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Research Article

FINE ROOT BIOMASS AND SOIL NUTRIENTS IN VAN PANCHAYAT FOREST OF ALMORA DISTRICT

***Vardan Singh Rawat**
Department of Botany D.S.B. Campus, Kumaun University, Nainital, Uttarakhand
**Author for Correspondence*

ABSTRACT
Fine root biomass has an important implication for individual plant growth, plant interactions and carbon nutrient cycling. Fine root biomass and carbon varies widely within and among species and across various seasons. *Quercus leucotrichophora, Pinus roxburghii* and *Rhododendron arboreum* are dominated tree species in Bhatkholi Van Panchayat forest. The total fine root biomass across the four aspects ranged from 4.28 t ha $^{-1}$ to 5.74 t ha $^{-1}$, while the total carbon stock ranged from 2.14 t ha $^{-1}$ to 2.87 t ha $^{-1}$. The average fine root biomass was 6.56±2.68 t ha $^{-1}$. The fine root biomass and carbon allocation across all seasons declined with increasing soil depth. Soil organic carbon values of the present study ranged from 1.41±0.54 to 2.97±0.46%. The soil bulk density ranged from 0.97±0.06 g cc^{-1} to 1.36±0.004 g cc^{-1}. Fine roots act as a medium for transfer of atmospheric carbon into the soil in the form of carbon containing compounds. These deposits have the potential for a greater contribution to long term soil carbon sequestration in reducing atmospheric CO_2 concentration.

Key Words: *Community Managed Forest**,** Fine Root, Biomass, Carbon Sequestration Rate*

INTRODUCTION
Fine root production has been estimated to account for up to 33% of global annual Net Primary Production (Gill and Jackson, 2000). Fine root turnover has important implications for individual plant growth, plant interactions, belowground carbon and nutrient cycling. Fine root production is regulated by the nutrient availability in forest litter accumulation (Cuevas and Medina, 1988; Aerts *et. al.,* 1992). Fine roots are constantly renewed, and their productivity often exceeds aboveground productivity despite the fact that living fine root biomass constitutes only a small fraction of the total stand biomass (Helmisaari *et al*., 2002). The distribution of fine roots in different soil depths is assumed to be related to climate and site characteristics. Soil properties affect the growth dynamics of fine roots and mycorrhiza both directly and indirectly via the aboveground parts of plants. Fine roots of trees and under storey vegetation play an important role in the carbon and nutrient dynamics of forest soils (Rawat, 2012). Carbon and nutrient inputs into the soil in the form of fine root litter may be several times larger than the corresponding inputs from aboveground litter (Ruess *et al.*, 1996, Scheffer and Aerts, 2000). Thus, a high proportion of soil organic matter originates from dead and decomposing fine roots. However, there is insufficient quantitative information available about their contribution to the carbon and nutrient budgets (Trumbore and Gaudinski, 2003). The present study to highlights the seasonal dynamics of fine root biomass and their role in carbon transfer from the atmosphere into the soil in community managed forest in Lamgara block of Almora district of Uttarakhand.

MATERIALS AND METHODS
The study was carried out in the four selected sites of the Bhatkholi Van Panchayat forest of Almora district (latitudes 29º 34′ 42″ N and E longitudes, 79º 43' 2"; altitude 1646 to 1715 m asl). The average annual rainfall ranged from 274.5 mm to 463.2 mm. The mean temperature ranged from 2.18°C (January) to 27.87°C (June). The dominated tree species of the Van Panchayat are *Quercus leucotrichophora*, *Pinus roxburghii, Rhododendron arboreum,* and *Myrica esculenta*. Fine root (< 1 mm in diameter) were estimated in following the ingrowth core method. The soil core were obtained by driving a sharp edged

steel tube (8.5 cm internal diameter) in to the soil upto a depth of 1m (0-20, 20-40, 40-60, 60-80, 80-100 cm soil depths). A total of 360 soil samples were taken for each depth class in three seasons (winter, summer and rainy season). In this modified ingrowth process, fine roots were excavated from the soil core with the help of a steel tube and hole refilled with soil. Samplings were carried out in three directions from the measured trees following Usman (1993). Root samples collected from different directions kept in separate polythene bags depth wise and brought to the laboratory. Roots were separated from other organic material by passing the soil core through sequence of sieves. Soil samples were collected from 5-6 pits dug upto 100 cm depth in different locations within each aspect. From each pit 300 to 500 g soil samples were collected from 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, 40-50 cm, 50-60 cm, 60-70 cm, 70-80 cm, 80-90 cm and 90-100 cm soil depths. Soil texture was determined after removing the gravel particles, air drying the soil samples and than passing through a series of sieves with different size holes following Jina (2006). Soil moisture was determined on fresh weight basis following Jackson (1958). Soil carbon estimation was based on rapid titration method of Walkey and Black following Jackson (1958). For total Nitrogen (N), available Phosphorus (P) and available Potassium (K), three composite samples at different soil depths (0-30, 30-60, 60-100 cm) were taken. The total nitrogen (%) was determined by micro-Kjeldahl method (Peach and Tracey, 1956). Soil phosphorous and potassium were extracted by wet ashing of 1 g soil material in acid mixture consisting of 10 ml H_2SO_4 +3 ml HNO_3 + ml $HClO_4$ (Jackson, 1958). Soil potassium was determined by using flame Photometer and phosphorous was determined by spectrophotometer following Jackson (1958). For determining soil bulk density, soil samples were collected by means of a special metal core-sampling cylinder of known volume from different layers considered for soil carbon estimation for different soil depths. Samples of soil were brought to the laboratory and oven dried at 60°C till constant weight and soil bulk density was calculated following Misra (1968). Analysis of variance (ANOVA) and Standard errors were calculated by using SPSS version 16 software.

RESULTS

Site I

The fine root biomass at site I was 5.74 t ha $^{-1}$. The fine root biomass was maximum in rainy season (3.40 t ha $^{-1}$) followed by summer and winter seasons (1.42 t ha $^{-1}$ and 0.92 t ha $^{-1}$, respectively). The fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 70.8% to the total fine root biomass. Of the total biomass, 39.3% was observed upto 0-20 cm soil depth, 31.5% upto 20-40 cm, 14.7% upto 40-60 cm, 8.9% upto 60-80 cm and 5.6% was recorded upto 80-100 cm soil depth (Fig 1). The total fine root carbon stock across the three seasons was 2.87 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (1.70 t ha $^{-1}$, Fig. 2). The total organic soil carbon upto 100 cm soil depth was 273.70 t ha $^{-1}$. The organic soil carbon percent varied from 2.08±0.09% to 2.97±0.46%. The maximum soil organic carbon percent being in top soil layer of upto 10 cm (2.97±0.46%) and thereafter it decreased with increasing soil depth (Fig. 3). Contrary to this, the soil bulk density followed an inverse trend and varied from 0.97±0.06 g cc^{-1} to 1.29±0.01 g cc^{-1}. Across different soil depths, the sand percent varied from 30.29±3.11% to 42.33±3.69% and the proportion of clay percent varied from 39.27±3.58% to 55.34±5.22%. Soil moisture percent ranged from 9.77±1.35 to 14.50±1.15%, while the soil nitrogen, phosphorus and potassium value varied from 0.11 to 0.13%, 0.0002 to 0.0006% and 0.0081 to 0.0102%, respectively across various soil depths (Table 1).

Site II

The fine root biomass at this site was 5.07 t ha $^{-1}$. The fine root biomass was maximum in rainy season (2.98 t ha $^{-1}$) followed by summer and winter seasons (1.32 t ha $^{-1}$ and 0.78 t ha $^{-1}$, respectively). The fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 66.3% to the total fine root biomass. Of the total biomass, 41% was observed upto 0-20 cm soil depth, 25.3% upto 20-40 cm, 16.3% upto 40-60 cm, 10.6% upto 60-80 cm and 6.8% was recorded upto 80-100 cm soil depth

(Fig 1). The total fine root carbon stock across the three seasons at this aspect was 2.54 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (1.49 t ha $^{-1}$, Fig. 2). The total organic soil carbon upto 100 cm soil depth was 279.52 t ha $^{-1}$. The organic soil carbon percent varied from 1.95±0.41% to 2.91±0.40% across all the soil depths (Fig. 3). The maximum soil organic carbon percent being in top layer of upto 10 cm (2.91±0.40%) and thereafter it decreased with increasing soil depth. Contrary to this, the soil bulk density followed a reverse trend and varied from 1.02±0.05 g cc^{-1} to 1.33±0.005 g cc^{-1}. Across the various soil depths, the sand percent varied from 23.21±3.88% to 35.68±2.64% and the clay percent varied from 48.53±4.41% to 63.64±6.20%. Soil moisture percent ranged from 7.08±1.26 to 11.28±3.39%, while the soil nitrogen, phosphorus and potassium value varied from 0.09 to 0.14%, 0.0002 to 0.0005% and 0.0026 to 0.0039%, respectively across various soil depths (Table 1).

Table 1: Stand structure and soil characteristics of the Bhatkholi Van Panchayat forest in Lamgara block of Central Himalaya

Altitude (m)	1646 to 1715
Dominant Vegetation	*Quercus leucotrichophora* and *Pinus roxburghii*
Total Tree density (ind ha^{-1})	193 to 324.3
Total basal area (m^2 ha^{-1})	5.26 to 9.41
Total litter fall (t ha^{-1})	5.12 to 7.47
Sand (%)	23.21±3.88 to 70.51±2.42
Clay (%)	17.87±1.9 to 63.64±6.20
Soil bulk density g cc^{-1} (0-100cm)	0.97±0.06 to 1.36±0.004
Soil carbon (%)	1.41±0.54 to 2.97±0.46
Annual range of soil moisture (%)	6.52±1.09 to14.50±1.15
Nitrogen (%)	0.09 to 0.16
Phosphorus (%)	0.0001 to 0.0007
Potassium (%)	0.0026 to 0.0102

Site III

The fine root biomass at this site was 4.28 t ha $^{-1}$. The fine root biomass was maximum in rainy season (2.60 t ha $^{-1}$) followed by summer and winter seasons (1.08 t ha $^{-1}$ and 0.60 t ha $^{-1}$, respectively). The fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 72% to the total fine root biomass. Of the total biomass, 40.5% was observed upto 0-20 cm soil depth, 31.6% upto 20-40 cm, 15.4% upto 40-60 cm, 7% upto 60-80 cm and 5.5% was recorded upto 80-100 cm soil depth (Fig. 1). The total fine root carbon stock across the three seasons at this aspect was 2.14 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (1.30 t ha $^{-1}$, Fig. 2). The total organic soil carbon upto 100 cm soil depth was 273.55 t ha $^{-1}$. The organic soil carbon percent varied from 1.82±0.46% to 2.88±0.45% across different soil depths. The maximum soil organic carbon percent being in top layer of upto 10 cm (2.88±0.45%) and thereafter it decreased with increasing soil depths (Fig. 3). Contrary to this, the soil bulk density followed a reveres trend and varied from 1.02±0.004 g cc^{-1} to 1.36±0.004 g cc^{-1}. Across the various soil depths, the sand percent varied from 27.41±3.68% to 38.39±3.31% and the clay percent varied from 45.73±4.69% to 60.86±6.01%. Soil moisture content ranged from 6.52±1.09 to 9.96±0.82. The soil nitrogen and potassium value varied from 0.10 to 0.16% and 0.0084 to 0.0099%, respectively across different soil depths, while the soil phosphorus content was same (0.0001%) across different soil depths (Table 1).

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Site IV

The fine root biomass at this was 4.60 t ha $^{-1}$. The fine root biomass was maximum in rainy season (2.82 t ha $^{-1}$) followed by summer and winter seasons (1.12 t ha $^{-1}$ and 0.66 t ha $^{-1}$, respectively). The fine root biomass declined with depth. The top soil layer (upto 40 cm) contributed approximately 71.5% to the total fine root biomass. Of the total biomass, 40.9% was observed upto 0-20 cm soil depth, 30.5% upto 20-40 cm, 13.8% upto 40-60 cm, 8.5% upto 60-80 cm and 6.3% was upto 80-100 cm soil depth (Fig. 1). The total fine root carbon stock across the three seasons at this aspect was 2.30 t ha $^{-1}$. The contribution of fine root carbon stock was maximum in rainy season (1.41 t ha $^{-1}$, Fig. 2). The total organic soil carbon upto 100 cm soil depth was 218.96 t ha $^{-1}$. The organic soil carbon percent varied from 1.41±0.54% to 2.92±0.59% across different soil depths (Fig. 3). The maximum soil organic carbon percent being in top layer of upto 10 cm (2.92±0.59%) and little variation was recorded in the middle layers. Contrary to this, the soil bulk density varied from 1.03±0.002 g cc $^{-1}$ to 1.28±0.005 g cc $^{-1}$ across all the soil depths and followed an inverse trend. Across the various soil depths, the sand percent varied from 50.93±4.92% to 70.51±2.42% and the clay percent varied from 17.87±1.9% to 38.88±5.23%. Soil moisture content ranged from 7.90±0.86% to 14.38±0.56% across different soil depths, while the soil nitrogen, phosphorus and potassium value varied from 0.10 to 0.15%, 0.0004 to 0.0011% and 0.0032 to 0.0053%, respectively across different soil depths (Table 1).

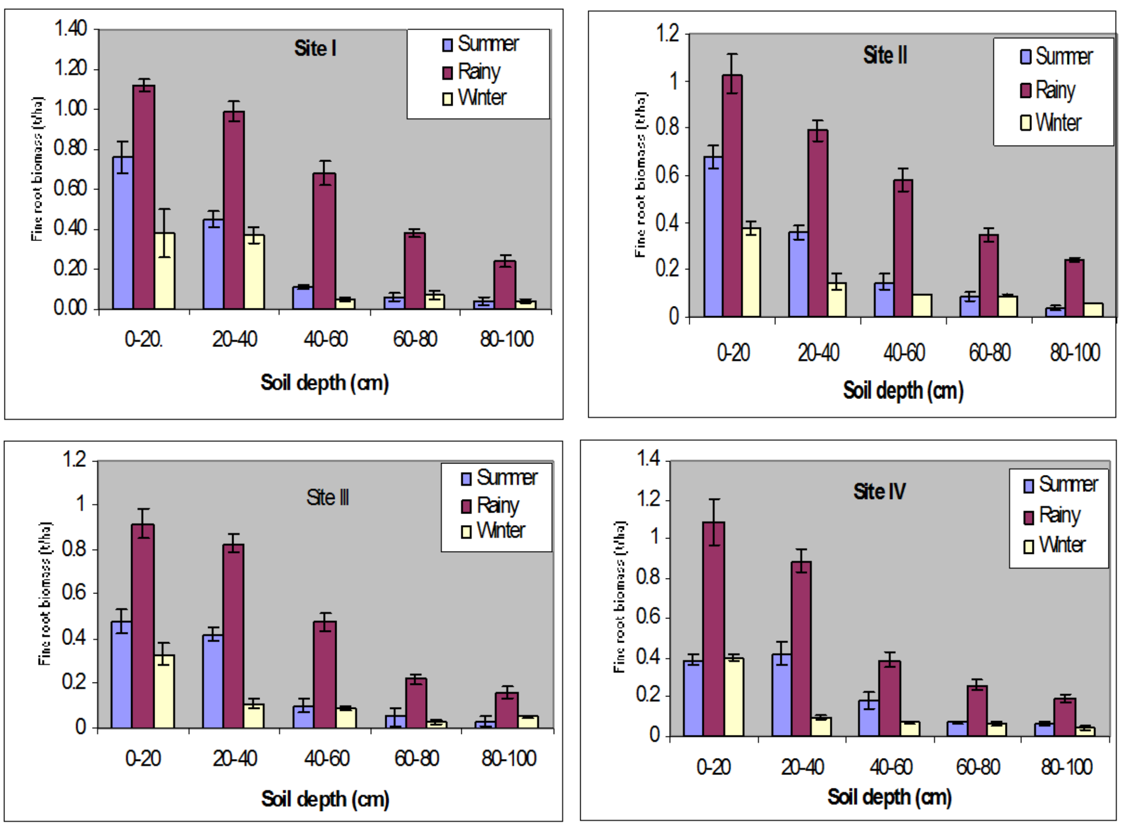

Figure 1: Fine roots biomass (t ha $^{-1}$) of Bhatkholi Van Panchayat across different site and season

The analysis of variance (ANOVA) showed that fine roots biomass varied significantly (P<0.05) between seasons, forest site, soil depths and the combined effects of season x forest site and season x soil depths. The analysis of variance also showed that the soil organic carbon, total soil nitrogen and soil phosphorus values varied significantly ($P<0.01$) among the forest sites. ANOVA also showed that the combined effects of site x soil depths of carbon and nitrogen varied significantly at $P<0.05$. However, the soil carbon, soil nitrogen and the soil potassium values did not vary significantly across soil depth for all the sites.

DISCUSSION

Fine roots are the important below ground components carrying out vital functions of nutrient and water absorption. Fine root biomass mass varied greatly with respect to soil depths, forest types, locations and species composition (Aerts *et. al*., 1992; Fogel, 1983; Persson, 1982). The same forest types have quite different fine root biomass values depending on the methodology used, the time of sampling and the definition of what constitutes a fine root (Burke and Raynal, 1994; Steele *et al.*, 1997). The top soil layer (upto 40 cm) contributed approximately 70-75% to the total fine root biomass (Usman, *et al.*, 1999). The growth of fine roots was greater in the surface layers when fresh litter was present. The leaf litter forms a shelter for the surface roots by providing a moist microclimate for the developing new fine roots. The nutrients that are released from the litter are not leached down to the soil but are transferred directly to the surface roots which are growing intermingled with the decaying matter (Went and Stark, 1968).

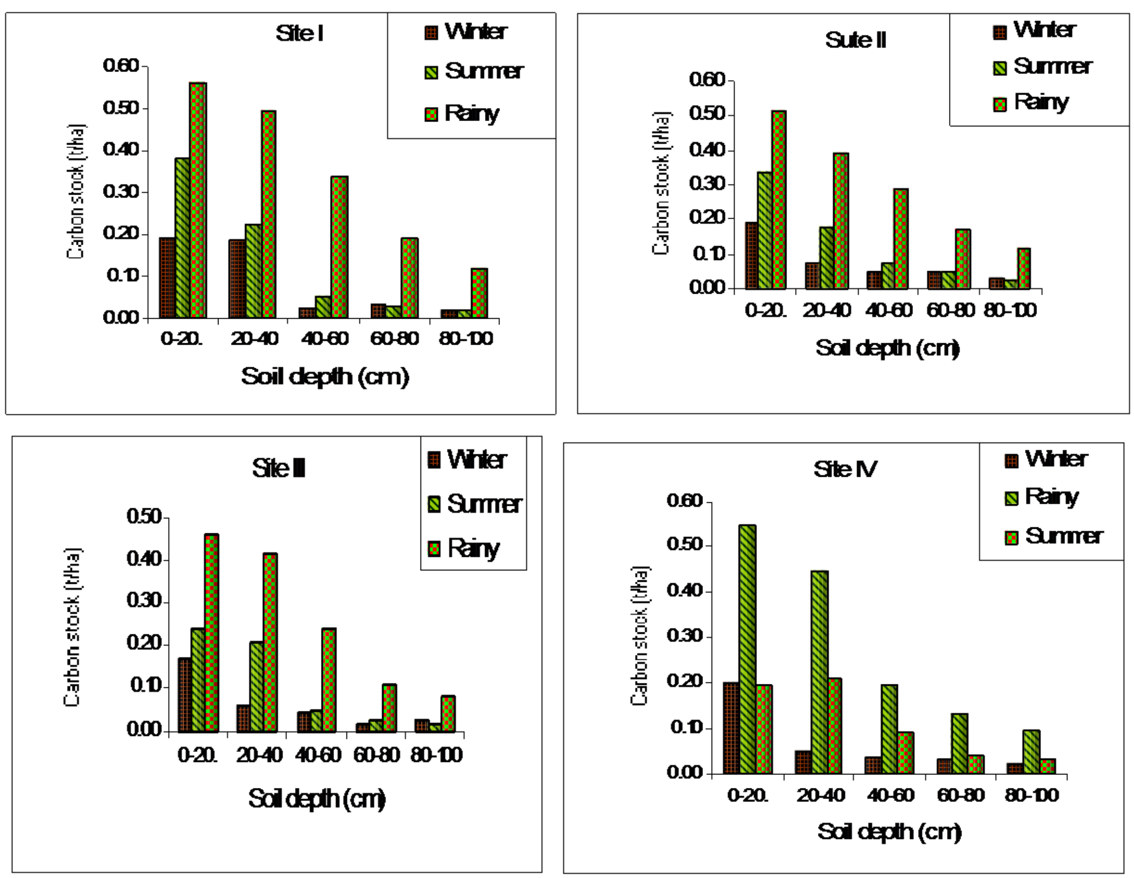

Figure 2: Fine roots carbon stock (t ha $^{-1}$) of Bhatkholi Van Panchayat across different sites and seasons

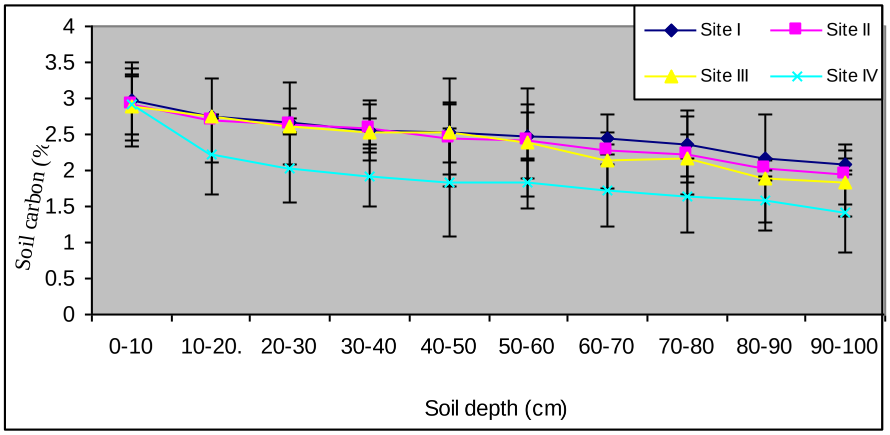

Figure 3: Soil carbon percent of Bhatkholi Van Panchayat across different soil depth and site

Singh *et al*., (1990) and Upadhyay and Singh (1989) stated that the more microbial activity in the upper soil layer accelerates decomposition. In addition in Central Himalaya, the temperature is favourable throughout the year which ensures a supply of nutrients to the top soil layer. These are the reason for the higher fine root biomass in the top soil layers in the present study across all seasons. The fine root biomass in the present study declined towards deeper soil layers. The vertical distribution of fine root biomass, production and mortality presents a characteristic pattern of decreasing fine root biomass values with soil depth. The fine root biomass in the present study was higher during the rainy season (63.51%) followed by summer and winter seasons (18.24% each). Similar seasonal patterns of fine root biomass were observed by Keys and Grier (1981) for a spruce sub alpine forest in British Columbia and in the Central Himalayan high altitude forests of India by Adhikari (1992) and Garkoti (1992). The fine root biomass was higher during rainy season due to rapid nutrient release during rainy season (Khiewtam and Ramakrishnan, 1993). The fine root biomass in the present study falls with in the range reported earlier for different forests of world (1.8 to 16 t ha^{-1} yr^{-1}). Soil organic carbon values of the present study varied from 1.41±0.54 to 2.97±0.46%, while the soil bulk density ranged from 0.97±0.06 g cc^{-1} to 1.36±0.004 g cc^{-1}. These values are generally comparable with the values reported earlier for the surrounding community managed forests (Singh, 2009, Jina, 2006). Root biomass was inversely proportional to the soil bulk density. According to Nambiar and Sands (1992) when bulk density increases, soil strength increases and aeration decreases leading to adverse effects on root growth.

Fine root acts as a medium for transfer of atmospheric carbon into the soil in the form of carbon containing compounds. Root necrosis and exudates contribute significant quantities of carbon deposited in sub surface soil. These deposits have the potential for a greater contribution to long term soil carbon sequestration in reducing atmospheric CO_2 concentration due to slow oxidation than surface soil.

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