Peertechz

LIFE SCIENCES GROUP

OPEN JOURNAL OF Plant Science

ISSN: 2640-7906 DOI: https://dx.doi.org/10.17352/ojps

Tran Van Do[1,2]*, Osamu Kozan[2], Le Xuan Truong[3], Nguyen Toan Thang[1], Dang Van Thuyet[1], Phung Dinh Trung[1] and Nguyen Thi Thu Phuong[1]

[1]Silviculture Research Institute, Vietnamese Academy of Forest Sciences, Hanoi, Vietnam
[2]Center for Southeast Asian Studies, Kyoto University, Kyoto, Japan
[3]Vietnam Forestry University, Hanoi, Vietnam

Dates: Received: 28 December, 2016; **Accepted:** 29 December, 2016; **Published:** 30 December, 2016

***Corresponding author:** Tran Van Do, Center for Southeast Asian Studies, Kyoto University, 46 Shimoadachi-cho, Yoshida Sakyo-ku, Kyoto 606-8501, Japan, Email: dotranvan@hotmail.com

Keywords: Continuous inflow method; Decomposition; Mortality; Seasonality; Soil core sampling

https://www.peertechz.com

Research Article

Fine root Production in Evergreen Broadleaved Forest, Northeast Vietnam

Abstract

Estimating production of fine roots (diameter ≤ 2 mm) is significant important to understand carbon cycle of forest ecosystem as it may contributes up to 70% of total net primary production. The estimation of fine root production is left behind in many parts, especially in developing countries including Vietnam. In this study, fine root production was estimated for tropical evergreen broadleaved forest in northeast of Vietnam using soil core sampling and litter bags by applying continuous inflow method. Masses of live fine roots and of dead fine roots were collected in May and December 2014, and April 2015. Decomposition ratios of dead fine roots were estimated for May–December 2014 (summer/ growing season), and December 2014–May 2015 (winter). Results indicated that decomposition ratios were significant different between summer (0.0022 day^{-1}) and winter (0.0018 day^{-1}). The difference of decomposition ratios resulted in difference of the fine root production (0.75 g m^{-2} d^{-1} in summer vs 0.35 g m^{-2} d^{-1} in winter). Throughout the year, fine root production in tropical evergreen broadleaved forest, northeast of Vietnam was 0.55 g m^{-2} d^{-1}.

Introduction

The production of fine roots (diameter ≤ 2 mm) contributes markedly to carbon cycle of forest ecosystems [1]. In carbon-cycle model, fine root is a significant organic matter pool [2] with high net primary productivity [3] and turnover [4]. Fine root production contributes up to 70% total net primary production of forest ecosystems [4,5]. Several factors, including vegetation type, edaphic conditions, and climate, affect fine root production [1,5,6]. Fine root production and turnover increase from boreal to tropical forests as indicated by Finer et al. [1]. However, the use of different methods in estimation resulted in different fine root turnover at the same site [7].

There are several methods for estimating fine root production [8-15] all having advantages and disadvantages. Recently, new and modified methods have been proposed by Osawa and Aizawa [16] and Tran et al. [17,18], which use soil core technique for mass of living fine roots and that of death fine roots, and litter bag technique for decomposition ratio of death fine roots. Such modified methods are quite simple and can be applied to any forest ecosystems.

The objective of the present study was to estimate production of fine roots in tropical evergreen broadleaved forest of northeast of Vietnam using soil core and litter bag techniques.

Study Site and Methods

Study site

This study was conducted in tropical evergreen broadleaved forest of Ba Be National Park (BBNP). The BBNP is located at 105°36′55″E, 22°24′19″N in northeast of Vietnam with a total area of 23.240 ha. The research site has annual rainfall of 1,400 mm, falling mainly from April to October, mean annual temperature of 22°C, and humidity of 80%. The soil was developed in limestone. There is diversity of flora in BBNP. A total of 1,281 plant species has been found, which belong to 162 families and 672 genera.

Plot establishment and data collection

In the core zone of BBNP at elevation of 450 m, where there is no disturbance found, a permanent plot of 900 m^2 (30 m × 30 m) was established in May 2014.

All three individuals with diameter at breast height (dbh) > 5 cm were identified to species and measured for dbh in May 2014. Each individuals was tagged with a red number for the following data collection.

Soil core technique was used to collect fine roots [16]. In permanent plot, soil cores were collected systematically at spacing of 5 m × 5 m. A total of 36 soil cores were collected in

Citation: Do TV, Kozanb O, Truong LX, Thang NT, Thuyet DV, et al (2016) Fine root Production in Evergreen Broadleaved Forest, Northeast Vietnam. Open J Plant Sci 1(1): 018-021.

a time. Soil cores were collected three times including May and December 2014, and April 2015. A stainless steel tube of 32 mm in diameter and length of 80 cm was used to take sequential soil cores to a depth of 20 cm. Collected soil was washed through water and sieved to collected fine roots. It was repeated several times to fully collect all fine roots in collected soil. Collected fine roots were then classified to live and death fine roots. The live and dead fine roots were distinguished by their color and resilience [19]. Fine roots were dried in a forced air oven at 70°C for 72 h, and live fine root mass (B) and dead fine root mass (N) were weighed separately.

For evaluating the decomposition ratio of dead fine roots, litter bags were used. These bags were 10 cm wide and 10 cm long, and were made with a root-impermeable, water-permeable (RIWP). The RIWP sheet has a pore size of approximately 6 µm and blocks the ingrowth of almost all fine roots; however, fine soil particles, rainwater, mycorrhizal hyphae, and other microorganisms can penetrate through the sheet. Fine root samples for the decomposition experiment were prepared as follows. Dead fine roots were collected from BBNP, carefully washed free of soil, and oven-dried at 70°C for 72 h. A known mass (from 1 g to 1.5 g per bag) of oven-dried fine roots was added to each litter bag. In total, 49 bags were buried in the field in May 2014 at a spacing of 4 m × 4 m in a 30 m × 30 m sampling plot. Before burying to the field, all litter bags were soaked in ordinary water in room temperature for 24 hours to ensure that water content in fine roots inside bags was the same that in the field. The bags were buried at a depth of 15 cm, which is the zone most fine roots distribute in soil. In December 2014, 25 litter bags were collected. While only 20 other litter bags were collected in April 2015. After collection, remaining fine roots inside the litter bags were separated from soil particles by washing and sieving and then oven-dried to constant mass for calculating the decomposition ratio (γ) separately for each time interval; γ = (initial mass - remaining mass)/ initial mass.

Estimating decomposition, mortality and production of fine roots

Continuous inflow method [16] was used to estimate decomposition, mortality, and production of fine roots.

The collected data from sequential soil cores were B_i and B_j (mass of live fine roots) and N_i and N_j (mass of death fine roots) at collection time points i and j, respectively, and those from litter bags was γ_{ij} (fine root decomposition ratio between time points i and j). $\Delta B = B_j - B_i$; $\Delta N = N_j - N_i$.

Fine root decomposition (d_{ij}) equaling to mass of death fine roots decomposed (disappeared from soil) between time points i and j was estimated following Eq. 1;

$$\tilde{d}_{ij} = -\Delta N - \left(\frac{\Delta N}{\tilde{a}_{ij}} + N_i\right)\Delta \ln\left(1 - {}_{ij}\right) \quad (1)$$

Fine root mortality (m_{ij}) equaling mass of fine roots died (death fine roots) between time points i and j was estimated following Eq. 2;

$$m_{ij} = \Delta N + d_{ij} \quad (2)$$

Fine root production (g_{ij}) equaling mass of fine roots produced between time points i and j was estimated following Eq. 3;

$$g_{ij} = \Delta B + \Delta N + d_{ij} \quad (3)$$

Statistical analysis

Spatial variation in live mass (B), death mass (N), and decomposition ratio (γ_{ij}) was quantified as standard error. ANOVA analysis and Turkey's Post Hoc Test were applied to evaluate the difference of means of B and N among three collected dates and between pair of collected dates. While *t* test was applied to compare dead fine root decomposition ratios between May–December 2014 and December 2014–April 2015, not assuming equal variances. To estimate the standard error of fine root decomposition, mortality, and production, 36 collected soil cores for each collection date were randomly divided into six groups of six cores each for six mean values of B and N. The continuous inflow method to estimate decomposition (Eq. 1), mortality (Eq. 2), and production (Eq. 3) were then applied to yield six corresponding values. The mean and standard error of these six values were taken as means and their standard errors. Comparison of estimates (production, mortality, and decomposition) between collection intervals was performed by *t* test, not assuming equal variances.

Results and Discussion

Survey forest had tree density of 856 stems ha^{-1}, mean dbh of 15.6 cm and total basal area of 25.3 m^2 ha^{-1}. The biggest tree in survey plot was 60.8 cm, even there was no disturbance found in the study site.

Dry masses of dead fine roots and live fine roots were significant different among three collected dates (p = 0.05). The highest mass of live fine roots was in April 2015, while the highest mass of dead fine roots was in December 2014 (Table 1).

Decomposition ratio of dead fine roots was higher in May–December 2014 than that in December 2014–May 2015 (Table 1). From May to October is a rainy-summer season in this study site, where temperature is always > 20°C. This favorites activities of organic decomposers, leading to higher decomposition ratio of death fine roots in May–December 2014 compared to December 2014–April 2015, when temperature may drop to < 10°C and humidity is low [20].

In the present study site, decomposition, mortality, and production of fine roots were season-dependent (Figure 1).

Table 1: Dry masses (±SE) of live fine roots and dead fine roots, and decomposition ratio (±SE)

Parameters	Collected date		
	May 2014	December 2014	April 2015
Dry mass of live fine roots (g m^{-2})	469.3 ±49.1[a]	532.9 ±29.2[b]	600.8 ±38.6[c]
Dry mass of death fine roots (g m^{-2})	9.7 ±4.5[a]	25.7 ±5.1[b]	15.5 ±3.4[c]
Decomposition ratio (day^{-1})		0.0022 ±0.0002[a]	0.0018 ±0.0001[b]

Means with different letters in the same line are significant different (p = 0.05).

Citation: Do TV, Kozanb O, Truong LX, Thang NT, Thuyet DV, et al (2016) Fine root Production in Evergreen Broadleaved Forest, Northeast Vietnam. Open J Plant Sci 1(1): 018-021.

Comparing between May–December 2014 and December 2014–April 2015, there were statistical significant differences for decomposition (d) and production (g), but not for mortality (m). The values for decomposition, mortality, and production in May–December 2014 were 0.08 g m^{-2} d^{-1}, 0.16 g m^{-2} d^{-1}, and 0.35 g m^{-2} d^{-1}, respectively. The values for the same three processes in December 2014–May 2015 were 0.25 g m^{-2} d^{-1}, 0.17 g m^{-2} d^{-1}, and 0.75 g m^{-2} d^{-1}, respectively. In this study forest, total fine root decomposition was 45.3 g m^{-2}, mortality was 51.6 g m^{-2}, and total production was 161.7 g m^{-2}.

There was lower decomposition ratio in December 2014–April 2015 compared to May–December 2014 (Table 1). But mass of decomposition of death fine roots was higher (Figure 1a,b). Late March–December is known as growing season of forest in this study site, which also is peak of fine root producing. Therefore, fine roots died in this time vare becoming organic matter available for decomposing in the following season, leading to higher mass of decomposition in December 2014–April 2015. December–February is winter season and is known as not growing season of forest. While, March–April is beginning growing season, leading to higher fine root production (Figure 1b,c) in this time to absorb water and nutrient preparing for the growing season.

Production of fine roots in the present study site was lowest compared to that of other forest ecosystems around the world (Table 2). Soil in the present study developed in limestone, which has low soil fertility and organic matter. This is probably a reason for lowest fine root production in tropical evergreen broadleaved forest, northeast Vietnam. Other factors affecting the fine root production in this study could be the species composition, the climate condition, and the age of forest [1,5,6]. However, fine root production in these forest ecosystems (Table 2) was estimated using different methods and for both natural forests and plantation, which may be unequally to compare [7,16].

Conclusion

In the present study, continuous inflow method was applied to estimate fine root production, mortality, and decomposition using sequence soil core and litter bag techniques. It was found that decomposition ratio of dead fine roots was seasonal-dependent, which was higher in growing season/summer season (0.0022 day^{-1}) compared to winter season (0.0018 day^{-1}).

The total fine root production in the present study was 0.55 g m^{-2} d^{-1}, which was much lower than that of Amazonia forests and other plantations around the world. Therefore, to deeply understand the contribution of fine root production to forest carbon cycle, estimating fine root production of each forest type in each geographical location is necessary.

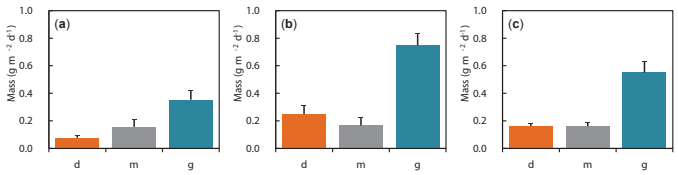

Figure 1: Fine root decomposition (d), mortality (m), and production (g) in May–December 2014 (a), December 2014–April 2015 (b), and May 2014–April 2015 (c). Vertical bars indicate ±SE.

Table 2: Comparison of the fine root production in present study site (g m^{-2} d^{-1}) to that of other forest ecosystems

Location	Forest type	Production	Estimation method	Source
Northeast Vietnam (105°36'E, 22°24'N)	Tropical evergreen broadleaved forest	0.55	Soil core, continuous inflow method	Present study
Atlantic lowlands, Costa Rica (10°26'N, 83°59'W)	16-year-old plantation of *Hyeronima alchorneoides*	3.57	Measured as sum of the mass of fine roots extracted from the ingrowth core	[21]
	16-year-old plantation of *Pentaclethra macroloba*	1.76		
	Closed canopy forest	2.33		
Central, Japan (34°58'N, 135°56'E)	80-year-old plantation of *Chamaecyparis obtusa*	3.24	Soil core, continuous inflow method	[16]
Amazonia forests	Primary tropical old-growth rainforest; Caxiuana, Brazil	2.08	Measured as sum of the mass of fine roots extracted from the ingrowth core	[22]
	Primary tropical old-growth rainforest; Tambopata, Peru	1.86		
Fujia, China (26°11'N, 117°26'E)	Natural forest of *Castanopsis kawakamii*	1.18	Soil cores, compartment-flow method	[23]
	40-year-old plantation of *Castanopsis kawakamii*	0.73		

Acknowledgement

This research was funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under grant number 106-NN.06-2016.10.

References

1. Finer L, Ohashi M, Noguchi K, Hirano Y (2011) Fine root production and turnover in forest ecosystems in relation to stand and environmental characteristics. Forest Ecology Management 262: 2008-2023. Link: https://goo.gl/36wxsX

2. Potter CS (1999) Terrestrial biomass and the effects of deforestation on the global carbon cycle. Bioscience 49: 769-778. Link: https://goo.gl/DkDOD1

3. Jackson RB, Mooney HA, Schulze ED (1997) A global budget for fine root biomass, surface area, and nutrient contents. Proc Natl Acad Sci USA 94: 7362-7366. Link: https://goo.gl/pZKkzV

4. Gill RA, Jackson RB (2000) Global patterns of root turnover for terrestrial ecosystems. New Phytologist147: 13-31. Link: https://goo.gl/gRMkrA

5. Vogt KA, Vogt DJ, Palmiotto PA, Boon P, O'Hara J, et al. (1996) Review of root dynamics in forest ecosystems grouped by climate, climatic forest type and species. Plant and Soil 187: 159-219. Link: https://goo.gl/nePNPQ

Citation: Do TV, Kozanb O, Truong LX, Thang NT, Thuyet DV, et al (2016) Fine root Production in Evergreen Broadleaved Forest, Northeast Vietnam. Open J Plant Sci 1(1): 018-021.

6. Yuan ZY, Chen YH (2012) Indirect Methods Produce Higher Estimates of Fine root Production and Turnover Rates than Direct Methods. PlosOne 7:e48989. Link: https://goo.gl/6CWrQU

7. Brunner I, Bakker MR, Björk RG, Hirano Y, et al. (2013) Fine-root turnover rates of European forests revisited: an analysis of data from sequential coring and ingrowth cores. Plant and Soil 362: 357-372. Link: https://goo.gl/4nDo2Y

8. Fairley RI, Alexander IJ (1985) Methods of calculating fine root production in forests. In: Fitter AH, Atkinson D, Read DJ (eds) Ecological interactions in soil: plants, microbes and animals. Blackwell Scientific Publications Oxford 37-42. Link: https://goo.gl/HpWaTz

9. Kurz WA, Kimmins JP (1987) Analysis of some sources of error in methods used to determine fine root production in forest ecosystems: a simulation approach. Canadian Journal Forest Research 17: 909-912. Link: https://goo.gl/4xqlnG

10. Raich JW, Nadelhoffer KJ (1989) Belowground carbon allocation in forest ecosystems: global trends. Ecology 70: 1346-1354. Link: https://goo.gl/orGd2D

11. Hendricks RL, Pregitzer KS (1993) The dynamics of fine root length, biomass, and nitrogen content in two northern hardwood ecosystems. Canadian Journal Forest Research 23: 2507-2520. Link: https://goo.gl/E3ERiQ

12. Wilson CA, Mitchell RJ, Boring LR, Hendricks JJ (2002) Soil nitrogen dynamics in a fire-maintained forest ecosystem: results over a 3-year burn interval. Soil Biology and Biochemistry 34: 679-689. Link: https://goo.gl/acA3Tf

13. Bernier PY, Robitaille G (2004) A plane intersect method for estimating fine root productivity of trees from minirhizotron images. Plant and Soil 265: 165-173. Link: https://goo.gl/0fQc6R

14. Majdi HK, Pregitzer K, Moren AS, Nylund JE, Agren GI (2005) Measuring fine root turnover in forest ecosystems. Plant and Soil 276: 1-8. Link: https://goo.gl/0shIBS

15. Metcalfe DF, Meir P, Williams M (2007) A comparison of methods for converting rhizotron root length measurements into estimates of root mass production per unit ground area. Plant and Soil 301: 279-288. Link: https://goo.gl/jG9hVI

16. Osawa A, Aizawa R (2012) A new approach to estimate production, mortality and decomposition of fine roots using litter-bag experiments and ordinary soil-core techniques. Plant and Soil 355: 167-181. Link: https://goo.gl/2tBxqb

17. Tran VD, Osawa A, Sato T (2016) Estimation of fine-root production using rates of diameter-dependent root mortality, decomposition and thickening in forests. Tree Physiology 36: 513-523. Link: https://goo.gl/mVjIov

18. Tran VD, Sato T, Osamu K (2016) A new approach for estimating fine root production in forests: A combination of ingrowth core and scanner. Trees 30: 545-554. Link: https://goo.gl/f8XtjZ

19. Hishi T, Takeda H (2005) Dynamics of heterorhizic root systems: protoxylem groups within the fine-root system of *Chamaecyparis obtusa*. New Phytologist 167: 509-521. Link: https://goo.gl/PucNFg

20. Nguyen VD (2016) General natural conditions of Ba Be. Cng thông tin đin t Bc kn – Huyn Ba B.

21. Valverde-Barrantes OJ, Raich JW, Russel AE (2007) Fine-root mass, growth and nitrogen content for six tropical tree species. Plant and Soil 290: 357-370. Link: https://goo.gl/H6xkKi

22. Aragão LEOC, Malhi Y, Metcalfe DB, Silva-Espejo JE, et al. (2009) Above- and below-ground net primary productivity across ten Amazonian forests on contrasting soils. Biogeosciences 6: 2759-2778. Link: https://goo.gl/MqHCkr

23. Yang YS, Chen GS, Guo JF, Xie JS, Wang XG (2007) Soil respiration and carbon balance in subtropical native forest and two managed plantations. Plant Ecology 193: 71-84. Link: https://goo.gl/KzJcl8

Citation: Do TV, Kozanb O, Truong LX, Thang NT, Thuyet DV, et al (2016) Fine root Production in Evergreen Broadleaved Forest, Northeast Vietnam. Open J Plant Sci 1(1): 018-021.