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Dynamics of fine and coarse roots and nitrogen mineralization in a humid subtropical forest ecosystem of northeast India

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Abstract The present study was carried out to understand whether fine root growth and N mineralization are synchronized in such a manner that helps to conserve N in the humid subtropical forest ecosystem, and to assess whether or not these processes are influenced by human disturbance. The study was conducted in two pairs of undisturbed and disturbed stands of subtropical humid forest in the Jaintia hill district of Meghalaya, northeast India. The amount of fine root (540–754 g m^{-2}) and coarse root (307–387 g m^{-2}) mass in the protected stands was higher than those recorded (fine root 422–466 g m^{-2}, coarse root 247–305 g m^{-2}) in the unprotected stands. The total annual root production was also higher in the protected stands (1,102–1,242 g m^{-2}) than the unprotected stands (890–940 g m^{-2}). The mean concentration of NH_4^+–N and NO_3^-–N was higher in the protected stands than in the unprotected stands. The inorganic-N (NH_4^+–N and NO_3^-–N) concentration was markedly high during the dry period and low during the wet period in all the stands. Inorganic-N concentration, nitrification and N mineralization rates were significantly ($P<0.01$) higher in the surface (0–10 cm) than the subsurface (10–20 cm) layer. The low and high N mineralization rates observed during the dry and wet periods, respectively, coincided with the lean and peak periods of fine root mass. Disturbance in the forests caused a reduction in fine root mass as well as in N mineralization.

Keywords Fine and coarse root · Biomass and production · Nitrogen mineralization · Subtropical humid forest · Disturbance

Introduction

The conservation of nutrients, water and soil organic matter in natural forest ecosystems is maintained through high above- and belowground production processes, which in terrestrial ecosystems are strongly influenced by the rates at which N is supplied to the plants (Olff et al. 1994). In the forest ecosystem where N is a limiting nutrient for plant growth, the supply of available N generated during N mineralization is of crucial importance. However, it is not clear whether or not the fine root turnover rate increases (Nadelhoffer et al. 1985; Roy and Singh 1995) or decreases (Keyes and Grier 1981) with higher nutrient availability. Although fine roots constitute only a small proportion of the total biomass in a forest ecosystem, they play a crucial role in nutrient dynamics within the ecosystem (Vogt et al. 1991) by enriching the soil with organic matter and nutrients through their fast turnover rate, and prevent leaching losses of nutrients by efficient absorption. Their other functions include anchorage, absorption of water and synthesis of various essential compounds including growth regulators (Kramer and Boyer 1995; Fitter 1996). They undergo rapid change due to perturbations (Hendrick and Pregitzer 1993) and their amount increases during regrowth of forest vegetation after disturbance (Arunachalam et al. 1996). However, the conversion of tropical forests into plantations reduces the fine root biomass and net primary productivity (Sundrapandian et al. 1999).

The humid subtropical forest in the state of Meghalaya, which accounts for 41% (9,195 km^2) of its total forest cover (Champion and Seth 1968), has been greatly disturbed and degraded by shifting cultivation. Some patches of protected forests found in the state are called “sacred groves”. The present paper aims to investigate seasonal changes in fine and coarse root biomass and N mineralization rate in the protected and disturbed stands of a subtropical humid forest ecosystem to understand whether or not growth of fine roots and N mineralization are synchronized to help conserve N in the ecosystem, and to evaluate the influence of human disturbance on these processes.

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Materials and methods

Study sites

The study was conducted in two well-protected patches of subtropical humid forest and their adjoining disturbed stands in the Jaintia Hill District of Meghalaya in northeast India. One forest (Ialong) is located about 8 km east (25° 28′N, 92°16′E, altitude 1,350 m a.s.l.), of the town of Jowai and the other (Raliang) is 28 km (25°30′N, 92°28′E, altitude 1,300 m a.s.l.) from Jowai, the headquarters of the Jaintia Hill District. One portion of each of the two forests, covering an area of about 20 and 30 ha, is well protected and has the status of a sacred grove. Another portion (30–40 ha) is open to use by nearby villagers for their timber and fuel wood requirements. The periphery of the disturbed stands is burnt annually during the winter to promote herbage growth during the ensuing rainy season for cattle fodder. The intensity of fire and grazing is, however, not high enough to cause serious damage to the vegetation, which appears quite dense due to abundant coppicing of trees.

The climate of the area is monsoonal with distinct wet and dry seasons. The wet season extends from April to October followed by a dry period from November to March. During the wet season the monthly rainfall ranges from 131 to 1,557 mm, while in the dry period it is usually <50 mm per month. The annual rainfall was 6,539 mm during the study period (2000–2001). The mean monthly temperature varied from a maximum of 26°C in April to a minimum of 5°C in January.

Vegetation sampling

A quantitative study of woody species [≥5 cm diameter at breast height (dbh)] was carried out by laying fifty 10×10-m quadrats in each protected and unprotected forest stand. Tree saplings (<5 cm dbh and >30 cm height), and seedlings (<30 cm height) and species of the ground vegetation were studied in thirty 5×5- and 1×1-m quadrats, respectively, in each stand. Frequency, density and importance value index of the species were calculated according to Muller Dombois and Ellenberg (1974).

Root sampling

In each of the four stands (two protected and two unprotected), ten randomly located soil cores were sampled at monthly intervals from June 2000 to May 2001, using a cylindrical iron corer (20 cm length, 6.3 cm inner diameter). Cores were divided into two depths: 0–10 and 10–20 cm starting from the soil surface. The samples were transferred to the laboratory in polythene bags and stored in a deep freeze at −20°C until the roots were separated. Roots were retrieved by a wet-sieving method (Bohm 1979) within 21 days as recommended by Parrotta and Lodge (1991).

The separated roots were assigned to four diameter classes: <2, 2–5, 5–10 and 10–15 mm; they were measured by vernier callipers. In each class, live and dead roots were distinguished on the basis of pliability and the degree of cohesion between the cortex and periderm. Live roots were often smooth and light coloured as compared to the dead roots that were wrinkled and dark in colour (Persson 1983). Fine (<2 mm) and coarse (>2–15 mm) roots were washed twice to ensure the removal of all adhering soil particles.

The clean root samples were dried to a constant weight at 80°C for 48 h and weighed. Annual root production was determined by summing the positive increments in live root biomass in each diameter class and the concurrent increment, if any, in the dead root mass in a given diameter class during successive samplings (Persson 1978). This includes an estimated increase in root mass between the last sampling in May 2001 and an assumed value equivalent to the first sampling in June 2000.

Soil analysis and N mineralization

Texture, soil organic C (SOC), total Kjeldahl N (TKN) and available P concentration of soil samples collected from two depths were determined in all stands on a seasonal basis according to Allen et al. (1974). In situ N mineralization was studied on a monthly basis for one annual cycle from June 2000 to May 2001 using a buried bag technique (Eno 1960). At each sampling date, soils were collected from 0- to 10- and 10- to 20-cm soil depths at five randomly located places in each of the four stands. Each soil sample was sieved through a 2-mm-mesh screen and part was sealed into sterilized polyethylene bags and inserted back into the soil at its respective depth. The other part was brought to the laboratory and bulked according to soil depth. NH_4^+–N and NO_3^-–N concentrations were determined within 24 h as reported by Allen et al. (1974). The buried bags were retrieved after 1 month and the soil samples were analysed for final NH_4^+–N and NO_3^-–N concentrations. The increase in the concentration of NH_4^+–N and NO_3^-–N during the field incubation over a 1-month period is defined as net N mineralization and the increase in amount of NO_3^-–N alone is referred to as nitrification.

Statistical analysis

The field and laboratory data were statistically analysed using ANOVA (fixed model effect) to ascertain the effects of season, soil depth and stand on nitrification and net mineralization rates and root mass. The relationship between N availability and fine root biomass was tested through linear regression following Zar (1974).

Table 1 Plant community characteristics of protected and unprotected stands at Ialong and Raliang. *dbh* Diameter at breast height

	Ialong		Raliang	
	Protected	Unprotected	Protected	Unprotected
Dominant species				
Woody species (≥5 cm dbh)	*Microtropis discolor* *Engelhardtia spicata* *Betula alnoides*	*Castanopsis purpurella* *Schima wallichii* *Engelhardtia spicata*	*Actinodaphne obovata* *Sarcosperma griffithii* *Prunus jenkensii*	*Castanopsis purpurella* *Lithocarpus elagans* *Helecia nilagirica*
Ground vegetation	*Globba clarkei* *Selaginella* sp. *Isachne himalaica*	*Isachne himalaica* *Lophatherum gracile* *Galinsoga parviflora*	*Isachne himalaica* *Ophiorrhiza mungos* *Globba clarkei*	*Isachne himalaica* *Impatiens benthamii* *Lophatherum gracile*
Density				
Woody species (no. individuals ha^{-1})	1,476	1,340	938	1,308
Tree saplings (no. 100 m^{-2})	46	41	76	57
Tree seedlings (no, 100 m^{-2})	1,410	955	2,300	775
Ground vegetation (no. plants 100 m^{-2})	2,474	2,078	1,997	1,887
Tree basal area (m^2 ha^{-1})	57.46	49.64	71.44	36.52

Table 2 Physicochemical characteristics of soils of protected and unprotected stands of the forest at Ialong and Raliang. *SOC* Soil organic C, *TKN* total Kjeldahl N

Forest stand	Soil depth (cm)	Sand (%)	Clay (%)	pH	SOC (%)[a]	TKN (%)[a]	Available P (μg g^{-1})[a]
Ialong							
Protected stand	0–10	84.36±0.02	4.55±0.55	4.89±0.06	4.90±0.06	0.45±0.009	15.35±0.83
	10–20	81.36±0.71	7.02±0.01	4.58±0.05	4.35±0.04	0.36±0.007	12.68±0.84
Unprotected stand	0–10	84.38±1.59	4.54±0.01	5.16±0.06	4.19±0.03	0.38±0.004	14.23±0.69
	10–20	77.64±0.89	7.98±0.90	4.81±0.05	3.79±0.04	0.32±0.006	10.08±0.40
Raliang							
Protected stand	0–10	58.76±0.72	16.45±0.92	4.65±0.07	4.95±0.06	0.47±0.007	17.90±1.04
	10–20	37.52±1.01	26.72±0.71	4.46±0.04	4.30±0.05	0.42±0.013	13.32±1.17
Unprotected stand	0–10	81.19±1.22	6.07±0.88	4.98±0.10	4.41±0.06	0.38±0.006	13.10±0.72
	10–20	73.19±0.86	13.17±1.19	4.66±0.08	3.94±0.04	0.31±0.009	9.47±0.41

[a] Means of four seasons across the year (n=12; ±SEM)

Results

Vegetation

The protected stands at Ialong was dominated by *Microtropis discolor* and *Engelhardtia spicata* and at Raliang by *Actinodaphne obovata* and *Sarcosperma griffithii*. In the unprotected stand, *Castanopsis purpurella* and *Schima wallichii* at Ialong and *Castanopsis purpurella* and *Lithocarpus elagans* at Raliang were the dominant and co-dominant species. The density of woody species varied between protected and unprotected stands without showing any trend; it decreased in the unprotected stand at Ialong but increased at Raliang. The density of tree seedlings, saplings and ground vegetation was significantly lower in the unprotected stands than in the protected stands. The basal area of woody species was about 1–2 times lower in the unprotected stands (Table 1).

Table 3 Mean live (*L*) and dead (*D*) dry mass of fine (<2 mm) and coarse (2–15 mm) roots (g m^{-2}) in protected and unprotected forest stands at Ialong and Raliang

Stand	Depth (cm)	Fine root			Coarse root		
		L	D	Total	L	D	Total
Ialong							
Protected	0–10	319.99	43.38	363.37	135.02	19.17	154.19
	10–20	143.43	33.50	176.93	141.23	11.49	152.72
	Total	463.42	76.88	540.3	276.25	30.66	306.91
Unprotected	0–10	233.94	62.75	296.68	113.20	17.03	130.23
	10–20	90.53	34.41	124.95	104.8	12.30	117.10
	Total	324.47	97.16	421.63	218.0	29.33	247.33
Raliang							
Protected	0–10	444.19	74.35	518.54	178.67	17.54	196.21
	10–20	179.43	56.37	235.81	184.60	16.25	200.85
	Total	623.62	130.72	754.34	363.27	33.79	397.06
Unprotected	0–10	258.10	71.43	329.53	152.17	34.74	186.91
	10–20	92.05	44.04	136.09	92.48	25.93	118.41
	Total	350.15	115.47	465.62	244.65	60.67	305.32

Soil properties

The soil texture varied from loamy sand to sandy loam in the four stands. The soil in the protected stands was more acidic than that in the unprotected stands and acidity increased with increasing soil depth (Table 2). The SOC, TKN and available P concentration were significantly higher in the protected stands than in the unprotected stands. The surface layer (0–10 cm) had significantly higher concentrations of SOC, TKN and available P than the subsurface (10–20 cm) soil layer.

Fine and coarse root biomass and root production

In all the four stands 67–71% of the total fine root (<2-mm diameter) mass was present in the upper soil layer (0–10 cm), while the lower soil layer (10–20 cm) had only 29–33% of the total fine root mass (Table 3). The coarse root mass (2–15 mm diameter) also showed a similar trend, with the upper soil layer having 49–61% of the total coarse root mass in all the stands, except in the protected stand in Raliang where the lower soil layer (10–20 cm) had 51% of the total coarse root mass (Table 3). The fine roots contributed 60–66% to the total root mass in all the stands.

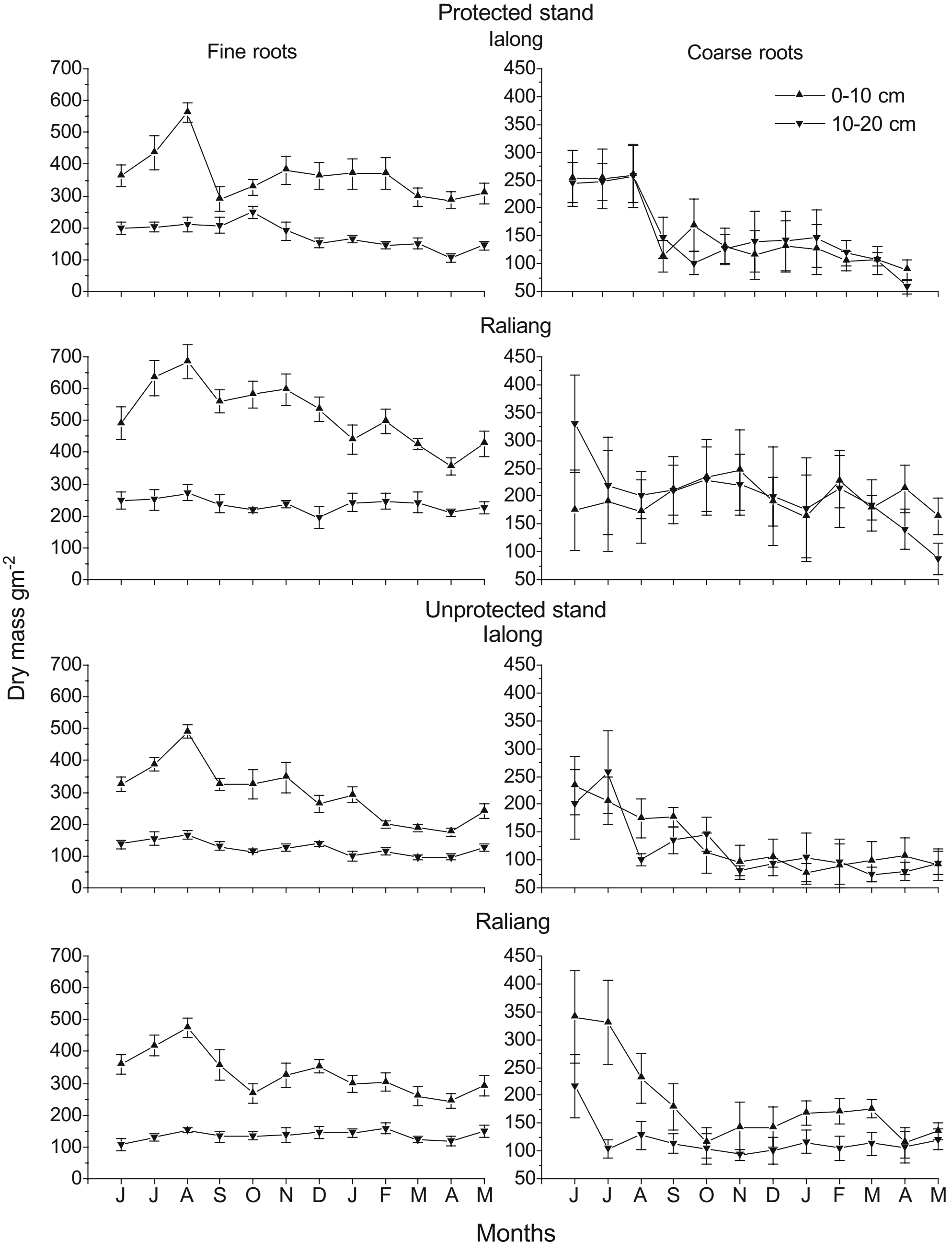

Fig. 1 Monthly variation of fine and coarse (live + dead) roots in protected and unprotected stands of a subtropical forest at Ialong and Raliang. *J J A S O N D J F M A M* June July August September October November December January February March April May

Table 4 Root production (g m^{-2} $year^{-1}$) in the protected and unprotected forest stands at Ialong and Raliang (percent of total *in parentheses*)

Categories	Ialong		Raliang	
	Protected	Unprotected	Protected	Unprotected
Diameter class (mm)				
<2	534.78 (49)	474.27 (50)	568.59 (46)	424.32 (48)
2–5	254.84 (23)	224.99 (24)	234.87 (19)	343.43 (39)
5–10	302.73 (27)	201.88 (21)	268.91 (22)	88.91 (10)
>10	9.95 (1)	39.47 (4)	169.33 (14)	33.7 (4)
Soil depth (cm)				
0–10	635.62 (58)	587.25 (62)	707.31 (57)	611.78 (69)
10–20	466.68 (42)	353.36 (38)	534.36 (43)	278.58 (31)

The accumulation of fine and coarse root mass in the protected stand was significantly ($P<0.01$) higher than in the corresponding unprotected stands. Both varied significantly ($P<0.01$) between the months in all the stands (Fig. 1). In the surface layer, fine root mass peaked during the wet season (June–August) in all stands, but in the subsurface layer, monthly variation was not marked. Unlike fine roots, the difference between the upper and lower soil layers across the months was not prominent for the coarse roots except in the unprotected stand at Raliang.

The mean accumulation of live and dead fine roots was significantly ($P<0.01$) higher in the upper soil layer than in the lower soil layer in all the four stands, and the protected stand had greater live as well as dead fine root mass than the unprotected stand. The coarse root mass was also

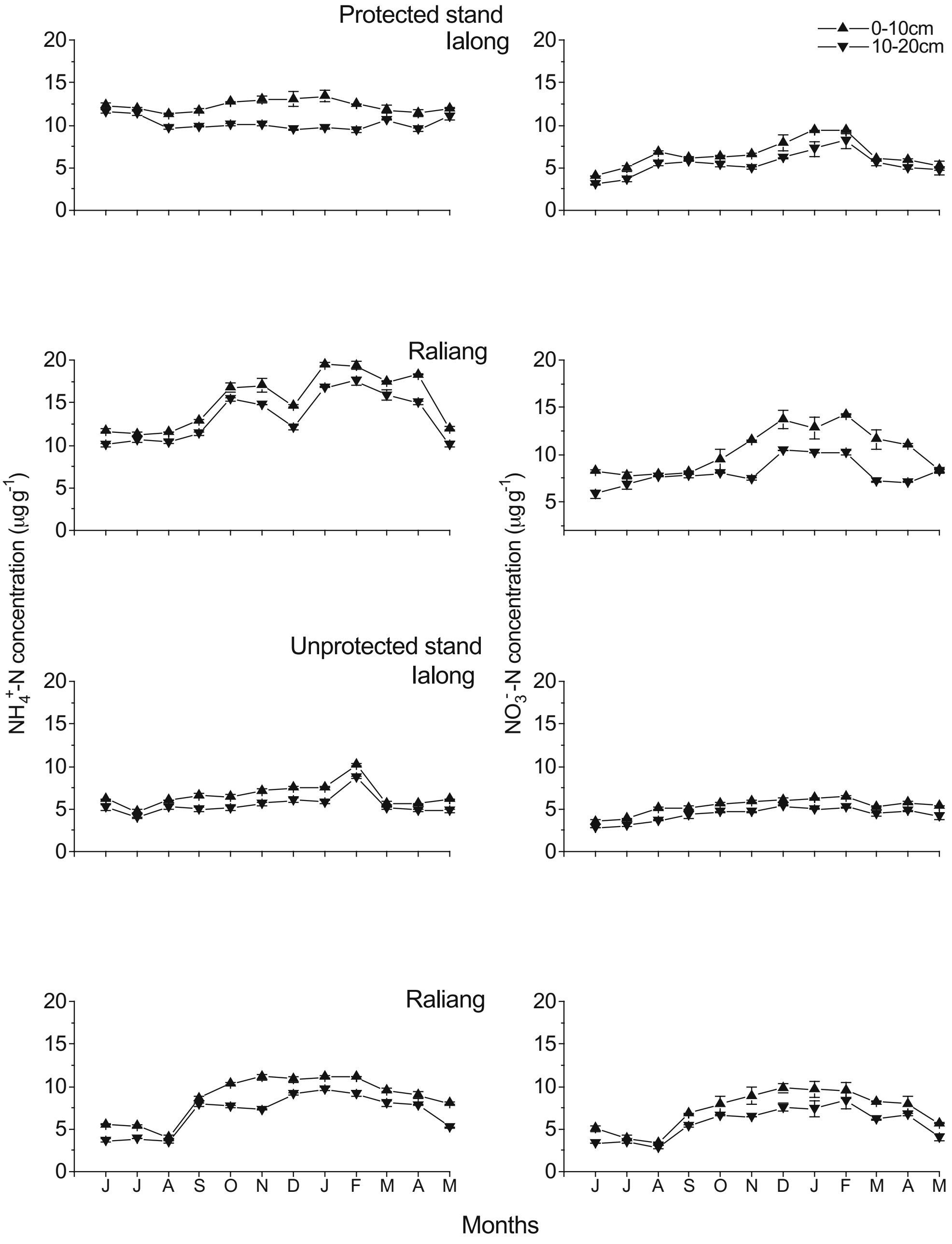

Fig. 2 Monthly variation of NH_4^+–N and NO_3^-–N in protected and unprotected stands of subtropical forest at Ialong and Raliang

Table 5 Average soil inorganic-N pool (μg g^{-1}) and N mineralization rate (μg g^{-1} $month^{-1}$) in the protected and unprotected forest stands at Ialong and Raliang [values are the means of 12 months across the year (*n*=12; ±SEM)]

Stand	Depth (cm)	Concentration (μg g^{-1})			Net rate (μg g^{-1})	
		NH_4^+–N	NO_3^-–N	Total inorganic-N	Nitrification	N mineralization
Ialong						
Protected	0–10	12.27±0.71	6.55±0.48	18.82	5.82±1.17	14.13
	10–20	10.20±0.62	5.40±0.49	15.60	4.75±1.17	11.06
Unprotected	0–10	6.64±0.38	5.36±0.27	12.00	6.01±1.16	11.44
	10–20	5.45±0.38	4.35±0.30	9.80	4.61±1.20	9.20
Raliang						
Protected	0–10	15.22±1.24	10.40±0.80	25.62	5.84±1.14	13.76
	10–20	13.26±1.05	8.09±0.48	21.35	4.47±0.97	11.15
Unprotected	0–10	8.72±0.65	7.22±0.58	15.94	5.77±1.17	11.86
	10–20	6.91±0.60	5.69±0.49	12.60	4.62±1.05	9.55

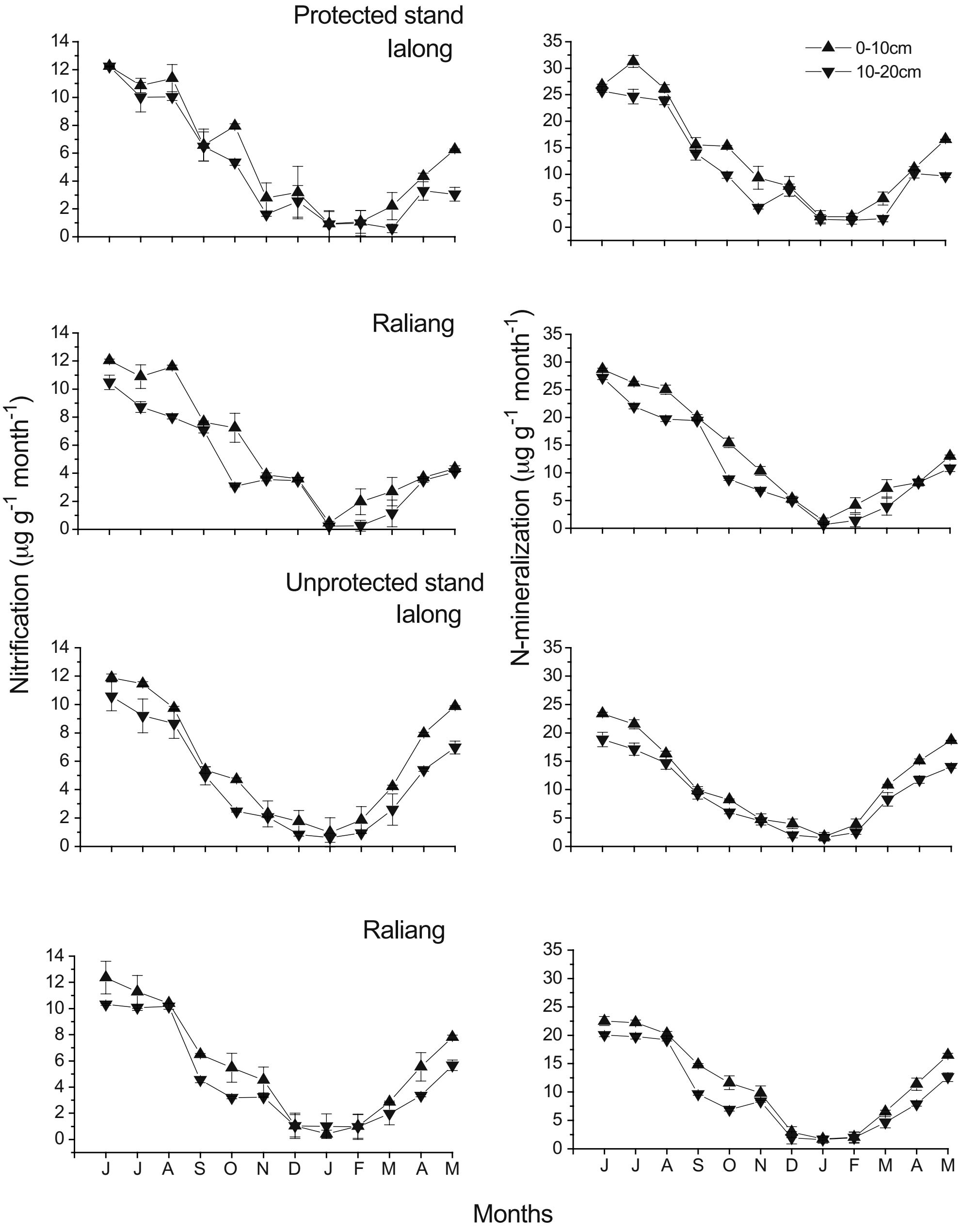

Fig. 3 Monthly variation of nitrification and net N mineralization rate in protected and unprotected stands of subtropical forest at Ialong and Raliang

greater in the upper soil layer than in the lower layer, but the difference between the two layers was not as prominent as for fine roots. In this case the live fraction was also greater in the protected stand but in the case of the dead fraction the trend was not consistent (Table 3).

The total annual root production was higher in the protected stands (Raliang 1,242 g m^{-2}, Ialong 1,102 g m^{-2}) than in their corresponding unprotected stands (Raliang 890 g m^{-2}, Ialong 941 g m^{-2}) (Table 4). The fine roots contributed 49 and 46% to the total annual production in the Ialong and Raliang protected stands, respectively. The corresponding values for the unprotected stands were 50 and 48%. The surface layer accounted for 57–69% of the total root production.

Inorganic-N concentration, nitrification and net N mineralization

NH_4^+-N was the dominant form of inorganic-N in the soils of all the four stands. The soil in the protected stands had significantly ($P<0.01$) higher NH_4^+–N than the unprotected stands. In the former it ranged between 11.04 and 19.51 µg g^{-1} in the upper layer and between 9.34 and 17.56 µg g^{-1} in the lower layer. In the unprotected stands the NH_4^+–N concentration in the upper layer ranged from 4.75 to 1.14 µg g^{-1} and in the lower layer from 3.89 to 9.68 µg g^{-1} (Fig. 2). Although a distinct seasonal trend was not observed, the values were low during the rainy season (June–August) at both soil depths, and they showed an increasing trend during winter (December–February).

The NO_3^--N concentration in all stands decreased with increasing soil depth. Its monthly trend was somewhat similar to that of NH_4^+–N. The soils of protected stands had a higher concentration (upper layer 3.99–14.24 µg g^{-1}, lower layer 3.03–10.47 µg g^{-1}) of NO_3^-–N than the unprotected stand (upper layer 3.41–9.78 µg g^{-1}, lower layer 2.81–8.29 µg g^{-1}) (Fig. 2).

Total inorganic-N in soil was greater in the protected stands than in their corresponding unprotected stands, though the values at Raliang were higher than at Ialong. The surface layer had a significantly higher ($P<0.01$) concentration than the subsurface layer (Table 5).

The nitrification rate varied significantly ($P<0.01$) due to soil depth and season, but the difference between the forest stands was not significant. The seasonal variation in nitrification rate at the two soil depths was similar in all the stands except that the subsurface layer showed a higher rate during winter in the Raliang unprotected stand (Fig. 3). Nitrification was at its peak during the rainy season (June–August), thereafter it showed a continuous declining trend reaching its minimum level during winter (January–February). However, the mean nitrification rate (6.01 µg g^{-1} month^{-1}) in the surface layer of the Ialong unprotected stand was higher than in the other three stands (Table 5).

Net N mineralization rate showed a marked seasonal variation in all the stands. It peaked during the rainy season (June–July), followed by a sharp decline until winter (December–February) (Fig. 3). The peak rate (31.27 µg g^{-1} month^{-1}) was recorded in the topsoil layer of the Ialong protected stand, while the lowest rate (0.42 µg g^{-1} month^{-1}) was obtained for the Raliang unprotected stand (Fig. 3). An ANOVA of the results showed that the mineralization rate was significantly ($P<0.01$) higher in the undisturbed stands than in the disturbed stands. Similarly, the surface soil layer exhibited a significantly higher ($P<0.01$) rate than the subsurface layer.

The mean monthly N mineralization rate in the upper soil layer was 13.76 µg g^{-1} month^{-1} in the Raliang and 14.14 µg g^{-1} month^{-1} in the Ialong protected stands. The corresponding values for the lower layer were 11.06 and 11.15 µg g^{-1} month^{-1}. In the unprotected stands, the rate varied from 11.44 to 11.86 µg g^{-1} month^{-1} in the upper layer and from 9.20 to 9.55 µg g^{-1} month^{-1} in the lower layer (Table 5).

Discussion

The fine roots were concentrated mostly (67–71%) in the upper soil layer in all the four stands. A high concentration of fine roots in the upper soil layer is an important feature of the humid tropical ecosystem where they play a crucial role in storage and rapid recycling of nutrients (Khiewtam and Ramakrishnan 1993). A similar trend of fine root concentration in the upper soil layer has been reported by Srivastava et al. (1986) from teak forests, Arunachalam et al. (1996) from a subtropical humid forest undergoing recovery and John et al. (2001) from subtropical pine forests of different ages in northeast India. The high concentration of fine roots in the surface layer may be attributed to better aeration, and high organic matter, N and available P contents in this layer.

Seasonal variation in fine root mass observed in tropical forests has been related to soil moisture and soil temperature conditions (Srivastava et al. 1986; Sundrapandian et al. 1999). Apart from soil conditions, the phenology of the species in the community also influenced root growth, since the peak biomass was observed when most plants were in their vegetative growth stage during the rainy season. The low fine root mass during spring, which marks the beginning of new shoot growth after the dormant phase, could be due to their slow growth in the preceding winter and the translocation of food reserves from the root system (Singh and Coleman 1997). A similar seasonal trend in fine root biomass has been reported from dry tropical and humid subtropical forest ecosystems (Srivastava et al. 1986; Sundrapandian and Swamy 1996; John et al. 2001).

A significant reduction in the fine root mass and annual production in the disturbed stands is attributed to the change in the dominant tree species and decrease in stand basal area, as well as the decrease in density of tree saplings and seedlings and ground vegetation. Besides vegetational change, unprotected stands had low N, P and organic matter contents due to losses caused by annual winter fire and surface run off during the ensuing rainy season.

The annual fine root production obtained at the present study sites (424–569 g m^{-2}) is within the range (178–

591 g m^{-2}) reported from dry tropical forest (Roy and Singh 1994), evergreen (476 g m^{-2}) and deciduous (526.8 g m^{-2}) tropical forests (Sundrapandian et al. 1999) and (160–591 g m^{-2}) temperate forest (Nadelhoffer et al. 1985). The values are, however, lower than those reported by John et al. (2001) for 6- to 23-year-old stands of pine forest (734–1,054 g m^{-2}) and Arunachalam et al. (1996) for 7- to 16-year-old oak–pine forest (1,841–2,388 g m^{-2}). In both of these cases, high root production was obtained in young stands, which were dominated by perennial grasses that are known to contribute more to the belowground productivity. In their studies production gradually decreased with increasing stand age. In a young forest stand, more fine roots are produced and distributed in the upper soil layer for the rapid absorption of water and nutrients by relatively fast-growing plants. With age as growth rate declines more fine roots are converted into coarse roots to provide better structural support to older trees, therefore the annual fine root production declines (John et al. 2001). The low annual production of fine roots obtained in the present study could be attributed to the older age and different species composition of both the trees as well as the ground vegetation of the studied stands.

The low NO_3^-–N and total inorganic-N in soil during rainy season may be due to its rapid absorption by fine roots, which exhibited peak growth during this season to meet the demand of a vigorously growing shoot system, higher runoff and leaching losses due to heavy rainfall. The denitrification rate could be another reason for low NO_3^-–N and inorganic-N levels in the soil during this season. However, an increase in NO_3^-–N and inorganic-N during the dry winter season may be attributed to a reduction in plant uptake owing to a low fine root mass due to the death of annual species, cessation of tree growth and low leaching and runoff losses. Singh et al. (1991) have reported that during dry periods the mineralized N is either immobilized in microbial biomass or is accumulated in soil as inorganic-N, resulting in a greater pool of mineral-N during this period as compared to the wet period. Birch (1958) reported that during the dry season soil starts to dry due to evaporation, which facilitates the upward movement of NO_3^- and release of free NH_4^+ and amino acids from the drying soils. All these factors together might have led to the greater accumulation of mineral-N in the soil during the dry winter at the present study sites.

The greater amount of NH_4^+–N in the soil at the study sites could be due to its acidic nature that has been reported to inhibit growth and the activity of autotrophic nitrifiers in soil (Chao et al. 1993). A predominance of NH_4^+ in acidic soil of a subtropical broad-leaved forest recovering after disturbance has also been reported by Maithani et al. (1998), and from temperate forests in eastern New York State by Verchot et al. (2001).

A low rate of nitrification in the presence of an adequate concentration of NH_4^+ found in all the stands corroborates the findings of Maithani et al. (1998), and may be attributed to the inhibition of nitrification by organic compounds in soil or plant extracts (Montangnini et al. 1986).

The importance of soil moisture on N mineralization has been reported from dry tropical savanna (Singh et al. 1991), and subtropical humid forest of northeast India (Maithani et al. 1998). Rewetting of dry soil increases N mineralization (Birch 1958). In the present study the N mineralization rate was slow during the winter when soil moisture (20–46%) and soil temperature (16–19°C) were lower than in the rainy season (31–62% and 20–23°C). A positive relation between N mineralization rate and fine root mass observed in the present study (r=0.45, P<0.01, y=235.68+6.12x for 0- to 10-cm depth; r=0.32, P<0.05 and y=107.15+1.87x for 10- to 20-cm depth) indicates that greater N mineralization enhances the accumulation of fine roots. Roy and Singh (1995) have also reported similar relationship from dry tropical forest.

Conclusions

Disturbance in the forests brought about a reduction in the mineral-N pool as well as in N mineralization in the soil. This was mediated through a change in species composition and a decline in the density and dominance (tree basal cover) of species in the community. These changes in the community influenced the microclimate on the forest floor, altered the resource quality of the litter and microbial activity in soil (Upadhaya 2002), mineralization of N and the mineral-N pool, as well as fine roots, whose seasonal growth was synchronized with N mineralization in the soil.

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