PFA Act of India by three states, namely Bihar, MP and WB, results in its fraudulent channelization for human consumption and BGF is the safe escape route. Also, the pretext that *L. sativus* cultivation is meant for fodder use is far from ground reality. The food safety measures taken up by the states cultivating *L. sativus* are inadequate. Such lapses should be taken more seriously and health safety of unsuspecting consumers should not be allowed to be exploited by unscrupulous elements.

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ACKNOWLEDGEMENTS. We are grateful to the Director, ITRC, Lucknow for interest in the present study. S.K.K. thanks the Indian Council of Medical Research, New Delhi, for award of Emeritus Medical Scientist scheme.

Received 19 November 2007; revised accepted 29 January 2008

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Effects of disturbance on fine roots and soil microbial biomass C, N and P in a tropical rainforest ecosystem of Northeast India

The tropical rainforests are one of the most fragile and complex ecosystems on the earth characterized by high biodiversity. They once covered 20% of the earth's land surface, but at present they occupy less than 7% area of the earth's surface in the America, South East Asia and Africa[1,2]. In Northeast India, tropical rainforests are restricted to the far eastern part of the region, particularly Tirap and Changlang districts of Arunachal Pradesh, and Tinsukia and Dibrugarh districts of Assam. Due to restricted distribution and inaccessibility of rainforests in the region, very few studies have been taken up concerning the impacts of anthropogenic disturbances on nutrient cycling and water balance. Thus, the present study offers essential base-line data on forest ecosystem dynamics following disturbance, which might help in the redevelopment or reconstruction of degraded forests *per se*.

The fine root system of the forest plays a crucial role in the fluxes of energy and matter in the biosphere and carries out the essential functions of soil resource acquisition[3]. Despite its importance, studies on fine root dynamics are limited in the tropical rainforest ecosystem, mainly due to difficulties associated with root sampling[4]. The fine roots increase the surface area for growth and multiplication of soil microorganisms, which are key components in nutrient cycling. The soil microbial biomass constitutes a transformation matrix for all the natural organic materials in the soil and acts as a labile reservoir of plant-available nutrients[3]. The Jeypore Reserve Forest (JRF) of Assam is one of the remnant pockets of tropical rainforest in the region. The effect of human-induced disturbance on fine roots and soil microbial biomass C, N and P dynamics in the tropical rainforest ecosystem of northeast India was studied in the undisturbed, selectively logged and clear-felled stands in the JRF.

The study was carried out in and around the JRF under the Dibrugarh Forest Division of Assam (lat. 27°05′–27°28′N; long. 95°20′–95°38′E; altitude 220 m asl) on the southern bank of the River Brahmaputra. Two disturbed stands and one undisturbed stand were selected and the disturbed stands were divided into two groups, viz. moderately disturbed (MD, disturbance index 54%) and highly disturbed (HD, disturbance index 88%) stands on the basis of their disturbance index[5]. The undisturbed stand (ca. 2 ha) was in the core area of the JRF, the MD stand was selectively logged (ca. 2 ha) area and the HD stand (ca. 2.5 ha) was at a distance of about 1 km from the undisturbed stand. It was clear-felled ten years ago for settled cultivation. The area falls within the humid tropical climate with well-pronounced wet summer and winter seasons. Mean monthly temperature varies between 17 and 36°C. The average annual rainfall during the last five years ranged between 2500 and 5000 mm and the relative humidity remains high throughout the year (>80%).

Soil sampling was done both in the undisturbed and disturbed forest stands during January, April, July and October in 2004–05, which represent winter, spring, rainy and autumn seasons respectively. From each stand, 20 soil cores (5.5 cm inner diameter) were collected randomly from 0–15 cm soil depth after clearing the litter layer on the ground and mixed to obtain composite samples. Soil physico-chemical properties like texture, pH, moisture content, water-holding capacity, organic carbon, total Kjeldahl nitrogen (TKN) and phosphorus concentration were determined according to Allen *et al.*[6], and Anderson and Ingram[7].

Root biomass and production were determined according to soil-core method[8,9] by collecting samples from 0–15 cm depth at each site on seasonal basis. Fine roots (<2 mm diameter) and coarse roots (>2 mm diameter) were separated by wet-sieving method and their biomass was determined after oven-drying at 80°C for 48 h. Root production was calculated by summing all the positive biomass increments (increments significant at $P < 0.05$) between sampling dates[9].

Chloroform fumigation-extraction method was used to estimate microbial biomass C, N and P. Microbial biomass C and N was determined in fresh soil by chloroform-fumigation extraction method[10,11], using 0.5 M K_2SO_4 as extracting solution. Microbial biomass P was determined by chloroform fumigation-extraction method[12] using 0.5 M, $NaHCO_3$ as extracting solution.

ANOVA test was used to test the effect of site on fine roots and microbial biomass. Correlation and regression tests were applied to study the relationship between microbial biomass C, N and P and fine roots and soil characteristics[13].

The undisturbed stand was characterized by well-defined vegetation stratification, where plants were distributed in four distinct strata. Similar stratification was observed in the MD stand with lower number of tree species. However, in the HD stand, stratification was completely disrupted and only a few adult trees were sparsely distributed in the stand. Selective logging and clear-felling caused significant reduction in species richness, density and basal area of trees and shrubs in the disturbed stands. However, the number of herbaceous species increased in the MD stand due to reduced competition of the canopy trees and better light intensity and temperature regimes on the forest floor. Moisture and water-holding capacity of the soil was reduced in the disturbed stands due to change in soil

Table 1. Vegetation and soil characteristics of the undisturbed and disturbed stands

Parameter	Undisturbed stand	Moderately disturbed stand	Highly disturbed stand
Vegetation			
Number of tree species	82	53	13
Tree density (No. per ha)	658	369	41
Tree basal area (sq. m per ha)	85.55	20.83	5.02
Soil			
Texture	Sandy clay loam	Sandy loam	Sandy loam
WHC (%)	66.48 ± 2.60	52.03 ± 1.44	38.40 ± 2.82
Bulk density (g per cubic cm)	0.67 ± 0.008	0.83 ± 0.02	0.88 ± 0.008
Moisture (%)	29.86 ± 1.91	20.18 ± 1.17	17.96 ± 0.96
pH	4.95 ± 0.23	5.74 ± 0.15	6.13 ± 0.14
SOC (kg per ha)	11024 ± 513	7889 ± 248	6865 ± 348
TKN (kg per ha)	4294 ± 148	2967 ± 133	2200 ± 78
P (kg per ha)	636 ± 22	619 ± 33	453 ± 17

SOC, Soil organic carbon; WHC, Water-holding capacity; TKN, Total Kjeldahl nitrogen.
Each value is the mean of eight seasons across the two years (±SE; n = 24).

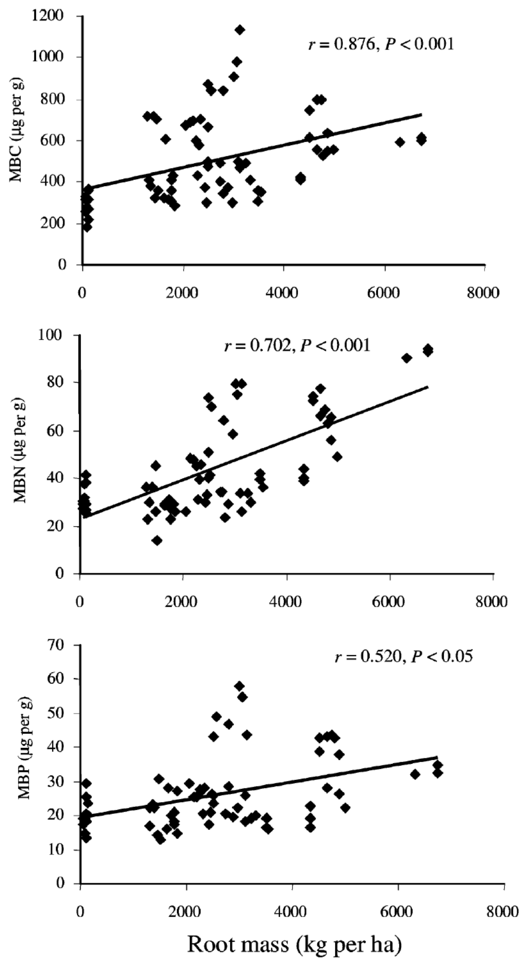

Figure 1. Relationship between total root mass with microbial biomass C, N and P.

Table 2. Root biomass (kg per ha) and production (kg per ha per yr), and microbial biomass (μg per g) in the undisturbed and disturbed stands

Parameter	Undisturbed stand	Moderately disturbed stand	Highly disturbed stand
Fine root mass	7419.39 ± 301.42	4838.63 ± 124.68	2867.12 ± 116.64
Coarse root mass	2056.60 ± 211.62	1512.75 ± 214.09	546.52 ± 13.48
Fine root production	2114.54 ± 128.67	1315.18 ± 86.32	1169.65 ± 31.42
Coarse root production	1091.72 ± 39.64	627.53 ± 65.67	150.29 ± 7.84
Microbial biomass C	1145.72 ± 51.01	452.93 ± 13.52	246.14 ± 12.68
Microbial biomass N	92.93 ± 3.87	34.95 ± 1.03	27.15 ± 1.60
Microbial biomass P	56.18 ± 1.48	22.55 ± 1.02	16.24 ± 0.68

Each value is the mean of eight seasons across the two years (± SE; $n = 24$).

texture from sandy clay loam in the undisturbed stand to sandy loam in the disturbed stands.

The chemical characteristics of the soil also differed markedly between the undisturbed and disturbed stands (Table 1). Low soil pH in the undisturbed stand could be the result of greater accumulation of partially decomposed organic matter on the forest floor, while higher soil pH in the disturbed stands could be due to low accumulation of decomposed organic matter. Significantly greater soil organic carbon (SOC), TKN, and P concentration in the undisturbed stand might be due to greater inputs of organic matter through above- and below-ground litter.

Fine and coarse root biomass and production in the humid tropical forest ecosystem, besides being influenced by vegetation characteristics and seasonality of the climate, is adversely affected by disturbance. The undisturbed stand with greater tree density and basal area had greater root mass compared to the disturbed stands. A significant ($P < 0.001$) reduction in root mass and production in the disturbed stands is attributed to the change in tree species composition and decrease in stand basal cover ($r = 0.903$, $P > 0.01$) and density ($r = 0.999$, $P > 0.001$). The humid tropical forest with thick above-ground vegetation is characterized by a dense network of fine roots on the forest floor. It plays an important role in the conservation of nutrients in tropical rainforests[14]. Lower fine root mass and production in disturbed stands may therefore be attributed to tree thinning, causing lower input of organic matter accumulation and nutrients on the forest floor. Root biomass and production values obtained in the present study are comparable with different tropical and subtropical forests of the region and the world.

Vegetation had the greatest effect on microbial biomass C, N and P dynamics. In the disturbed stands, low microbial biomass was mainly due to loss of vegetation (Table 2). A significant positive correlation between total root biomass and microbial biomass indicates that roots contributed significantly in increasing the microbial biomass in the soil (Figure 1). Low root biomass in the disturbed stands might have caused reduction in the microbial biomass. A significant positive correlation ($r = 0.899$, $P < 0.001$) between soil TKN and microbial N, and positive correlation between organic C, TKN and P in the soil and microbial P, show the importance of soil organic matter and nutrients in determining the accumulation of nutrients by soil microbes[15].

From the foregoing discussion, it is evident that destruction of above-ground vegetation adversely affects the fine roots and microbial biomass as well as physico-chemical characteristics of the soil. Greater accumulation of fine roots in the undisturbed stand helps in microbial colonization and immobilization of nutrients. This suggests that the soil microbial biomass and its activities are dependent on the quality, quantity and turnover of detrital organic matter in the forest floor.

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ACKNOWLEDGEMENTS. Financial support by the Ministry of Environment and Forests, Government of India is acknowledged. We thank the Principal Chief Conservator of Forests and Divisional Forest Officer, Dibrugarh Forest Division, Assam for permission to work in the Jeypore Reserve Forest. We thank the two anonymous reviewers for their valuable comments which helped in improving the manuscript. A.R.B. thanks Dr U. K. Sahoo, Department of Forestry, Mizoram University for cooperation and help.

Received 7 February 2007; revised accepted 23 January 2008

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