, and a total of 567 sample points were set. All roots were removed from soil cores with a sieve with a diameter of 3 mm. The soil was kept without roots, and then N, P was added to the soil. 270 soil cores of 30 privet samples were dealt with N of the 10 gradients, while another 270 soil cores of 30 privet samples were dealt with P of the 10 gradients, and 27 sampling points of three privet samples were not done with any fertilizer processing thus as a control.

Table 1. Tree and Soil characteristics properties

Tree characteristics		Soil characteristics	
Tree height (m)	4.37±0.31	pH	8.79±0.09
DBH (cm)	10.01±0.27	EC (ms/cm)	0.42±0.06
Crown width (m)	2.31±0.25	Organic matter (g/kg)	3.60±0.63
Plant distance (m)	3×3	Total salt content (g/kg)	0.78±0.03
Planting age (years)	8	Bulk density (g/cm ³)	1.37±0.02
		Soil Moisture (%)	29.23±2.92
		Total N (g·kg ⁻¹)	0.82 ± 0.04
		Total P (g·kg ⁻¹)	0.27 ± 0.02
		Total K (g·kg ⁻¹)	11.85 ± 0.73
		Texture	Sand loam

Data are provided in the form of mean ± standard deviation (SD). *DBH* diameter at breast height or basal

Figure 2. Sample points for soil N and P addition

Urea (CON₂H₄, 43% nitrogen content) was chosen as N fertilizer and calcium superphosphate (P₂O₅, 13% phosphorus content) as P fertilizer. Then the treated soil was put into nylon mesh bags with a pore size of 2 mm (l=10 cm, w=6cm), then the nylon mesh bags were placed in the cavities made through the core drilling. Then the soil inside the cores was gently patted, making its bulk density to a certain extent consistent with the surrounding soil bulk density. Then PVC tubes were put in the core positions (φ=5 cm, h=1 cm). The PVC pipes were covered with thin soil, in case that soil erosion caused by rainfall should affect the experiment results. The soil cores were set from June 16th, 2018 to June 18th, 2018 when it's the peak growth season for privet root system as well as the

most demanding season of privet for nitrogen and phosphorus fertilizer to blossom. During the study period in 2018, the average temperature was 18~28°C. The average precipitation was 134 mm. The average soil moisture content was 19.09%, and the average soil temperature was 21.34°C. The average temperature in July was 21~30°C, the average precipitation was 156 mm, the average moisture content of soil was 27.58, and the average temperature of soil was 28.41°C. In August, the average temperature was 20 ~ 30°C, the average precipitation was 140 mm, the average moisture content of the soil was 23.79 and the average temperature of the soil was 26.51°C.

Root sampling

The fine roots of *Ligustrum lucidum* ait grew slowly after August, so the soil cores was removed again (Wang, 2004; Jiang, 2016) after 60 days of root removal (in mid-August). The roots between nylon mesh and soil were cut off with a sharp soil knife. The soil cores were cut with a soil knife at the bottom and the excavated cores were taken out. Then, they were put into plastic bags and brought back to the laboratory in time.

Root determination

After the soil core being fully rinsed in water, the roots in nylon bags were sifted out with a soil sieve with a 2 mm diameter and the root surface were dried with absorbent paper. The prepared root samples were placed in a transparent scanner tray for the roots' full stretching. The root samples were scanned with a digital scanner Epson scanner. The root scan & analysis system of Win-RHIZO 2005C (Regent Instruments Inc., Quebec, Canada) was used to scan the root image and the length, diameter, surface area and other data of the root system were obtained then. Afterwards, root samples were placed in 80°C oven for drying for 48 h to a constant weight, and then the dry weight was weighed (accuracy: 0.0001 g). According to the root length and dry weight of each sample point, we calculated the biomass and specific root length, and then calculated root length density, specific surface area and surface area density according to the root length, surface area and the volume of soil cores. Finally, we calculated the average value of the samples in 27 soil cores in each treated soil layer and converted the average values into root biomass, root length density, specific root length, specific surface area, and root surface area density per unit volume. Root biomass, root length density, specific root length, specific surface area, and root surface area density were calculated as follows:

$$\text{Root biomass (g/m}^2\text{)} = g \times A \quad (\text{Eq.1})$$

$$\text{Root length density (m/m}^3\text{)} = L/V \quad (\text{Eq.2})$$

$$\text{Specific root length (m/g)} = m/g \quad (\text{Eq.3})$$

$$\text{Specific surface area (cm}^2\text{/g)} = a/g \quad (\text{Eq.4})$$

$$\text{Root surface area density (m}^2\text{/ m}^3\text{)} = a/V \quad (\text{Eq.5})$$

where, a is Root surface area; A is the area of soil; g is fine root dry weight; L is total length of fine root; m is the length of dry fine root in each Sample point; V is the volume of soil.

Statistical analysis

The average value of each processed sample was calculated and was ready for statistical analysis. Univariate anova and LSD multiple comparisons ($\alpha = 0.05$) were used to test the significant differences in the effects of different nitrogen and phosphorus addition treatments on the total length, average diameter, surface area, volume, biomass, specific root length, root length density, specific surface area, and root surface area density of the great privet root system. All statistical analyses were performed with SPSS 20.0 (IBM SPSS, Chicago, USA) software. Excel 2010 software was used to draw pictures.

Results

Effects of N and P addition on root morphology

As is seen in Fig. 3a, the total length of the root-system of *Ligustrum lucidum* ait appeared to increase first and decrease later under different N treatments. When 1 and 3 g were added, compared with the control group, the total length of root significantly increased by 57.62% and 62.39% ($P < 0.05$), when 5-11 g nitrogen were respectively applied, the total length of root system decreased gradually. No root growth was observed when 13 g N was applied. Under different P treatments, when 1 and 3 g were added, the root total length increased by 9.50% and 77.37% ($P < 0.05$). With 5-20 g applied, the total length of the root system gradually decreased, but no non-root-growth was found (Fig. 3a).

Figure 3. Effects of fertilization on the morphology of the root system of *Ligustrum lucidum* ait. (a) total root length, (b) root diameter, (c) root surface area, (d) root volume

The average diameter of root showed a tendency of thinning first and thickening then under different nitrogen and phosphorus treatments (Fig. 3b). Compared with the control group, the average diameter of the privet roots was thinned and significant difference was

found when 1 and 3 g N were applied ($P < 0.05$). When 3 g N was applied, the average diameter of root system reduced to the minimum, 0.19 mm. The average diameter of root system gradually increased when 5-11 g nitrogen were applied, and the maximum diameter 0.24 mm appeared at 11 g. When 1-20 g P were applied, the average diameter of roots showed a trend of thickening after thinning. When 3 g P was applied, the average diameter of the root system reduced to the minimum and the significant difference was achieved ($P < 0.05$). When 20 g P was applied, the maximum diameter was 0.23 mm.

When 1, 3 g N and P were applied, the average surface area and volume of root system gradually increased and the significant difference occurred, compared with the control group ($P < 0.05$) (Fig. 3c,d). The root surface area increased by 45.61% and 120.87%, and root volume increased by 96.34% and 169.97% when 1 and 3 g nitrogen were applied. With 5-11 g N, root surface area and volume gradually decreased. When 1 and 3 g P were applied, the root surface area increased by 21.79%, 111.15%, and the volume 15.96%, 147.50%. And the difference was significant ($P < 0.05$). When 11-20 g P were applied, compared with the control, no significant difference was found about the root diameter ($P > 0.05$) (Fig. 3b).

Effects of N and P addition on root biomass, root length density and specific root length

As is seen in Fig. 4a, with the increase of nitrogen and phosphate application, root biomass showed a trend of increasing first and decreasing then. Compared with the control group, the biomass and root length density of privet root increased and significant differences were found when 3 g N and P were applied ($P < 0.05$).

Figure 4. Effects of fertilization on root biomass (a), root length density (b), and specific root length (c) of *Ligustrum lucidum* ait

The application of 1 and 3 g N increased the biomass by 69.85% and 102.75%, respectively 4.30 g·m⁻² and 5.13 g·m⁻², and it also increased the root length density by 54.51% and 59.19%, respectively 1417.99 m·m⁻³ and 1460.90 m·m⁻³. The application of 3 g P increased the biomass by 98.05% and the root length density by 73.87%, respectively 5.01 g·m⁻² and 1595.62 g·m⁻² (Fig. 4a,b).

With the increase of N application, specific root length increased first and decreased then. When 1 and 3 g N and P were applied, the specific root length significantly increased compared with the control ($P < 0.05$) (Fig. 4c). The maximum specific root length reached $45.96 \text{ m} \cdot \text{g}^{-1}$ and $43.01 \text{ m} \cdot \text{g}^{-1}$ when nitrogen and phosphorus were applied to the roots respectively. The effect of nitrogen on specific root length was more significant compared with phosphate. When 5-11 g nitrogen were applied, the specific root length gradually reduced. The root stopped growing at 13 g. When 5-20 g phosphate fertilizer were applied, the specific root length gradually reduced.

Effects of N and P on specific surface area and surface area density

As is seen in Fig. 5a, with the increase of N and P application, the specific surface area of root showed a trend of increasing first and decreasing then. Compared with the control group, the root specific surface area reached the maximum and significant difference was found ($P < 0.05$) when 7 g N and P were applied ($350.20 \text{ cm}^2 \cdot \text{g}^{-1}$ and $279.02 \text{ cm}^2 \cdot \text{g}^{-1}$). With the increase of N and P application, the surface area density increased first and decreased then (Fig. 5b). Compared with the control group, the root surface area density had a significant difference ($P < 0.05$) when 1 and 3 g N and P were applied. The root surface area density was also the largest, increasing by 106.99% and 97.88%, respectively, which were $1.18 \text{ m}^2 \cdot \text{m}^{-3}$ and $1.13 \text{ m}^2 \cdot \text{m}^{-3}$ when 3 g N and 3 g P were added (Fig. 5b).

Figure 5. Effects of fertilization on specific surface area (a) and surface area density (b) of the root system of *Ligustrum lucidum ait*

Discussion

Effects of N and P addition on root morphology

Studies have shown that plant roots are highly plastic and can respond to the availability of different soil N and P contents. That is to say, when nutrients are limited, the ability to obtain nutrients can be improved by increasing the total length, surface area and volume of roots (Cuevas et al., 1991; Schmid and Kazda, 2002; Yang et al., 2003).

Increasing root length is an effective strategy for plants' nutrient and water obtaining. Under the treatments of 3 g N and 3 g P, the total length of root system increased by 62.39% and 77.37%, Wang et al. (2005) got this result too. Different nitrogen and phosphorus treatments had different effects on the total length of the root system of privet (Fig. 3a,b). Among those, 1 g, 3 g N and P significantly increased the total length of root system. 5-11 g N applications significantly decreased the total length of root system. No root growth was observed when 13-20 g N were applied. The total length of root system

significantly decreased when 5-20 g P were applied and no root growth was found. The reason was that the application of 1 g, 3 g N and P can change the ways of root system to obtain nutrient resources, promote the growth of the root system, and reflect the effects of N and P on the promotion (positive feedback) of the root system. Secondly, the lignification degree of the newly formed root system was low, which was easily affected by the soil environment and was very sensitive to the changes of soil resources. To obtain more nutrients, the root system grew rapidly. The applications of 5-20 g N and P inhibited the root growth to some extent, especially the death of plant roots was found after 13g addition of N.

Root diameter is an important parameter reflecting root structure and function (Robinson, 2010). Under different nitrogen and phosphorus treatments, the average diameter of root showed the phenomenon of first thinning and then thickening (Fig. 3b). N application of 1 g, 3 g and 5 g had a significant impact on the average diameter of root system, under which the average diameter became thinner. The average diameter under P application of 5-20 g gradually increased. The reason why the diameter first decreased and then increased under different fertilization treatments was that under the condition of low addition of N and P, the extension of root cells made the root diameter decrease for the root system to obtain more nutrient resources. With the high addition of N and P, N relatively inhibited the growth of the root system. To survive, the root system changed its survival strategies, appearing to be the increase of the root diameter and the prolonging of the root life to obtain nutrients and maintain its survival. For example, Wells et al. (2002) proved the relationship between root life and diameter of *Amygdalus persica l.* And it testified to a significant positive correlation between root life and diameter (Wells et al., 2002). Kern (2004)'s research showed that fertilization could significantly increase the root diameter of a poplar and shorten the root turnover time (Kern et al., 2004). According to the characteristics of root plasticity and the "cost-benefit" theory, the growth strategy of the root system always tends to choose the method with the minimum cost and the maximum benefit for survival (Eissenstat and Yanai, 1997; Bardgett et al., 2014).

Different N and P treatments can significantly affect root surface area and volume (Fig. 3c,d). Compared with the control group, application of 1 g, 3 g N and P increased root surface area by 45.61%, 120.87%, root volume by 96.34% and 169.97%. The increase of root surface area and volume is a way for the root system to have greater absorption surface area and maximally obtain soil nutrient resources.

Effects of N and P addition on root biomass, root length density, specific root length and surface area density

Addition of N and P significantly affected root biomass and root length density (Fig. 4a,b). At present, the effects of increased soil nitrogen availability on root biomass and production appear to be reduction and increase (Cotrufo and Gorissen, 1997; Kou et al., 2015). For example, the application of N can increase the fine root biomass of *Populus deltoides* by 21% (Kern et al., 2004) and the fine root biomass of *Picea abies* by 92% (Majdi, 2001). For example, the application of N can reduce the fine root biomass of *Larix kaempferi* by 15% and that of *Pseudotsuga menziesii* by 40% (Son and Wang, 2010). The response of root biomass to N addition may be related to the climate and soil nutrient conditions in the study area. And the effect of N addition on root biomass is also related to the genetic characteristics, phenological characteristics, N addition amount and treatment time of different roots.

In this study, compared with the control group, the biomass of root significantly increased after 1 and 3 g N application (69.85% and 102.75%, respectively) (Fig. 4a). Root biomass significantly decreased after 5-11 g N applications ($P < 0.05$). When 13 g N application was applied, no root growth was observed, and high nitrogen directly caused little root growth, reflecting the negative feedback effect of N on root. The increase of root biomass may be attributed to the increase in the effectiveness of soil N following the fertilization, which met the demand for N of the root system. Plant roots adopted the strategy of "rapid investment - income" to increase the carbon distribution to the root system and promote the growth of the root system. High nitrogen inhibits the growth or non-growth of the root system, leading to the reduction of root biomass. With respect to phosphorus addition, the biomass of root significantly increased after the 3 g phosphate fertilizer application (an increase of 98.05%). The reason may be that the phosphorus elements were involved in the composition of nucleic acids, nucleotides, and phospholipids, which was also the main component of cytoplasm and nuclei, so under a reasonable phosphorus add, the elongation of root cells can be increased. The total root length and root length density increased, leading to the increase of biomass. Under the treatment of high phosphorus, the root cell elongation decreased, root length decreased, and the biomass showed a trend of gradual decreasing. Root biomass gradually reduced when 5-20 g phosphate fertilizers were applied.

Specific root length refers to the total root length of unit mass root system, and it is an important indicator of root morphology and physiological function (Eissenstat, 1992; Pregitzer et al., 2002). Studies have shown that the value of specific root length is associated with the effectiveness of soil resources (Burton et al., 2000; Gordon and Jackson, 2000). It is generally believed that a root with a larger length has relatively higher nutrient and water absorption efficiency, and the value of specific root length can indicate the physiological activity of the root (Pregitzer et al., 2002).

The effects on specific root length are manifested in: under low N/P addition, compared with the control, the specific root length significantly increased ($P < 0.05$), and the high addition of N/P (5-20 g) significantly inhibited the increase of root length (Fig. 4c). The main reason was that the newly formed long roots had low lignification degree and high plasticity, and were easily affected by the soil environment, leading to the root system's length adjustment to satisfy its absorption of nutrients from soil (Guo et al., 2004). Different N and P addition's influence on root length density and surface area density was consistent with that of root biomass (Fig. 4b, 5b). Among those, under the application of 5 g nitrogen and phosphorus, the root length density under phosphorus treatment was 9.22% higher than that under nitrogen treatment. The reason may be that under reasonable fertilization, phosphate fertilizer can increase the number of root tillers and stem tillers, leading to the increase of underground biomass and root length density.

In general, in the case of 1 g, 3 g N and P, N had a significant effect on total length, surface area, volume, biomass, and root length density of the root system, whose reason may be related to the mobility of N and P elements in soil. Phosphate roots in soil are usually affected by the obligate adsorption of iron oxide and aluminum oxide in soil. In the soil, N has a stronger mobility than P, mainly because nitrate nitrogen mobility is very strong. Under the condition of good ventilation, ammonia nitrogen can be converted into nitrate nitrogen through the action of nitrifying bacteria. The nitrate nitrogen which has a good mobility can easily spread to the root surface, realizing the rapid absorption of N elements and promoting the changes of root morphology and the biomass increase (Wang, 2004).

Scientific fertilization of artificial forests in new reclamation areas

N and P are the most demanding limiting nutrients for plant root growth. According to the cost-benefit theory, root growth depends on a large amount of nitrogen and phosphorus input (Eissenstat and Yanai, 1997; Nadelhoffer, 2000; Norby and Jackson, 2000). For example, Jackson et al. (1997) found that for every unit of nitrogen absorbed by the root system, 41 units of carbon were consumed (Jackson et al., 1997). Statistics also showed that when the first fruit of tomato grew to 4 cm in length, the amount of phosphorus absorbed from soil accounted for about 90% of that in the whole growth period. Therefore, the effectiveness of soil N and P significantly affected root growth. Hendrick and Pregitzer (1996) believed that root biomass may be positively correlated with soil nutrient availability or negatively correlated, depending on the plant species and the spatial heterogeneity of available nutrients distributed in soil (Hendrick and Pregitzer, 1996). In this study, it was found that the total length, surface area, volume, biomass, root length density and surface area density of the roots significantly increased when 1 g, 3 g N and P were applied, among which the effect of 3 g N and P was the best, showing that N and P promoted (positive feedback) the root system. When 5-20 g N and P were applied, the total length, surface area, volume, biomass, root length density and surface area density of the root significantly reduced, reflecting the inhibition (negative feedback) of N and P on the root system. Among those, no root growth was found in the soil core when 11 g N was applied, seriously hindering the growth of the root system. Although the soil's N and P content in coastal salt land is very low for the growth of vegetation, it is not better to apply more N and P but better to master the threshold of N and P required by plants. In this way a scientific and reasonable fertilization can be achieved.

Plant root growth, death and turnover is a dynamic process. The time of experiment design makes a great difference to the results of the experiment. In different months, root growth, death and turnover laws are constantly changing (Pregitzer et al., 1993). The effect of fertilization on the annual and monthly dynamics of root system needs to be further studied in the future. In this experiment, root systems were not classified. In different N and P treatment cases, the differences between all levels of N and P content within the root sequences and the different treatments are not clear. From the research of root physiological processes of carbon - nitrogen - phosphorus, it's more helpful for knowing the root better, and more helpful for knowing soil's N and P availability and reaction mechanism of spatial heterogeneity better, all of which needs to be discussed further.

Conclusions

The results showed that reasonable addition of N and P could significantly change the morphology and biomass of root system. Reasonable N and P add (3 g) can make the root total length, surface area, volume, biomass, root length density and root surface area density increase significantly, reflecting the promotion of root system (positive feedback) of N and P. More of that than the threshold will reduce these indexes gradually, reflecting the nitrogen and phosphorus's inhibition to the root system (negative feedback). With the treatments of different N and P gradients, the root diameter showed a tendency of first thinning and then coarsening, and the specific root length and specific surface area showed a trend of first increasing and then decreasing. The main reason for the occurrence was that the mobility of the two elements in soil was related to the absorption strategy of the root system. The study showed that the application of 3 g N and P into the soil filled

with 196.25 cm³ significantly promoted the growth of the root system, and more of that than the threshold will lead in the inhibition of N and P on the root. Short-term N and P addition had significant effects on total length, diameter, surface area, volume, biomass, root length density, specific root length, specific surface area and root surface area density of the privet root system ($P < 0.05$).

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