

Nitrogen Addition Did Not Alter the Relationships Between the Leaf and Root Traits of *Machilus Pauhoi* seedlings

Yuxing Zou

Fujian Normal University <https://orcid.org/0000-0001-5549-3445>

Baoyin Li

Fujian Normal University

Hua Yu

Fujian Normal University

Xiaoping Chen

Fujian Normal University

Xingyu Deng

Fujian Normal University

Dongliang Cheng

Fujian Normal University

Quanlin Zhong (✉ qlzhong@126.com)

Fujian Normal University

Research

Keywords: leaf trait, root trait, correlation, Machilus pauhoi

Posted Date: June 25th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-37224/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Leaves and roots are important resource acquisition organs of seedlings and both are sensitive to the environment. However, it is currently unclear whether leaf and root traits have a similar response model to nitrogen (N) deposition. Furthermore, the relationships between the responses of leaf and root traits to N deposition are still unknown.

Exogenous nitrogen input experiments were conducted to simulate the effects of nitrogen deposition in Shunchang County, south of China. We measured the biomass, morphological characteristics, and nutrient concentrations (total of 12 functional traits of leaves and roots) of *Machilus pauhoi* seedlings. The responses of leaf and root traits to N addition were analyzed. In addition, the relationships between paired leaf and root traits were analyzed.

We found that the responses of the leaves and roots to short-term nitrogen deposition were not consistent. The specific leaf area (SLA) (specific root length, SRL), tissue density (TD), carbon (C) content, N content, C/N, and N/phosphorus (P) of the leaf and root did not appear to respond to N addition. However, the biomass, P content, and C/P of the leaf and root markedly responded to N addition. The nutrient concentrations of the leaf and root were correlated, while the phenotypic traits were not. Furthermore, short-term N addition did not alter the relationship between the leaves and roots.

Our results show that, in the context of global change of nitrogen deposition, the correlation between the leaves and roots of a plant has a certain tolerance for nitrogen deposition, which is of great significance for the efficient cultivation of quality seedlings and understanding how terrestrial forest ecosystems respond to nitrogen deposition.

Introduction

Leaves and roots are important resource acquisition organs of seedlings. Leaves produce carbohydrates by photosynthesizing (Niinemets et al. 2010), while the root's main role is to absorb nutrients (Laliberte 2017). Both of them are plastic to environmental change and can, therefore, be used as indicators (Kou et al. 2018). Previous studies have been conducted on leaves and roots, such as leaf nutrients (Mayor et al. 2014), leaf microbial diversity (Laforest-Lapointe et al. 2017), root morphology (Zhou et al. 2019), root functional traits (Ma et al. 2018), and root decomposition (See et al. 2019). Furthermore, the theories of leaf (Osnas et al. 2013; Wright et al. 2004) and root economic spectra (Prieto et al. 2015; Roumet et al. 2016) have gained interest in recent years. As the vital components of the plant, a strategy was established between the leaves and roots, where the water and nutrients required for leaf photosynthesis are absorbed by the root and the carbohydrates that sustain root turnover are produced by the leaf (Chapin lii 1980; Fortunel et al. 2012). While the monitoring of roots is inconvenient, the observations of the above-ground organs may be extrapolated to the below-ground organs (Fort et al. 2012; Holdaway et al. 2011; Liu et al. 2010). A significant correlation was found between pairs of analogous leaf and root traits, such as the specific leaf area (SLA) and specific root length (SRL), leaf Nmass (leaf nitrogen

content per unit mass) and root N_{mass} (root nitrogen content per unit mass), and leaf N_{area} (leaf nitrogen content per unit area) and root N_{length} (leaf nitrogen content per unit area) (Holdaway et al. 2011; Liu et al. 2010; Reich 2014). While a relationship between the tissue density of the root and stem exists, this is not the case for the leaf (Fortunel et al. 2012). However, there are still few studies on the paired relationship between plant leaves and roots. Therefore, further research is required concerning the relationships between traits (Holdaway et al. 2011).

Nitrogen (N) deposition is an important part of the global nitrogen cycle (Stevens 2019). Due to anthropogenic influences, the amount of nitrogen entering a terrestrial ecosystem gradually increases (Liu et al. 2011). This is especially true for China's subtropical region in recent years, which has become an area that is severely affected by nitrogen deposition, with a deposition rate higher than 50 kg N ha⁻¹ yr⁻¹ (Zhu et al. 2015). Nitrogen is an essential nutrient that regulates plant growth and development (Vitousek 2004). An excess of nitrogen in an ecosystem will inevitably affect plant growth (Li et al. 2015; Oldroyd and Leyser 2020; Schleuss et al. 2020). However, current studies mainly focus on certain plant organs, such as the leaf (Laforest-Lapointe et al. 2017; Mayor et al. 2014; Osnas et al. 2013) or roots (Laliberte 2017; Ma et al. 2018; Zhou et al. 2019). Although some studies have reported on the effects of nitrogen deposition on plant leaves and roots (Lu et al. 2018; Talhelm et al. 2017; Xia et al. 2018), there is still a lack of research on whether nitrogen deposition alters the correlation between these organs. Therefore, it is necessary to acquire more information concerning the variation in leaf and root trait relationships in the context of global N deposition.

Machilus pauhoi, the dominant forest species in the south of China, is a rare evergreen broad-leaved species with rapid growth in subtropical areas. So far, studies have been carried out concerning the biomass (Zhong et al. 2001), roots (Wang et al. 2018b; Zou et al. 2018), leaves (Li et al. 2016a; Wu et al. 2016; Yu et al. 2019), and different provenances (Yu et al. 2018) of *M. pauhoi*. However, in the context of a global increase in nitrogen deposition, whether the leaves and roots of *M. pauhoi* seedlings express the same response model and the relationship between the two is not understood. We conducted a nitrogen deposition simulation experiment to investigate the response of *M. pauhoi* seedlings to N deposition. We hypothesized that: 1) The leaves and roots have different response strategies for the addition of exogenous nitrogen; and 2) Plant leaf and root traits may differ after N addition and the correlation between the leaf and root will change. Our research will provide important guidance for the efficient cultivation of quality seedlings in the context of nitrogen deposition.

Materials And Methods

Site Description and Experimental Design

This study was conducted in Shunchang County (117°48'E, 26°48'N), Nanping City, Fujian Province, south of China. The area is characterized by a subtropical monsoon climate with a mean annual temperature of 18.9 °C. The annual rainfall ranges from 1600 to 1900 mm, with most rainfall occurring from February to September. For the exogenous nitrogen input experiment, two-year-old *M. pauhoi* seedlings were selected.

The N treatment received an input of $100 \text{ kg}\cdot\text{hm}^{-2}\cdot\text{a}^{-1}$, which was double the local N deposition rate of $50 \text{ kg}\cdot\text{hm}^{-2}\cdot\text{a}^{-1}$. In addition, a control treatment was established for comparison (CT, $0 \text{ kg}\cdot\text{hm}^{-2}\cdot\text{a}^{-1}$). Each treatment was completed in triplicate for statistical significance.

The exogenous nitrogen input experiment was conducted in a 70% shade frame at the Forestry Technology Center of Shunchang County. Polyvinyl chloride pots (inner diameter of 30 cm and height of 30 cm) containing red soil from Shunchang County were used for seedling transplants. Two-year-old seedlings, which were planted in July 2014 and cultivated until the experiment began, were transplanted on March 1st, 2016. To allow for acclimatization, N addition commenced after two months and was conducted from May to November. Ammonium nitrate (NH_4NO_3) was used for the addition of N, and the soil surface area was calculated based on the inner diameter of the pot. Then, the amount of N added per pot was calculated using the soil surface area (N_{100} treatment: 2.02 g of NH_4NO_3). NH_4NO_3 was dissolved in 10 ml of distilled water and uniformly applied with a pipette to the treatment and control pots. Each treatment had 16 seedlings and three replicates, totaling 96 *M. pauhoi* seedlings.

Leaf/Root Sampling and Chemical Analysis

At the end of the experiment, the seedlings from each treatment were harvested. The leaves, stems, and roots were collected separately. Root samples were cleaned using distilled water, and then scanned with an Epson V370 scanner. Each organ from one seedling was one sample. All 288 samples were transported to the laboratory as soon as possible.

A Vernier caliper (0.01 mm) was used to measure the thickness of the leaves (top, middle, and bottom; avoiding important veins), and the average of these values was used as the leaf thickness (LT; mm). The leaf area (LA) was measured using a LI-3000C portable leaf-area meter (Li-Cor, Lincoln, NE, USA). The saturated weight (L_{mass}) was determined after submerging a leaf in deionized water for 24 h in the dark. The SLA and leaf tissue density (TD_L) were calculated for selected leaf samples. Root samples were analyzed using WinRHIZO root-scanning software (Regent Instruments Inc., Ottawa, ON Canada). The SRL and root tissue density (TD_R) were calculated for selected root samples.

The dry weights of the leaf and root (L_{mass} and R_{mass} , respectively) samples were determined after oven-drying at 65°C until a constant weight was obtained. For both the N and P analyses, the dried samples were ground into a fine powder using a sample grinder and screened with a 1-mm sieve. The N content was determined using a CHNS/O Elemental Analyzer (Vario EL III, Elementar, Langenselbold, Germany). The P content was determined using a Continuous Flow Analytical System (SAN ++, Skalar, Breda, Holland) after digestion and boiling in a solution of $\text{H}_2\text{SO}_4\text{-HClO}_4$. In addition, we investigated the total nutrient content of the leaves and roots (total leaf carbon content (TC_L), total leaf nitrogen content (TN_L), total leaf phosphorus content (TP_L), total root carbon content (TC_R), total root nitrogen content (TN_R), and total root phosphorus content (TP_R)). The formulae used for these calculations can be found in additional materials S1.

Statistical Analysis

A comparison between the different treatments was completed using an independent sample *t*-test. We calculated the relative effects (RE) of N addition [(means from N addition plots – means from ambient plots)/(means from ambient plots)×100] on the leaf and root traits of *M. pauhoi* seedlings (Duval et al. 2011). The independent sample *t*-test was also performed to determine the differences between the relative effects of the leaf and root.

The relationships between all leaf and root functional traits were best fit by the mathematical equation $\log(y) = \log(\beta) + \alpha \log(x)$, where β is the normalization constant and α is the scaling exponent. Model Type II regression was used to determine the numerical values of β and α using the (Standardized) Major Axis Estimation package ‘smatr’ version 3.4-3 in R software (R Core Development Team 2014; Taskinen 2012). Prior to the analysis, all data were \log_{10} transformed to fit a normal distribution pattern. All statistical analyses were performed in R (version 3.1.0) using the packages “*ggplot2* (Wickham 2016)” and “*ggpuber* (Kassambara 2020)”. OriginPro 2020 software (Origin Lab Corp., Northampton, MA, USA) was used to create the figures.

Results

Responses of the Leaf and Root Traits to Nitrogen Addition

The different leaf and root traits have different responses to nitrogen addition (Table 2). On the one hand, the SLA (SRL), TD, C, N, carbon/nitrogen (C/N), and nitrogen/phosphorus (N/P) of the leaf and root did not appear to respond to N addition. On the other hand, the biomass, P, and carbon/phosphorus (C/P) of the leaf and root markedly responded to N addition (Table 2). Overall, except for the TP_R , the total nutrient traits were significantly altered by the N treatment (Table 2).

Notably, despite the biomass of both organs increasing after nitrogen application, their proportions in the whole seedling varied (S2a). Overall, the proportion of leaves increased, the proportion of roots decreased, and the proportion of the biomass of these two organs showed a significant negative correlation (S2b).

RE of the Leaf and Root Traits

The response of the leaves and roots exhibited the same patterns for the following traits: 1) both the P_L and P_R and TD_L and TD_R were induced by N addition (Fig. 1); and 2) the C/P, TC, TN, and biomass increased significantly after N addition. Furthermore, we found that the responses of the following root and leaf traits differed: 1) after N addition, the SLA decreased, while the SRL increased, and the RE *t*-test results of the two were significant; and 2) the N, C, and C/N had different responses, even though their *t*-test results were not significant.

Standardized major axis (SMA) of the Leaf and Root Traits

The majority of the paired leaf and root traits exhibited a linear positive correlation, except for the C_R and C_L , SRL and SLA, NP_R and NP_L , and TD_R and TD_L (Fig. 2, Table 3). Notably, the relationships between the Bio_R and Bio_L , TN_R and TN_L , and TC_R and TC_L were not altered after the addition N, due to their common slope and intercept (Fig. 2, Table 3).

Specifically, the common slopes were 0.99 (95% CI = 0.89 – 1.23, $P = 0.67$) for N_R and N_L , 1.01 (95% CI = 0.92 – 1.27, $P = 0.85$) for C/N_R and C/N_L , and 1.03 (95% CI = 0.85 – 1.18, $P = 0.06$) for TP_R and TP_L . Across the two treatments, the scaling exponents of N_R and N_L , C/N_R and C/N_L , and TP_R and TP_L were 1.02, 1.01, and 0.99, respectively (Table 3), each of which were statistically indistinguishable from 1.0 (all $P_{1.0} > 0.05$) (Table 3).

Responses of the Leaf and Root Traits to Nitrogen Addition

The different leaf and root traits have different responses to nitrogen addition (Table 2). On the one hand, the SLA (SRL), TD, C, N, carbon/nitrogen (C/N), and nitrogen/phosphorus (N/P) of the leaf and root did not appear to respond to N addition. On the other hand, the biomass, P, and carbon/phosphorus (C/P) of the leaf and root markedly responded to N addition (Table 2). Overall, except for the TP_R , the total nutrient traits were significantly altered by the N treatment (Table 2).

Notably, despite the biomass of both organs increasing after nitrogen application, their proportions in the whole seedling varied (S2a). Overall, the proportion of leaves increased, the proportion of roots decreased, and the proportion of the biomass of these two organs showed a significant negative correlation (S2b).

RE of the Leaf and Root Traits

The response of the leaves and roots exhibited the same patterns for the following traits: 1) both the P_L and P_R , and TD_L and TD_R were induced by N addition (Fig. 1); and 2) the C/P, TC, TN, and biomass increased significantly after N addition. Furthermore, we found that the responses of the following root and leaf traits differed: 1) after N addition, the SLA decreased, while the SRL increased, and the RE t -test results of the two were significant; and 2) the N, C, and C/N had different responses, even though their t -test results were not significant.

Standardized major axis (SMA) of the Leaf and Root Traits

The majority of the paired leaf and root traits exhibited a linear positive correlation, except for the C_R and C_L , SRL and SLA, NP_R and NP_L , and TD_R and TD_L (Fig. 2, Table 3). Notably, the relationships between the

Bio_R and Bio_L, TN_R and TN_L, and TC_R and TC_L were not altered after the addition N, due to their common slope and intercept (Fig. 2, Table 3).

Specifically, the common slopes were 0.99 (95% CI = 0.89 – 1.23, P = 0.67) for N_R and N_L, 1.01 (95% CI = 0.92 – 1.27, P = 0.85) for C/N_R and C/N_L, and 1.03 (95% CI = 0.85 – 1.18, P = 0.06) for TP_R and TP_L. Across the two treatments, the scaling exponents of N_R and N_L, C/N_R and C/N_L, and TP_R and TP_L were 1.02, 1.01, and 0.99, respectively (Table 3), each of which were statistically indistinguishable from 1.0 (all $P_{1.0} > 0.05$) (Table 3).

Discussion

Leaf and Root Responses of Seedlings to N Addition

Nitrogen is one of the main limiting elements that plants need to absorb from soil to mature (Güsewell 2004). Plants optimize the uptake of nitrogen and phosphorus by changing their functional traits and interacting with microorganisms to facilitate nutrient capture (Oldroyd and Leyser 2020). Nitrogen addition improves the soil available N content, alters the processes of microbe nitrogen conversion (mineralization, nitrification, and denitrification), and affects the N absorption of plants (Matson et al. 1999). The effect of N on the plant P content is influenced by many factors. Plant P uptake may benefit from a higher N availability because plants might use N for up-regulating P uptake transport systems (Zeng et al. 2012). Similarly, elevated N and P inputs may alter root traits in a way that promotes plant nutrient uptake (Schleuss et al. 2020). Our first hypothesis, concerning the similarities between the responses of leaves and roots to exogenous nitrogen addition, was partially supported. According to the results, the N_L, P_L, and P_R of *M. pauhoi* seedlings decreased after N addition, which may have resulted from the “dilution effect” (Jarrell and Beverly 1981) because the leaf and root dry mass significantly increased. On the other hand, N addition caused soil acidification and bound the phosphorus with a metal ion to reduce the available P in the soil, which affected the plants owing to the decrease in the amount of P that could be absorbed (Bünemann et al. 2010; Kou et al. 2018). The decrease in the soil available P may have reduced the leaf P content, which, on account of the P availability, was insufficient to balance the increasing P requirements under N addition (Huang et al. 2016; Jonard et al. 2015; Li et al. 2016b). The mycorrhizal activity may have been inhibited by the N addition (Nilsson and Wallander 2003), even though nitrogen enrichment has been known to increase the phosphatase activity and soil P availability (Deng et al. 2017; Olander and Vitousek 2000). Consequently, the availability of the phosphorous required for the seedlings would be limited (Wallander et al. 2001). One exception is that the root N concentrations increase with increasing N availability (Hendricks et al. 2000). However, in this study, the N_L and N_R did not significantly respond to N addition. When nutrient concentrations are limited, the homeostasis of the leaf may be higher than that of the other plant organs (Jiang et al. 2014; Wang et al. 2018a; Wang et al. 2019). Roots absorb water and nutrients from the soil, which are transported to the leaf, potentially resulting in a lower homeostasis (Jin et al. 2017; Paez-Garcia et al. 2015; Wang et al. 2018a). This may partially explain why the N_R significantly responds to N addition, while the N_L does not.

The responses of phenotypic traits to N addition were various. N addition significantly suppressed the SLA, which is consistent with numerous previous findings (Peng et al. 2018; Xiao et al. 2016; Zhang et al. 2006). However, some other studies have found that N addition promoted (Valliere et al. 2017; Wang et al. 2016; Wu et al. 2008) or did not affect (Zhang et al. 2018) the SLA. The SLA (reciprocal of leaf mass of area (LMA)) represents the light resources captured on the LA per unit of leaf dry matter, which is closely related to the light interception efficiency of plants (Reich 2014). A decrease in the SLA may represent a deterioration in the environmental conditions, as plants begin to adopt conservative growth strategies (Rose et al. 2013). Li et al. (2015) constructed a multivariate analysis of the effects of nitrogen deposition on fine-root traits and found that N deposition had no visible effects on the root morphology, but significantly increased the total root biomass. Similar results were obtained in this study, with no visible change in the SRL or TD_R after N addition, while the Bio_R increased markedly. Other studies found similar results (Davidson et al. 2004; Högberg 2007; Zhang et al. 2006). This may illustrate that roots do not enhance the exchange rate of resources in the plant-soil interface by changing the root surface or length (Eissenstat 1992; Li et al. 2015). Furthermore, N addition may simulate carbon accumulation in the root biomass (Li et al. 2015). After nitrogen addition, the increase in the leaf biomass was greater than that of the root biomass and the plant growth strategy tended to allocate more nutrients to the above-ground parts. This helps to predict how plants distribute C between the above- and below-ground biomass in response to global change of nitrogen deposition.

At present, most studies on plant nutrient contents are based on unit mass, but lack the overall nutrient contents of the above-ground or below-ground parts, which may be why it is not conducive to measure the below-ground parts in the field. In this paper, the total amount of nutrients in the leaves and roots of seedlings increased obviously (except for the TP_R) after N addition. This means that the exogenous nitrogen addition facilitated the absorption of nutrients by seedlings. However, due to the complex nutrient uptake, utilization, and exchange mechanisms of plants and microorganisms, the effects of N addition on plant organs are still unclear and further research is required.

Paired Relationships of the Leaf and Root

Leaf traits are widely used to describe plant growth and resource use strategies because they are easy to measure. However, roots play an important role for plant organs, as they are located underground and form the interface between the plants and soil (Hajek et al. 2013). Both the leaf and root are important organs for plants to obtain resources, and the strategy of observing above-ground organs can be extrapolated to below-ground organs (Fort et al. 2012; Holdaway et al. 2011; Kembel et al. 2008; Liu et al. 2010).

Previous studies have found that the relationship between the N and P contents in plant organs can be expressed by an allometric relationship, and its slope is significantly smaller than 1 (Elser et al. 2010; Reich et al. 2010; Zhao et al. 2016). However, there are few studies on the exponential relationships between the same traits in different organs.

Our results found that the phenotypic traits of the leaves and roots may be independent of each other. The SLA and SRL, which represent the most important plant resource acquisition strategies, are irrelevant in this article. The lack of a relationship between the SLA and SRL is consistent with the results of Tjoelker et al. (2005) and Hajek et al. (2013), but differs from other studies that found a positive relationship (Liu et al. 2010; Withington et al. 2006). Tissue structure is an inherent constraint that prevents the simultaneous maximization of nutrient acquisition and conservation (Ryser 1996). No link between the TD_L and TD_R has been found, which may indicate that the leaves and roots of plants have different nutrient and growth strategies.

The relationship between the leaves and roots was not altered after N addition. Leaves and roots coordinate due to nutrient, water, and carbohydrate exchange (Chapin 1980; Fortunel et al. 2012). For the nutrient traits, the positive correlations between the N (Freschet et al. 2010; Liu et al. 2010; Tjoelker et al. 2005) and P (Holdaway et al. 2011; Kerkhoff et al. 2006) contents of the leaves and roots have been previously reported. The significant positive relationship between the N concentrations of the leaves and roots was also present in our research, which differs from the findings of Hajek et al. (2013), but is consistent with Liu's research in Chinese semi-arid and arid ecosystems (Liu et al. 2010). The addition of N decreased the intercept for the N_L and N_R but increased the intercept for the C/N_L and C/N_R . This may be because the seedlings tended to allocate more N to the roots, which would result in a higher C/N_R . Plants and microbes may invest an element that is in excess into the acquisition of a limiting element until their growth is equally limited by both elements (Bloom et al. 1985). In this paper, the relationship between the P_L and P_R was not altered by the N addition, even though the P contents in the leaves and roots were significantly affected. This indicated that the P content in the plant leaves and roots was more stable than the N content. The addition of nitrogen led to the rapid growth of plants, but the unit mass P content did not visibly change. Interestingly, differing from the common slope and intercept of the P_L and P_R , the TP_L and TP_R had different intercepts. In addition, the intercepts of the TP_L and TP_R were highest after fertilization, which indicated that, overall, the plants tended to allocate more P to the roots after nitrogen application. In general, plants tend to allocate more P and C to roots after the addition of nitrogen. Although the addition of nitrogen did not change the above-/below-ground distribution of N, we can still deduce that the N:P of the above-ground part of the plant was higher than that of the below-ground part. This proves that an increase in the P contents of the roots reduces the N:P, providing that the overall N contents is not altered.

Conclusion

The effects of N addition on *M. pauhoi* seedlings were tested. After investigating the leaf and root traits and their relationships, we found that N addition had no significant effects on the correlations between leaf and root traits. Further research into other species is required to clarify the relationship between the leaf and root for understanding ecosystem functions and services. Our research provides an important reference for the efficient cultivation of quality seedlings in the context of nitrogen deposition.

Declarations

Sources of Funding

This research was funded by the National Natural Science Foundation of China (31971643, 31370589, 31470501), the National Key Research and Development Program of China (2017YFC0505400), the Central Finance Forestry Science and Technology Promotion Project(2015-12), the Major S&T Project of Fujian Province (2019N5009), and the Fujian Natural Science Fund for Distinguished Young Scholars (2018J07003), and the Natural Science Foundation of Fujian Province of China (2018J01479).

Availability of data and materials

The datasets used and/or analysed during the current study are available from Mr. Yuxing Zou (looe_x@126.com) on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Author Contributions

Conceptualization, Y.-X.Z. and Q.-L.Z.; methodology, Y.-X.Z. and B.-Y.L.; software, Y.-X.Z. and X.-P.C.; validation, Y.-X.Z. and H.Y. ; formal analysis, Y.-X.Z.; investigation, X.-P.C., X.-Y.D. and H.Y.; resources, Y.-X.Z.; data curation, Y.-X.Z.; writing—original draft preparation, Y.-X.Z.; writing—review and editing, Y.-X.Z., Q.-L.Z. and D.-L.C.; supervision, B.-Y.L.; funding acquisition, Q.-L.Z., H.Y. and D.-L.C.

Acknowledgments

We would like to thank Jiajing Chen, Zhihao Zhang, Mengke Sun, Hanzhao Zeng and Ting Yang for their assistance in collecting plant and soil materials used for experiments. We are sincerely grateful to the anonymous reviewers for their valuable comments to improve the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Author details

¹ College of Geographical Science, Fujian Normal University, Fuzhou, Fujian Province 350007, China. ² Fujian Provincial Key Laboratory of Plant Ecophysiology, Fujian Normal University, Fuzhou, Fujian Province 350007, China. ³ State Key Laboratory of Subtropical Mountain Ecology (Ministry of Science

and Technology and Fujian Province funded), Fuzhou, Fujian Province 350007, China. ⁴ Ocean College, Minjiang University, Fuzhou, Fujian Province 350007, China

References

- Bloom AJ, Chapin lii FS, Mooney HA, (1985). Resource limitation in plants-an economic analogy. *Annu. Rev. Ecol. Evol. Syst.*, 16(1):363-392.
- Bünemann EK, Oberson A, Frossard E, 2010. Phosphorus in action: biological processes in soil phosphorus cycling. Springer Science & Business Media.
- Chapin lii FS, (1980). The mineral nutrition of wild plants. *Annu. Rev. Ecol. Syst.*, 11(1):233-260.
- Davidson EA, Reis De Carvalho CJ, Vieira IC, Figueiredo RDO, Moutinho P, Yoko Ishida F, Primo Dos Santos MT, Benito Guerrero J, Kalif K, Tuma Sabá R, (2004). Nitrogen and phosphorus limitation of biomass growth in a tropical secondary forest. *Ecol. Appl.*, 14(sp4):150-163.
- Deng Q, Hui D, Dennis S, Reddy KC, (2017). Responses of terrestrial ecosystem phosphorus cycling to nitrogen addition: A meta-analysis. *Glob. Ecol. Biogeogr.*, 26(6):713-728.
- Duval BD, Dijkstra P, Natali SM, Megonigal JP, Ketterer ME, Drake BG, Lerdau MT, Gordon G, Anbar AD, Hungate BA, (2011). Plant- Soil Distribution of Potentially Toxic Elements in Response to Elevated Atmospheric CO₂. *Environ. Sci. Technol.*, 45(7):2570-2574.
- Eissenstat DM, (1992). Costs and benefits of constructing roots of small diameter. *J. Plant Nutr.*, 15(6-7):763-782.
- Elser J, Fagan W, Kerkhoff A, Swenson N, Enquist B, (2010). Biological stoichiometry of plant production: metabolism, scaling and ecological response to global change. *New Phytol.*, 186(3):593-608.
- Fort F, Jouany C, Cruz P, (2012). Root and leaf functional trait relations in Poaceae species: implications of differing resource-acquisition strategies. *J PLANT ECOL*, 6(3):211-219.
- Fortunel C, Fine PV, Baraloto C, (2012). Leaf, stem and root tissue strategies across 758 Neotropical tree species. *Funct. Ecol.*, 26(5):1153-1161.
- Freschet GT, Cornelissen JHC, Logtestijn RSPV, Aerts R, (2010). Evidence of the 'Plant Economics Spectrum' in a Subarctic Flora. *J. Ecol.*, 98(2):362-373.
- Güsewell S, (2004). N : P ratios in terrestrial plants: variation and functional significance. *New Phytol.*, 164(2):243-266.
- Hajek P, Hertel D, Leuschner C, (2013). Intraspecific variation in root and leaf traits and leaf-root trait linkages in eight aspen demes (*Populus tremula* and *P. tremuloides*). *Front. Plant Sci.*, 4415.

- Hendricks JJ, Aber JD, Nadelhoffer KJ, Hallett RD, (2000). Nitrogen controls on fine root substrate quality in temperate forest ecosystems. *Ecosystems*, 3(1):57-69.
- Högberg P, (2007). Environmental science: nitrogen impacts on forest carbon. *Nature*, 447(7146):781-782.
- Holdaway RJ, Richardson SJ, Dickie IA, Peltzer DA, Coomes DA, (2011). Species- and community-level patterns in fine root traits along a 120 000-year soil chronosequence in temperate rain forest. *J. Ecol.*, 99(4):954-963.
- Huang Z, Liu B, Davis M, Sardans J, Peñuelas J, Billings S, (2016). Long-term nitrogen deposition linked to reduced water use efficiency in forests with low phosphorus availability. *New Phytol.*, 210(2):431-442.
- Jarrell WM, Beverly RB, (1981). The Dilution Effect in Plant Nutrition Studies. *Adv. Agron.*, 34:197-224.
- Jiang L, He S, Wu L, Yan Y, Weng S, Liu J, Wang W, Zeng C, (2014). Characteristics of stoichiometric homeostasis of three plant species in wetlands in Minjiang Estuary. *Wetl. Sci.*, 32:93-298.
- Jin K, White PJ, Whalley WR, Shen J, Shi L, (2017). Shaping an optimal soil by root–soil interaction. *Trends Plant Sci.*, 22(10):823-829.
- Jonard M, Fürst A, Verstraeten A, Thimonier A, Timmermann V, Potočić N, Waldner P, Benham S, Hansen K, Merilä P, (2015). Tree mineral nutrition is deteriorating in Europe. *Glob Chang Biol*, 21(1):418-430.
- Kassambara A, (2020). ggpubr: 'ggplot2' Based Publication Ready Plots.
- Kemmel SW, De Kroon H, Cahill JF, Mommer L, (2008). Improving the scale and precision of hypotheses to explain root foraging ability. *Ann. Bot.*, 101(9):1295-1301.
- Kerkhoff AJ, Fagan WF, Elser JJ, Enquist BJ, (2006). Phylogenetic and growth form variation in the scaling of nitrogen and phosphorus in the seed plants. *Am. Nat.*, 168(4):E103-E122.
- Kou L, Chen W, Jiang L, Dai X, Fu X, Wang H, Li S, (2018). Simulated nitrogen deposition affects stoichiometry of multiple elements in resource-acquiring plant organs in a seasonally dry subtropical forest. *Sci. Total Environ.*, 624:611-620.
- Laforest-Lapointe I, Paquette A, Messier C, Kemmel SW, (2017). Leaf bacterial diversity mediates plant diversity and ecosystem function relationships. *Nature*, 546(7656):145.
- Laliberte E, (2017). Below-ground frontiers in trait-based plant ecology. *New Phytol.*, 213(4):1597-1603.
- Li M, Jin BJ, Zhong QL, Ma YZ, Lu HD, Guo BQ, Zheng Y, Cheng DL, (2016a). Effect of nitrogen and phosphorus fertilization on leaf N and P stoichiometric characteristics of *Machilus pauhoi* seedlings. *Chin J Appl Environ Biol*(2):0285-0291.

- Li W, Jin C, Guan D, Wang Q, Wang A, Yuan F, Wu J, (2015). The effects of simulated nitrogen deposition on plant root traits: A meta-analysis. *Soil Biol. Biochem.*, 82:112-118.
- Li Y, Niu S, Yu G, (2016b). Aggravated phosphorus limitation on biomass production under increasing nitrogen loading: a meta-analysis. *Glob Chang Biol*, 22(2):934-943.
- Liu G, Freschet GT, Pan X, Cornelissen JH, Li Y, Dong M, (2010). Coordinated variation in leaf and root traits across multiple spatial scales in Chinese semi-arid and arid ecosystems. *New Phytol.*, 188(2):543-553.
- Liu X, Duan L, Mo J, Du E, Shen J, Lu X, Zhang Y, Zhou X, He C, Zhang F, (2011). Nitrogen deposition and its ecological impact in China: an overview. *Environ. Pollut.*, 159(10):2251-2264.
- Lu X, Vitousek PM, Mao Q, Gilliam FS, Luo Y, Zhou G, Zou X, Bai E, Scanlon TM, Hou E, Mo J, (2018). Plant acclimation to long-term high nitrogen deposition in an N-rich tropical forest. *Proc. Natl. Acad. Sci. U. S. A.*, 115(20):5187-5192.
- Ma Z, Guo D, Xu X, Lu M, Bardgett RD, Eissenstat DM, McCormack ML, Hedin LO, (2018). Evolutionary history resolves global organization of root functional traits. *Nature*, 555(7694):94.
- Matson PA, McDowell WH, Townsend AR, Vitousek PM, (1999). The globalization of N deposition: ecosystem consequences in tropical environments. *Biogeochemistry*, 46(1-3):67-83.
- Mayor JR, Wright SJ, Turner BL, (2014). Species-specific responses of foliar nutrients to long-term nitrogen and phosphorus additions in a lowland tropical forest. *J. Ecol.*, 102(1):36-44.
- Niinemets Ü, Portsmouth A, Tobias M, (2010). Leaf size modifies support biomass distribution among stems, petioles and mid-ribs in temperate plants. *New Phytol.*, 171(1):91-104.
- Nilsson LO, Wallander H, (2003). Production of external mycelium by ectomycorrhizal fungi in a Norway spruce forest was reduced in response to nitrogen fertilization. *New Phytol.*, 158(2):409-416.
- Olander LP, Vitousek PM, (2000). Regulation of soil phosphatase and chitinase activity by N and P availability. *Biogeochemistry*, 49(2):175-191.
- Oldroyd GE, Leyser OJS, (2020). A plant's diet, surviving in a variable nutrient environment. *Science*, 368(6486).
- Osnas JL, Lichstein JW, Reich PB, Pacala SW, (2013). Global leaf trait relationships: mass, area, and the leaf economics spectrum. *Science*, 340(6133):741-744.
- Paez-Garcia A, Motes CM, Scheible W-R, Chen R, Blancaflor EB, Monteros MJ, (2015). Root traits and phenotyping strategies for plant improvement. *Plants*, 4(2):334-355.

- Peng SZ, He NP, Hou JH, (2018). Effect of nitrogen addition on leaf nitrogen and phosphorus stoichiometric characteristics of different provenance *Acer mono* seedlings. *Sheng Tai Xue Bao*, 38(1):254-262.
- Prieto I, Roumet C, Cardinael R, Dupraz C, Jourdan C, Kim JH, Maeght JL, Mao Z, Pierret A, Portillo N, (2015). Root functional parameters along a land-use gradient: evidence of a community-level economics spectrum. *J. Ecol.*, 103(2):361-373.
- R Core Development Team, (2014). R: A language and environment for statistical computing. 1(1).
- Reich PB, (2014). The world-wide 'fast-slow' plant economics spectrum: a traits manifesto. *J. Ecol.*, 102(2):275-301.
- Reich PB, Oleksyn J, Wright IJ, Niklas KJ, Hedin L, Elser JJ, (2010). Evidence of a general 2/3-power law of scaling leaf nitrogen to phosphorus among major plant groups and biomes. *Proc. Royal Soc. B*, 277(1683):877-883.
- Rose L, Rubarth MC, Hertel D, Leuschner C, (2013). Management alters interspecific leaf trait relationships and trait-based species rankings in permanent meadows. *J. Veg. Sci.*, 24(2):239-250.
- Roumet C, Birouste M, Picon-Cochard C, Ghestem M, Osman N, Vrignon-Brenas S, Cao KF, Stokes A, (2016). Root structure-function relationships in 74 species: evidence of a root economics spectrum related to carbon economy. *New Phytol.*, 210(3):815-826.
- Ryser P, (1996). The importance of tissue density for growth and life span of leaves and roots: a comparison of five ecologically contrasting grasses. *Funct. Ecol.*, 10(6):717-723.
- Schleuss PM, Widdig M, Heintz-Buschart A, Kirkman K, Spohn MJE, (2020). Interactions of nitrogen and phosphorus cycling promote P acquisition and explain synergistic plant growth responses. *Ecology*, 101(5):e03003.
- See CR, Luke McCormack M, Hobbie SE, Flores-Moreno H, Silver WL, Kennedy PG, (2019). Global patterns in fine root decomposition: climate, chemistry, mycorrhizal association and woodiness. *Ecol. Lett.*, 22(6):946-953.
- Stevens CJ, (2019). Nitrogen in the environment. *Science*, 363(6427):578-580.
- Talhelm AF, Pregitzer KS, Burton AJ, Xia M, Zak DR, (2017). Simulated Nitrogen Deposition has Minor Effects on Ecosystem Pools and Fluxes of Energy, Elements, and Biochemicals in a Northern Hardwoods Forest, AGU Fall Meeting Abstracts, pp. B23I-08.
- Taskinen DIWaRaDaDSFaS, (2012). smatr 3 - an R package for estimation and inference about allometric lines. *Methods Ecol. Evol.*, 3:257-259.

- Tjoelker M, Craine JM, Wedin D, Reich PB, Tilman D, (2005). Linking leaf and root trait syndromes among 39 grassland and savannah species. *New Phytol.*, 167(2):493-508.
- Valliere JM, Irvine IC, Santiago L, Allen EB, (2017). High N, dry: experimental nitrogen deposition exacerbates native shrub loss and nonnative plant invasion during extreme drought. *Glob Chang Biol*, 23(10):4333-4345.
- Vitousek PM, 2004. *Nutrient Cycling and Limitation: Hawai'i as a Model System*. Princeton University Press.
- Wallander H, Nilsson LO, Hagerberg D, Bååth E, (2001). Estimation of the biomass and seasonal growth of external mycelium of ectomycorrhizal fungi in the field. *New Phytol.*, 151(3):753-760.
- Wang C, Xiao H, Liu J, Zhou J, Du D, (2016). Insights into the Effects of Simulated Nitrogen Deposition on Leaf Functional Traits of *Rhus Typhina*. *Pol. J. Environ. Stud.*, 25(3):1279–1284.
- Wang J, Wang J, Guo W, Li Y, Wang GG, Wu T, (2018a). Stoichiometric homeostasis, physiology, and growth responses of three tree species to nitrogen and phosphorus addition. *Trees*, 32(5):1377-1386.
- Wang J, Wang J, Wang L, Zhang H, Guo Z, Wang GG, Smith WK, Wu T, (2019). Does stoichiometric homeostasis differ among tree organs and with tree age? *For. Ecol. Manag.*, 453117637.
- Wang Y, Zhong QL, Xu CB, Zhang ZR, Liang CD, (2018b). Effect of adding a combination of nitrogen and phosphorus on fine root morphology and soil microbes of *Machilus pauhoi* seedling. *Sheng Tai Xue Bao*, 38(7):2271-2278.
- Wickham H, (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York.
- Withington JM, Reich PB, Oleksyn J, Eissenstat DM, (2006). Comparisons of structure and life span in roots and leaves among temperate trees. *Ecol. Monogr.*, 76(3):381-397.
- Wright IJ, Reich PB, Westoby M, Ackerly DD, Baruch Z, Bongers F, Cavender-Bares J, Chapin T, Cornelissen JH, Diemer M, (2004). The worldwide leaf economics spectrum. *Nature*, 428(6985):821.
- Wu F, Bao W, Li F, Wu N, (2008). Effects of water stress and nitrogen supply on leaf gas exchange and fluorescence parameters of *Sophora davidii* seedlings. *Photosynthetica*, 46(1):40-48.
- Wu YH, Wang LH, Cheng DL, Xu CB, Zhang ZR, Li J, Zhong QL, (2016). Effect of water and nitrogen treatment on photosynthetic characteristics and the biomass allocation of annual cutting seedling of *Machilus pauhoi*. *Journal of Anhui Agricultural University*, 43(2):202-208.
- Xia M, Talhelm AF, Pregitzer KS, (2018). Long-Term Simulated Atmospheric Nitrogen Deposition Alters Leaf and Fine Root Decomposition. *Ecosystems*, 21(1):1-14.

- Xiao D, Wang XJ, Zhang K, He NP, Hou JH, (2016). Effects of nitrogen addition on leaf traits of common species in natural *Pinus tabuliformis* forests in Taiyue Mountain, Shanxi Province, China. *Chinese J. Plant Ecol.*, 40(7):686–701.
- Yu H, Cheng D, Li B, Xu C, Zhang Z, Zhong Y, Zhong Q, (2019). Short-Term Nitrogen Addition Does Not Significantly Alter the Effects of Seasonal Drought on Leaf Functional Traits in *Machilus pauhoi* Kanehira Seedlings. *Forests*, 10(2):78.
- Yu H, Zhong QL, Huang YB, Cheng DL, Pei P, Zhang ZR, Xu CB, Zheng WT, (2018). Relationships between leaf functional traits of *Machilus pauhoi* understory seedlings from different provenances and geographical environmental factors. *Ying Yong Sheng Tai Xue Bao*, 29(2):449-458.
- Zeng H, Liu G, Kinoshita T, Zhang R, Zhu Y, Shen Q, Xu G, (2012). Stimulation of phosphorus uptake by ammonium nutrition involves plasma membrane H⁺ ATPase in rice roots. *Plant soil*, 357(1-2):205-214.
- Zhang H, Li W, Adams HD, Wang A, Wu J, Jin C, Guan D, Yuan F, (2018). Responses of woody plant functional traits to nitrogen addition: a meta-analysis of leaf economics, gas exchange, and hydraulic traits. *Front. Plant Sci.*, 9683.
- Zhang S, Dang Q-L, Yü X, (2006). Nutrient and [CO₂] elevation had synergistic effects on biomass production but not on biomass allocation of white birch seedlings. *For. Ecol. Manag.*, 234(1-3):238-244.
- Zhao N, Yu G, He N, Xia F, Wang Q, Wang R, Xu Z, Jia Y, (2016). Invariant allometric scaling of nitrogen and phosphorus in leaves, stems, and fine roots of woody plants along an altitudinal gradient. *J. Plant Res.*, 129(4):647-657.
- Zhong QL, Zhang ZY, Zhang CH, Zhou HL, Qiang HZ, (2001). The Dynamic Analysis of the Biomass and the Structure of *Machilus Pauhoi*. *Acta Agriculturae Universitatis Jiang xiensis*, 23(4):533-536.
- Zhou T, Wang L, Sun X, Wang X, Chen Y, Rengel Z, Liu W, Yang W, (2019). Light intensity influence maize adaptation to low P stress by altering root morphology. *Plant Soil* 1-15.
- Zhu J, He N, Wang Q, Yuan G, Wen D, Yu G, Jia Y, (2015). The composition, spatial patterns, and influencing factors of atmospheric wet nitrogen deposition in Chinese terrestrial ecosystems. *Sci. Total Environ.*, 511777-785.
- Zou YX, Zhong QL, You YL, Yu H, Zheng WT, Chen JJ, Cheng DL, (2018). Short-term effects of nitrogen and water treatments on fine root order morphology of *Machilus pauhoi* seedlings. *Ying Yong Sheng Tai Xue Bao*, 29(7):2323–2329.

Tables

Table 1. Information concerning the seedlings and soil traits (Avg ± SE)

Seedling Trait		Soil Trait			
TH (cm)	GD (cm)	STN (mg/g)	STC (mg/g)	STP (mg/g)	pH
61.33±15.76	5.58±1.35	0.7168 ±0.01	4.6299 ±0.05	1.142 ±0.07	4.97±0.18

Note: TH: tree height; GD: ground diameter; STN: soil total nitrogen content; STC: soil total carbon content; and STP: soil total phosphorus content

Table 2. Response of the leaf and root traits to nitrogen addition (Avg ± SE, n = 96)

Trait	Leaf			Root		
	CT	N	<i>p</i>	CT	N	<i>p</i>
SLA(SRL)	137.53±2.1 4	129.57±1.8 2	0.006*	7.95±0.35	8.81±0.33	0.076
TD	0.04±0	0.04±0	0.88	5.98±0.15	5.68±0.17	0.194
Bio	4.75±0.4	7.51±0.45	0**	8.48±0.42	11.89±0.54	0**
C	492.64±1.3 5	503.77±1.3 4	0**	443.17±4.1 6	445.85±4.8 5	0.676
N	15.51±0.44	14.97±0.36	0.343	10.62±0.3	11.35±0.27	0.071
P	1.19±0.04	1.07±0.03	0.016*	2.34±0.12	1.69±0.09	0**
C/N	33.18±1.12	34.57±0.96	0.348	42.71±1.21	39.78±1.01	0.066
N/P	13.16±0.4	14±0.29	0.093	5.02±0.27	7.48±0.35	0**
C/P	429.71±16. 44	497.5±17.4 8	0.006**	216.74±12. 45	302.98±16. 82	0**
TC	2343.14±19 8.63	3781.48±22 6.79	0**	3723.6±173 .51	5281.13±24 3.99	0**
TN	74.72±7.13	110.91±7.0 2	0**	90.22±5.62	136.36±6.2 1	0**
TP	5.76±0.61	7.92±0.54	0.01**	19.83±1.56	21.02±1.62	0.597

Note: "*" and "**" indicate a significant correlation at < 0.05 and 0.01, respectively. The RP and RNP were not analyzed. The abbreviations of the indicators are shown in table 2.

Table 3 Summary of the regression parameters (slopes and y-intercepts, α and $\log \beta$, respectively) for the relationships between paired leaf and root traits in the two treatments (n = 96)

	Treatment	N	α (95%CI)	β (95%CI)	r^2	p
SLA vs. SRL	CT	48	-0.37(-0.5,-0.28)	2.47(2.37,2.56)	0.01	0.52
	N	48	0.38(0.28,0.51)	1.76(1.65,1.86)	0.01	0.43
TD _L vs. TD _R	CT	48	0.4(0.3,0.54)	-1.7(-1.79,-1.61)	0.01	0.43
	N	48	0.32(0.24,0.42)	-1.62(-1.69,-1.55)	0.02	0.4
N _L vs. N _R	CT	48	1.08(0.85,1.36)	0.08(-0.18,0.35)	0.36	<0.001
	N	48	1(0.78,1.29)	0.12(-0.15,0.39)	0.27	<0.001
P _L vs. P _R	CT	48	0.61(0.47,0.79)	-0.14(-0.21,-0.08)	0.18	0.002
	N	48	0.62(0.49,0.79)	-0.11(-0.15,-0.06)	0.32	<0.001
C _L vs. C _R	CT	48	0.29(0.21,0.38)	1.93(1.71,2.16)	0.01	0.6
	N	48	0.24(0.18,0.32)	2.06(1.87,2.25)	0.02	0.33
C/N _L vs. C/N _R	CT	48	1.06(0.85,1.33)	-0.21(-0.6,0.17)	0.44	<0.001
	N	48	1.1(0.86,1.41)	-0.22(-0.66,0.22)	0.28	<0.001
N/P _L vs. N/P _R	CT	48	0.74(0.55,0.99)	0.61(0.45,0.76)	0.02	0.31
	N	48	0.44(0.33,0.58)	0.77(0.66,0.88)	0.08	0.05
Bio _L vs. Bio _R	CT	48	1.54(1.26,1.87)	-0.78(-1.06,-0.5)	0.55	<0.001
	N	48	1.38(1.08,1.76)	-0.62(-0.98,-0.25)	0.3	<0.001
TC _L vs. TC _R	CT	48	1.65(1.35,2.02)	-2.57(-3.76,-1.37)	0.53	<0.001
	N	48	1.41(1.1,1.81)	-1.69(-3.01,-0.37)	0.28	<0.001
TP _L vs. TP _R	CT	48	1.13(0.92,1.4)	-0.73(-1.03,-0.43)	0.51	<0.001
	N	48	0.83(0.65,1.07)	-0.2(-0.47,0.08)	0.25	<0.001
TN _L vs. TN _R	CT	48	1.52(1.29,1.8)	-1.13(-1.63,-0.64)	0.68	<0.001
	N	48	1.21(0.96,1.53)	-0.55(-1.16,0.06)	0.35	<0.001
C/N _L vs. TC/N	CT	48	0.97(0.78,1.21)	-0.07(-0.42,0.29)	0.43	<0.001
	N	48	0.86(0.67,1.1)	0.16(-0.18,0.51)	0.29	<0.001
N/P _L vs. TN/P	CT	48	0.74(0.56,0.98)	0.61(0.46,0.76)	0.08	0.049
	N	48	0.54(0.42,0.71)	0.69(0.56,0.81)	0.19	<0.001

Note: The abbreviations of the indicators are shown in S1.

Supplementary Information

The following additional information is available in the online version of this article:

Table S1 Computational formula for each trait

Note: LA: leaf area; Lmass: leaf mass; Lfmass: leaf fresh mass; Lsmass: leaf saturated mass; LT: leaf thickness; RL: root length; Rmass: root mass; Rvolume: root volume; and Rarea: root area

Figure S2 Proportions of the leaf and root biomass and their correlation

Note: A) Proportion of leaf and root biomass in the total seedling biomass under different treatments. The inner and outer rings are the control and N addition treatments, respectively. B) The relationship between the proportions of leaf and root biomass. Effects of N addition on the scaling relationship between Bio_R / Bio_{total} (Bio_{R/T}) and Bio_L / Bio_{total} proportion (Bio_{L/T}) in *M. pauhoi* seedlings. The lines are significant standardized major axis (SMA) regressions (P < 0.05). The scaling slopes of Bio_{R/T} and Bio_{L/T}

in *M. pauhoi* seedlings under different N treatments did not significantly differ, with a common slope of -1.2 (95% CI = -1.4 --1.0, P = 0.85) and common constant of -1.12 (95% CI = -1.12 --1.14, P = 0.36).

Figures

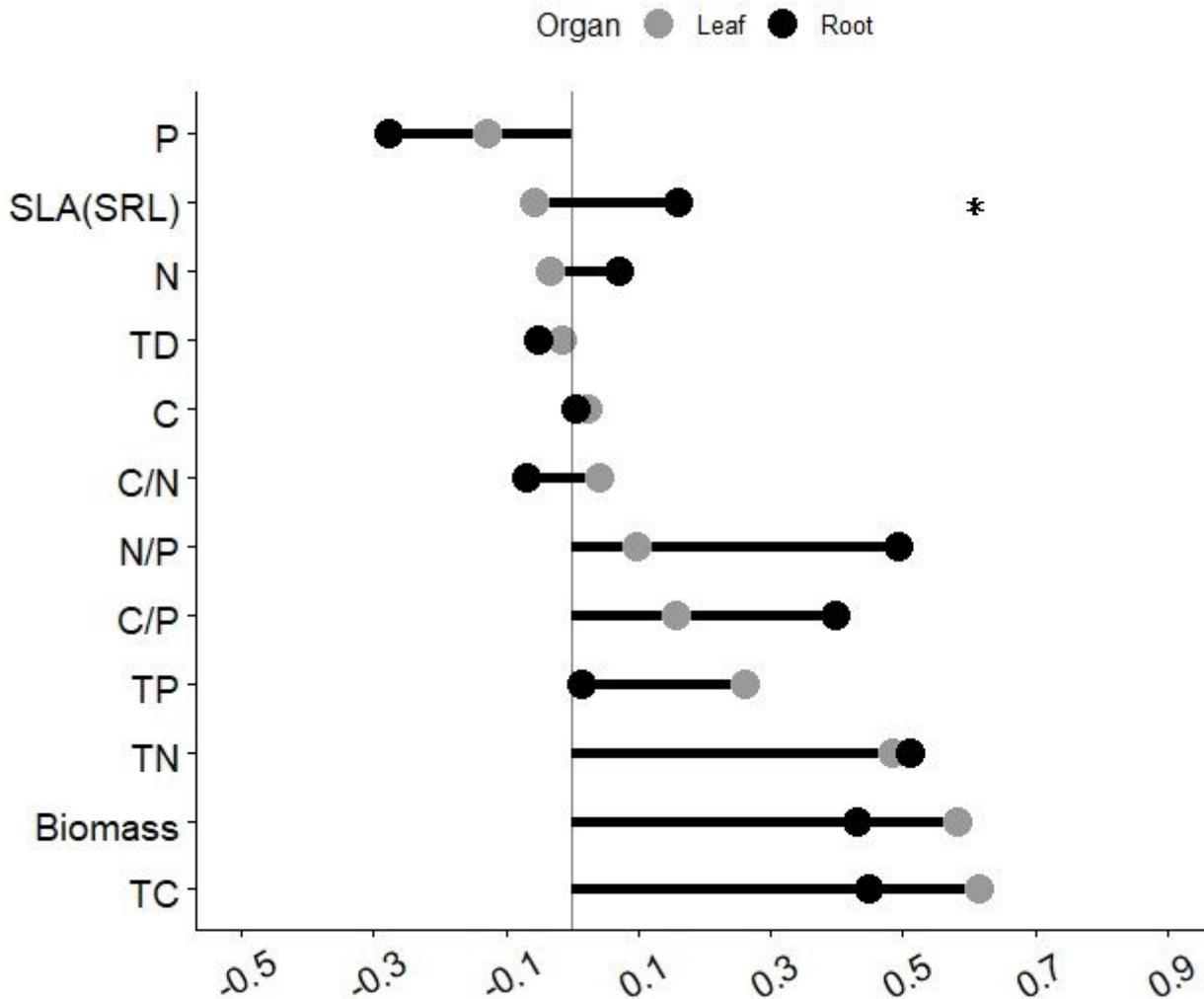


Figure 1

Relative effects [(means from N addition plots – means from ambient plots)/(means from ambient plots)×100] of nitrogen addition on the leaf and root traits of seedlings Note: “*” indicates that the relative effects of nitrogen addition on the leaf and root are significantly different. The abbreviations of the indicators are shown in S1.

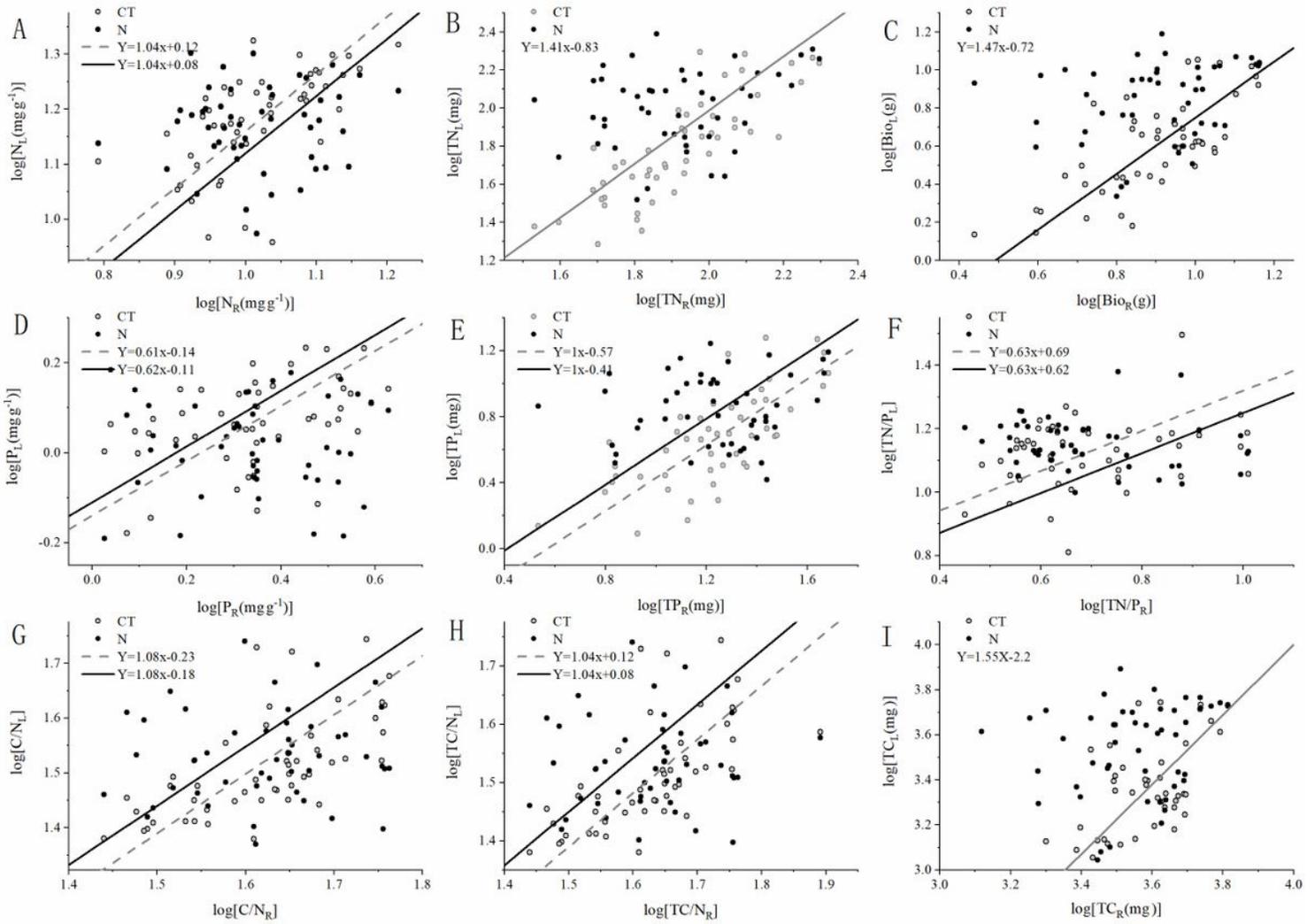


Figure 2

Standardized major axis(SMA) regression of leaf and root paired-trait correlation under N addition Note: (A)The relationship between the leaf and root nitrogen content, (B)The relationship between the leaf and root total nitrogen content, (C)The relationship between the leaf and root biomass, (D)The relationship between the leaf and root phosphorus content, (E)The relationship between the leaf and root total phosphorus content, (F)The relationship between the leaf and root total nitrogen/total phosphorus, (G)The relationship between the leaf and root carbon/nitrogen, (H)The relationship between the leaf and root total carbon/total nitrogen, and (I)The relationship between the leaf and root total carbon content. The insignificant correlation is shown in Table 3. The abbreviations of the indicators are shown in S1.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [APPENDIXS2.tif](#)
- [APPENDIXS1.xlsx](#)