FINE ROOT BIOMASS AND NUTRIENT CONCENTRATION AT SUBTROPICAL DISTURBED MIXED FOREST AND UNDISTURBED MIXED OAK FOREST OF MANIPUR, NORTH-EASTERN INDIA.

PH.APSARA DEVI AND E.J. SINGH

Ecology Research Laboratory, P.G. Department of Botany, DMC of Science Imphal – 795001, India.

DOI: 10.29322/IJSRP.10.12.2020.p10804
http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Abstract:

Fine root biomass and its nutrient concentration in different soil depths (0-10cm, 10-20cm and 20-30 cm) were studied in disturbed mixed Pine forest (forest site I) and undisturbed mixed oak forest (forest site II) at Senapati District, Manipur. Fine roots from both the study sites were collected by soil corer. Maximum fine root biomass were found in 1-10 cm (2037.80 gm^{-2} in forest site I and 2170.63 gm^{-2} in forest site II) throughout the year in both the study sites. Maximum fine root biomass was found in the month of December (205.65 gm^{-2} and 223.40 gm^{-2} in forest site I and site II respectively). The amount of nutrient (NPK) in fine roots varies in different soil depth in both the study sites throughout the year.

Index terms:

Live fine roots, nutrient concentration (NPK), disturbed mixed Pine forest (forest site I), undisturbed mixed oak forest (forest site II).

Introduction:

Fine roots (<2.00mm represent a dynamic portion of belowground biomass. The fine root only a small fraction of the total root biomass. The fine roots play an important role in the soil profile development and after the dead also adds to the organic matter of the soil thus enriching the soil fertility. The quantity and activity of the small diameter of the root systems are of great significance as regards to water and nutrient supply. The knowledge of fine root biomass is important for understanding energy flow and nutrient cycling (Aertis et al 1992; Khiewtmar and Ramakrishnan 1993). Fine roots conserve the nutrients by preventing the leaching losses from the ecosystem. Studies on fine root dynamics in forest ecosystem have been studied by several workers (McClaugherty et al 1982; Fitter 1985, Vogt et al 1996; Pregitzer et al. 2002) but there is limited information on fine root biomass and nutrient concentration (NPK) in three different soil depths in the disturbed mixed pine and undisturbed mixed oak forests in the subtropical forest at Senapati District of Manipur. The present study aims to study the fine root biomass and nutrient concentration (NPK) from three different soil depths in subtropical forest.

Study sites:

The study sites are situated in the Senapati District of Manipur. The forest site I is located at Motbung that lies at 24.99^0N and 93.90^0E at an altitude of 970m from the mean sea level and the forest site II is located at Saparmeina that lies at 25.04^0N and 93.94^0E at an altitude of 933m from the mean sea level. The climate of the area is monsoonic with warm moist summer, a distinct rainy season and cool dry winter. The average annual rainfall of the study sites is 1131.8 mm. the mean monthly maximum ranges from 4.9^0C (December) to 28.8^0C (July) during the study period as shown in figure I.

The disturbed mixed pine forest (forest site I) is dominated by *Pinus Khesiya* Royle, *Bauhenia Vareigata*, *Emblica officinalis*, *Cedrella toona* and other shrubs and herbs species. The disturbed mixed oak forest is dominated by *Quercus serrate*, *Schima wallichii*, *Quercus polystachya* and other shrubs and herbs.

Result:

The soil of forest site I is sandy loam in texture (sandy 42%, silt 25% and clay 33%). The soil temperature ranges from 8^0 to 30^0C, soil pH ranged from 4.63 to 6.67, soil moisture ranged from 21.15 to 26.13%, soil organic carbon ranged from 0.727 to 4.8%, soil total nitrogen ranged from 0.092 to 0.587%, soil available phosphorous 0.021 to 0.096% and soil potassium ranged from 0.115 to 0.482% as shown in table 1 & 2.

The soil forest site II is clayed loam in texture (sand 32%, silt 25% and clayed 42%). The soil temperature ranged from 9^0C to 30^0C, soil pH ranged from 4.69 to 6.66, soil moisture ranged from 20.15 to 26.13%, soil organic carbon ranged from 0.728 to 4.90%, soil nitrogen ranged from 0.125 to 0.692%, soil available phosphorous ranged from 0.023 to 0.096% and soil potassium ranged from 0.115 to 0.482% as shown in table 1 & 2.

The live fine root biomass in forest site I ranged from 136.15gm^{-2} to 205.65gm^{-2} in 0-10 cm, 16.28 to 162 gm $^{-2}$ in 10-20 cm and 4.25 to 68.70g^{-2} in 20-30 cm whereas in forest site II, it ranged from 145.23 to 223.40 gm^{-2} in 0-10 cm, 20-180 gm^{-2} in 10-20 cm and 8.32 to 78.29 gm^{-2} in 20-30 cm as shown in fig 2. Fine root biomass decreased with the increase in soil depth in both the study sites. Mean fine root biomass declined consistently from February to July and then increased from August to December in both the study sites as shown in table 3. Seasonally fine root biomass was maximum in winter season followed by rainy and summer season in both the study sites as shown in table 3, fig 3 showed the variation of fine root biomass among the three seasons in forest site I and forest site II. In forest site I, among the three seasons, the maximum mean value of fine root biomass was shown in winter season (129.86±61.48) gm^{-2} and minimum mean value in summer (74.58±59.70) gm^{-2}. The variation test value in forest site I predict significant F=9.32, P<0.01). In forest site II, the maximum mean value was also shown in winter season (139.64±63.66) gm^{-2} and the minimum mean value in rainy season (82.66±65.00)gm^{-2}. The variation test value in forest site II showed significant statistically (F=9.24, P<0.01). Monthly variation in fine root nitrogen concentration (%) at different depth of soil is shown in fig 4. Several variation in fine root nitrogen concentration (%) at different depth of soil is shown in Table 5 for both forest site I and site II. The ANOVA of fine root nitrogen concentration (%) show significant variation in both the study sites as shown in Table 6. In forest site I, the variation of FRN concentration (%) is highly significant (F_{season}=67.79, P<0.01; F_{depth}69.05, P<0.01; $F_{season\ with\ depth}$=2.62, P<0.05). Similar pattern of variation is observed in forest site II (F_{season}=157.64, P<0.01; F_{depth}=110.87, P<0.01; $F_{season\ with\ depth}$=3.81, P<0.01). Monthly variation in fine root phosphorous concentration (%) at different depth of soil is shown in fig 5. Seasonal variation in fine rot phosphorous concentration (%) is shown in table 7 at different soil depth for both the study sites. The ANOVA of fine root phosphorous concentration (%) as shown in table 8 evidenced variation of fine root phosphorous concentration (%) in both the study sites. In forest site I, the variation of FRP concentration (%) is highly significant (F_{season}=11.45, P<0.01) but insignificant with depth (F_{depth}=0.098, P<0.05; $F_{season\ with\ depth}$=0.152, P<0.05) statistically whereas in forest site II, in all seasons, the ANOVA showed highly significant (F_{season}=143.99, P<0.01; F_{depth}=156.02, P<0.01, $F_{season\ with\ depth}$=3.15,P<0.05). Monthly variation in fine root potassium concentration (%) is shown in fig 6. Seasonal variation in fine root potassium is shown in table 9 at different soil depth for both forest site I and site II. The ANOVA of fine root potassium concentration (%) as shown in table 10 predicted the variation of fine root potassium (FPK) concentration (%) in both the study sites. The variation of FRK concentration (%) in both the study sites. The variation of FRK concentration (%) in forest site I showed a significant (F_{season}=118.70, P<0.01, F_{depth}=67.52, P<0.01, $F_{season\ with\ depth}$=8.91, P<0.01). Similar pattern is also observed in forest site II showing highly significant in all three season (F_{season}=146.34, P<0.01; F_{depth}=104.26, P<0.01; $F_{season\ with\ depth}$=12.38, P<0.01).

Discussion:

Fine root biomass was maximum in winter season and minimum in summer and rainy season in both the study sites. The decrease in fine root biomass in summer and rainy seasons may be due to root mortality and decomposition. Similar seasonal trend in fine root biomass have been observed in several ecosystem (Harris et al, 1977, Santantonio and Hermann 1985 and Uma et al 2002). Table 11 compares the ranges of fine root biomass estimated in the present study with that of different forest ecosystem of the world. The present value of fine root biomass across the soil depth layer falls with the range reported for most of the Indian forests in which the value of fine root biomass varied from 32 to 340 gm^{-2} for <2 mm diameter to a depth of 30 cm (Behra et al, 1990 and Parthasarthy 1988). The greater in fine rot biomass in forest site II compared to forest site I may be attributed due to relativity low soil moisture, low temperature and relativity undistributed condition prevailing in forest site II. The maximum concentration of fine root nutrient concentration (%) exhibited in rainy season in both the study sites. In the present study, the fine root nutrient concentration is comparatively higher in forest site II that forest site I. the lower fine root concentration of nutrient (NPK) in forest site I may be due to more nutrient leaching on the upper soil surface and the sandy soil possibly may not hold much nutrients due to their low water holding capacity or alternately get accumulated in thicker root or in the upper ground part by translocation as fine root biomass and nutrient concentration varies greatly

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

with respect to season and other abiotic factors and sites quality.

Acknowledge:

I thankfully acknowledge the Ecology and Research Laboratory for providing facilities of P.G. Department of Botany, D.M. College of Science and proper guidance given by the E. Jadu Singh, Principal, D.M. College of Science.

Authors:

First Author: Ph. Apsara Devi and E.J. Singh, Ecology Research Laboratory, P.G. Department of Botany, D.M. College of Science, Imphal – 795001.

E-mail: thoidingjamapsara@gmail.com

Reference:

Aber, J.D.; Melillo, J.M.; Nadelhoffer, K.J.; McClaugherty, C.A. and Pastor, J. (1985). Fine root turnover in forest ecosystems in relation to quantity and form of nitrogen availability: a comparison of two methods, Oecologia, 66:317 – 321.

Adams, M.A. and Attiwill, P.M. (1986). Nutrient cycling and nitrogen mineralization in eucalypt forests of south eastern Australia. Plant and Soil. 92:341 – 362.

Aerts, R.; Bakker, C. and Caluwe, H. De (1992). Root turnover as determinant of the cycling of C, N and P in a dry heathland ecosystem. Biochemistry. 15:175 – 190.

Bowen, G.D. (1985) Roots as a component of tree productivity. In Attributes of trees as crop plants Edited by M.G.R. Cannell and J.E. Jackson. Institute of Terrestrial Ecology, Huntington, England. pp 303 – 315.

Burke, I.C.; Reiners, W.A. and Schimel, D.S. (1989). Organic matter turnover in sagebrush Steppe Landscape. Biogeochemistry 7:11 – 31.

Burke, M.K. and Raynal, D.J. (1994): Fine root growth phenology, production and turnover in a northern hardwood forest ecosystem. Plant and Soil 162:135 – 146.

Camire, D.; Cote, B. and Brulotte, S. (1991). Decomposition of roots of black older and hybrid popular in short-rotation plantings: Nitrogen and Lignin control. Plant Soil. 138:123 – 132.

Cavalier, J.; Wright, S.P. and Santamaria, J. (1999). Effects of irrigation on litterfall, fine root biomass and production in a semi deciduous lowland forest in Panama. Plant and Soil. 211:207 – 215.

Frsmd. J.D. (1981). Dynamics of coarse root production in a young plantation of Picea sitchensis. Forestry, 54:139 – 155.

Fahey, T.J. and Hughes, J.W. (1994). Fine root dynamics in a northern hardwood forest ecosystem. Hubbard Brook Experimental Forest, N.H. Ecology 82:533 – 548.

Fairley, R.I. and Alexander, I.J. (1985). Methods of calculating fine root production in forests. In Ecological interactions in Soil. Edited by A.H. Fitter et al. Special Publication No. 4 of the British Ecological Society. Blackwell Scientific Publications, Oxford, pp 37 – 42.

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Fitter, A.H. (1985). Functional significance of root morphology and root system architecture. In Ecological Interactions in Soil. Eds. A.H. Fitter; Atkinson; Read, D.J. and Usher, M.B. pp 87 – 106. Special publication of the British Ecological Society No. 4. Blackwell Scientific Oxford.

Harris, W.F.; Santantonio, D. and Meginity, D. (1980). The dynamic belowground ecosystem. In Forests: fresh perspectives: Edited by R.H. Waring. Oregon State University Press. Corvallis. OR pp 118 – 129.

Helja – Sisko Helmisaari, et al. 2012. Fine root biomass in relation to site and stand characteristics in Norway Spruce and Scot. Pine stands.

Hendrick, R.L. and Pregitzer, K.S. (1992). The demography of fine root in a northern hardwood forest. Ecology 73:1094 – 1104.

Hendrick, R.L. and Pregitzer, K.S. (1993). The dynamics of fine root length, biomass and nitrogen content in two northern hardwood ecosystems. Canadian Journal of Forest Research, 23:2507 – 2520.

Joslin, J.D. and Henderson, G.S. (1987). Organic matter and nutrients associated with fine root turnover in a white oak stand. Forest Science 33:330 – 346.

Khewtam, R.S. and Ramakrishnan, P.S. (1993). Litter and fine root dynamics of a relict sacred grove forest at Cherrapunji in north eastern India; for. Ecol. Manage. 60:327 – 344.

Klinge, H. (1976). Root mass estimation in lowland tropical rain forests of Central Amazonia, Brazil. Trop. Ecol. 17:79 – 88.

Liyun. Yang et al. 2010. Fine root biomass dynamics and Carbon storage along a successional gradient in Chingbai Mountain, China, Oxford Journal > Life Sciences > Forestry > Volume 83, issue 4 > Pp 379 – 387.

Lohmus, K. and Ivask, M. (1995). Decompostition and nitrogen dynamics of fine roots of Norway Spruce (Picea abies (L.) Karst.) at different sites. Plant and Soil. 168 – 169:89 – 94.

Makkonen, K. and Helmiaari, H.S. (1999). Assessing fine-root biomass and production in a Scots pine stand – comparison of soil core and root in growth core methods. Plant and soil 210:43 – 50.

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

McClaugherty, C.A.; Aber, J.D. and Melilo, J.M. (1982) the role of fine roots in the organic matter and nitrogen budgets of two forested ecosystems. Ecology, 63:1481 – 1491.

McClaugherty, C.R.; Aber, J.D. and Melillo, J.M. (1984). Decomposition dynamics of fine roots in forested ecosystems. Oikos 42:378 – 386.

Parrota, J.A. and Lodge, D.J. (1991). Fine root dynamics in a subtropical wet forest following hurricane in Puerta Rico. Biotropica 23:343 – 347.

Parthasarathy, N. (1986). Seasonal Dynamics of Fine Roots in a Tropical Forest in South India. J. Indian Bot. Soc. 66:338 – 345.

Paula Marquart, et al. 2012. Estimating fine root biomass with DNA fingerprint forest.

Person, H. (1978). Root dynamics in a young Scots pine stand in Central Seeden. Oikos 30:508 – 519.

Person, H. (1980). Fine root dynamics in a Scots pine stand with and without near-optimum nutrient and water regimes. Acta Phytogeogr. Suec. 68:101 – 110.

Silver, W.L. and Vogt, K.A. (1993). Fine root dynamics following single and multiple disturbances in a subtropical wet forest ecosystem. Journal of Ecology, 81:729 – 738.

Singh, B. (1998). Contribution of forest fine roots in reclamation of semiarid sodic soil. Arid

Stark, N. and Spratt, M. (1977). Root biomass and nutrient storage in rain forest Onisols near San Carlos de Rio Negro. Tropical Ecology, 18:1 – 9.

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

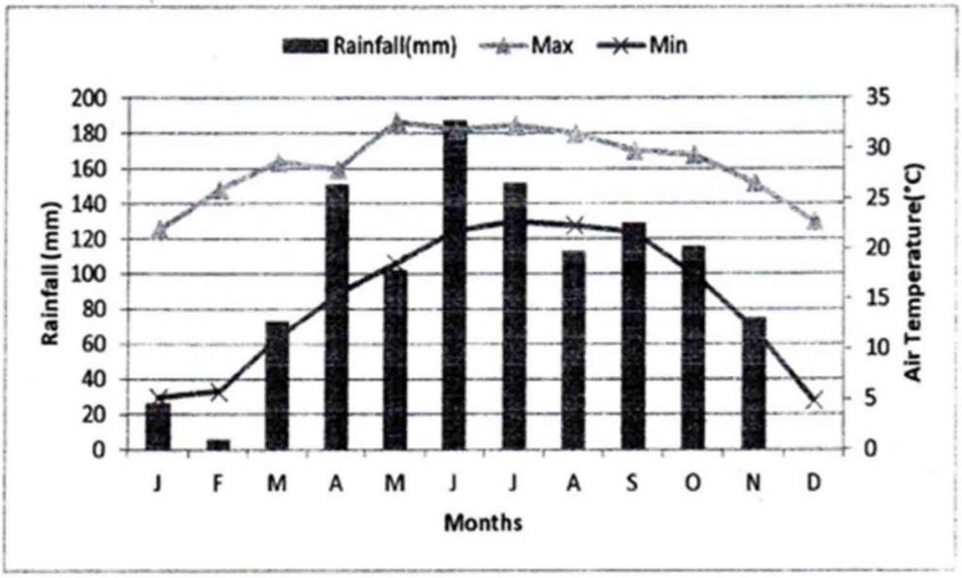


Figure 1: Climatic data of the study period

Table 1: Abiotic variables and physicochemical characteristics of soil.

Abiotic variables	Forest site I	Forest site II
Soil temperature (^{0}C)	20.33	21.32
Soil moisture (%)	24.60	24.75
Rainfall (mm)	94.31	94.31
Air temperature(^{0}C)	23.65	23.65

Table 2: Soil physicochemical characteristics.

Texture	Forest site I	Forest site II
Sand (%)	42	32
Silt (%)	25	25
Clay (%)	33	42
Soil organic carbon (%)	0.73-4.8	0.73-4.9
Soil total N (%)	0.09-0.58	0.125-0.692
Soil available P (%)	0.021-0.096	0.023-0.096
Soil Potassium K (%)	0.115-0.482	0.115-0.482

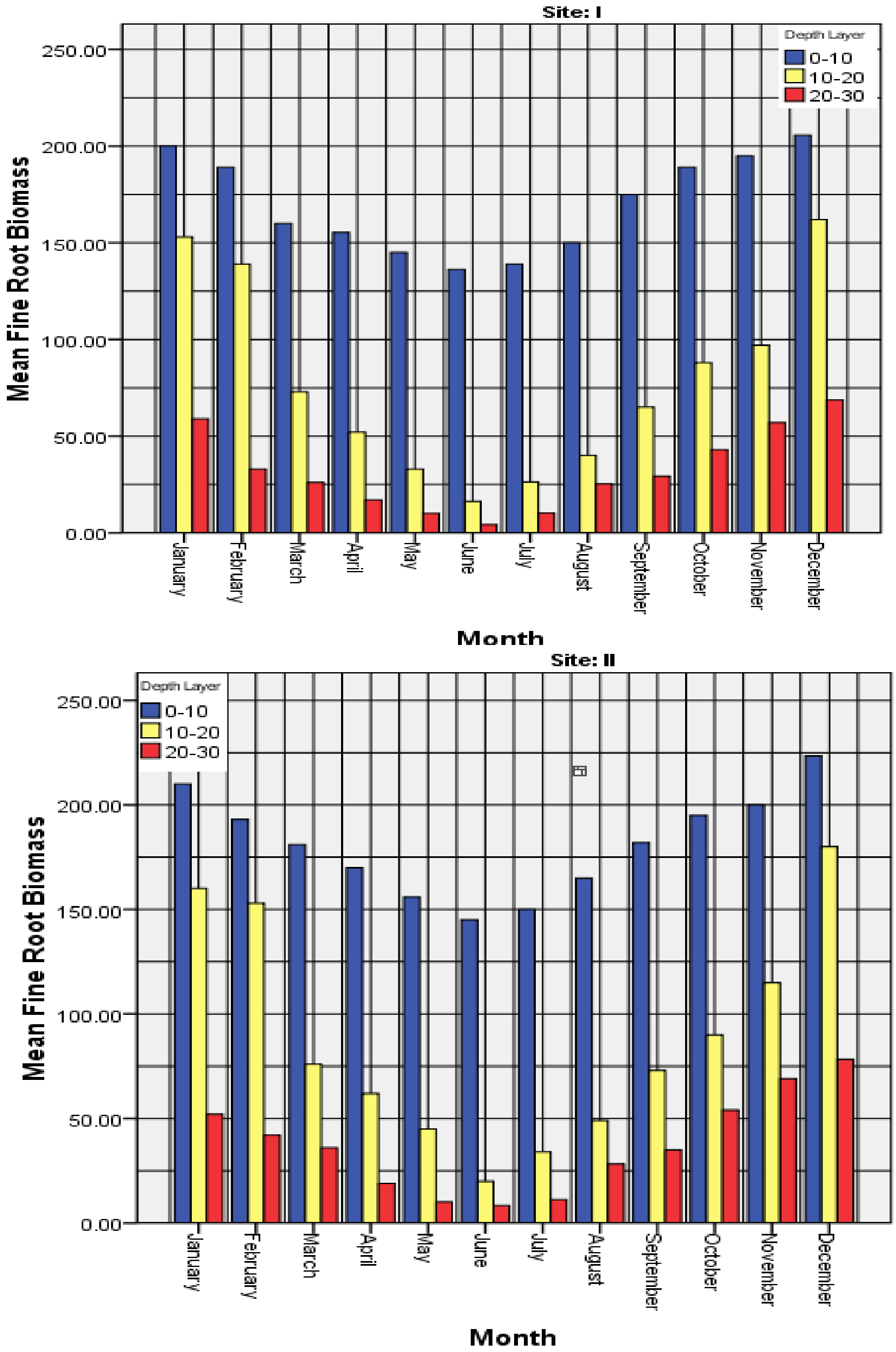


Figure – 2: Monthly variation in fine root biomass at different soil depth

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table – 3

Variation in fine root biomass in forest Site I and forest Site II

Site	Month	N	Mean	S. D	95%CI for mean		Test value
					Lower	Upper	
I	January	9	137.33	62.20	89.52	185.14	F=2.25 P<0.05
	February	9	120.33	69.01	67.29	173.38	
	March	9	86.29	58.91	41.02	131.58	
	April	9	74.78	62.32	26.87	122.68	
	May	9	62.67	62.57	14.57	110.76	
	June	9	52.23	63.16	3.68	100.77	
	July	9	58.51	60.77	11.80	105.23	
	August	9	71.76	59.04	26.37	117.14	
	September	9	89.77	65.78	39.20	140.33	
	October	9	106.67	64.77	56.88	156.46	
	November	9	116.33	61.51	69.05	163.61	
	December	9	145.45	60.59	98.87	192.03	
	Total	108	93.51	66.53	80.82	106.20	
II	January	9	140.67	69.96	86.89	194.44	F=2.23 P<0.05
	February	9	129.33	67.77	77.24	181.43	
	March	9	97.67	64.88	47.80	147.54	
	April	9	83.67	67.40	31.86	135.47	
	May	9	70.33	66.04	19.57	121.09	
	June	9	57.79	65.62	7.35	108.23	
	July	9	65.08	64.46	15.53	114.63	
	August	9	80.74	63.85	31.66	129.82	
	September	9	96.67	66.10	45.85	147.48	
	October	9	113.00	63.47	64.21	161.79	
	November	9	128.00	57.58	83.74	172.26	
	December	9	160.56	64.51	110.97	210.15	
	Total	108	101.96	69.22	88.7543	115.16	

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table – 4
Seasonal variation in fine root biomass in forest Site I and forest Site II

Site	Season	N	Mean	S. D	95%CI for mean		Test value
					Lower	Upper	
I	Summer	27	74.58	59.70	50.96	98.20	F=9.32 P<0.01
	Rainy	45	75.79	63.19	56.80	94.77	
	Winter	36	129.86	61.84	108.94	150.79	
	Total	**108**	**93.51**	**66.53**	**80.82**	**106.20**	
II	Summer	27	83.89	64.53	58.36	109.42	F=9.24 P<0.01
	Rainy	45	82.66	65.00	63.13	102.18	
	Winter	36	139.64	63.66	118.10	161.18	
	Total	**108**	**101.96**	**69.22**	**88.75**	**115.16**	

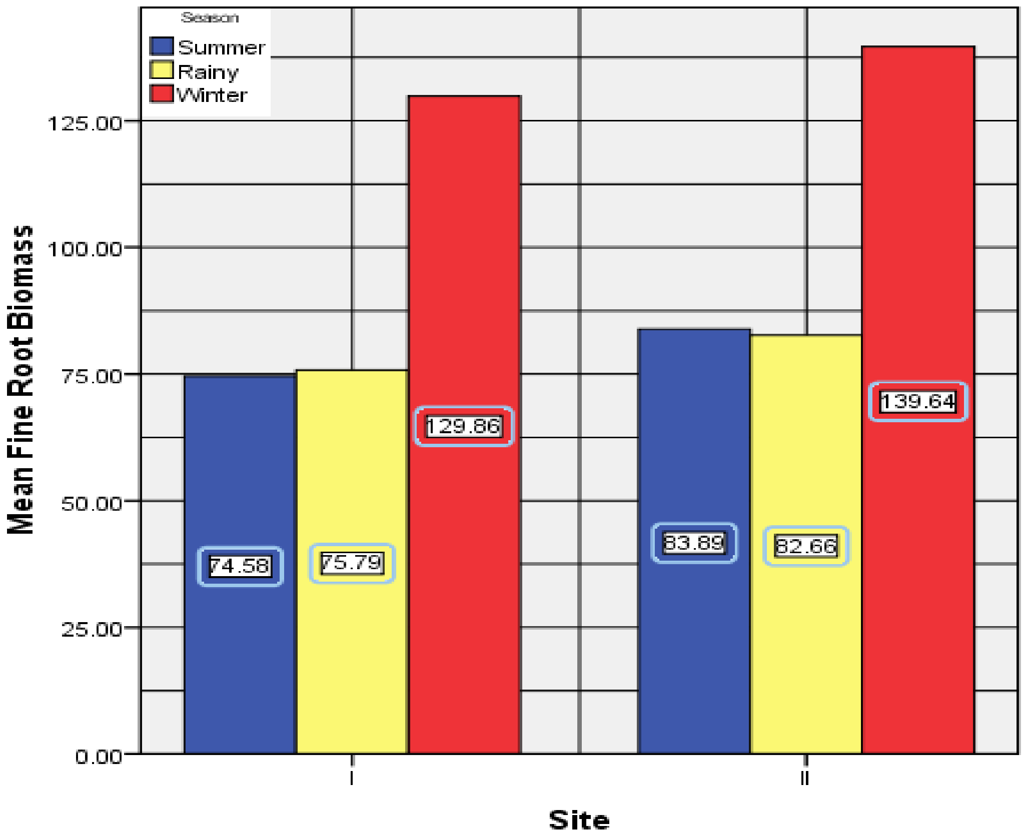
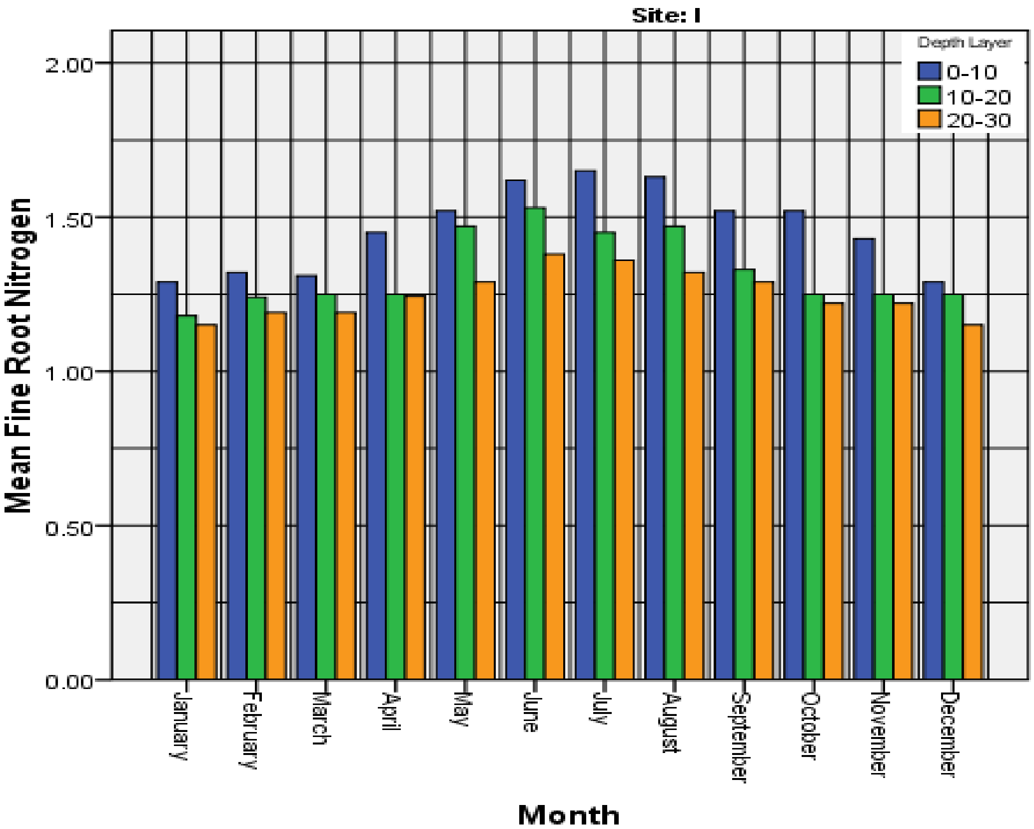


Figure – 3: Seasonal variation in fine root biomass at Site-I and Site-II

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804



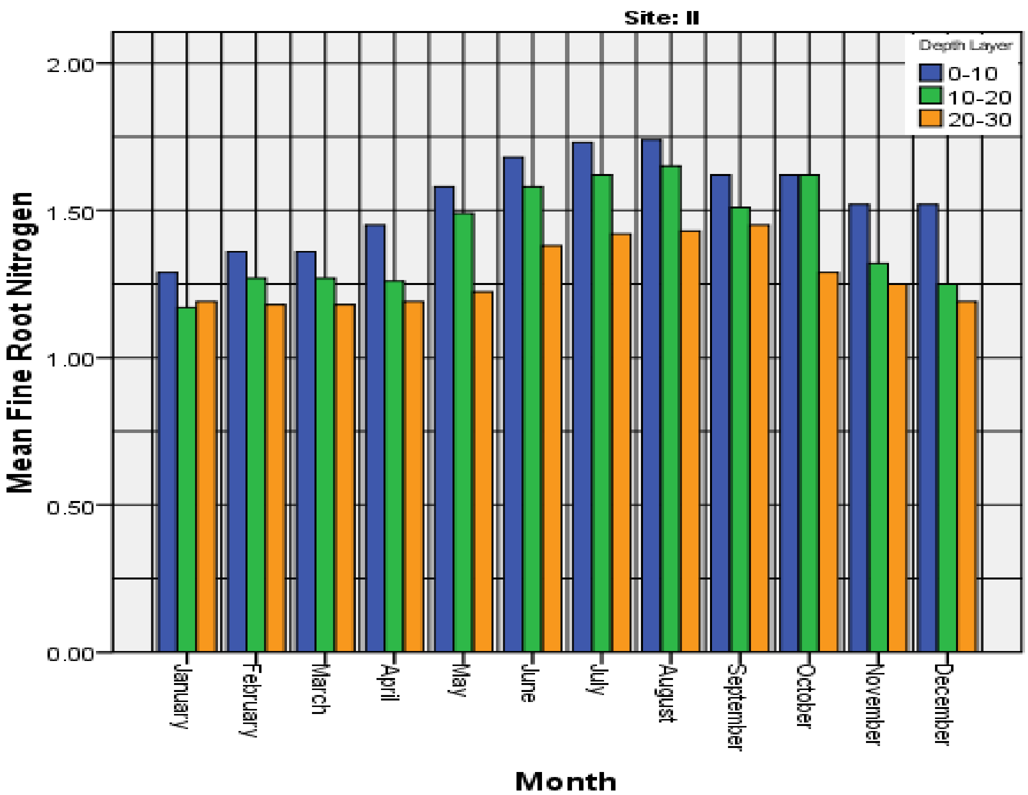


Figure – 4: Monthly variation in fine root Nitrogen concentration (%) at different soil depth

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table - 5

Variation in fine root nitrogen concentration (%) at different soil depth

Site	Season	Depth layer	Mean	S. D	N
I	Summer	0-10	1.43	0.09	9
		10-20	1.32	0.11	9
		20-30	1.24	0.06	9
		Total	1.33	0.12	27
	Rainy	0-10	1.59	0.06	15
		10-20	1.41	0.11	15
		20-30	1.31	0.06	15
		Total	1.44	0.14	45
	Winter	0-10	1.33	0.06	12
		10-20	1.23	0.03	12
		20-30	1.18	0.04	12
		Total	1.25	0.08	36
	Total	0-10	1.46	0.13	36
		10-20	1.33	0.12	36
		20-30	1.25	0.08	36
		Total	1.35	0.14	108
II	Summer	0-10	1.46	0.10	9
		10-20	1.34	0.11	9
		20-30	1.20	0.04	9
		Total	1.33	0.14	27
	Rainy	0-10	1.68	0.06	15
		10-20	1.60	0.05	15
		20-30	1.39	0.06	15
		Total	1.56	0.13	45
	Winter	0-10	1.42	0.11	12
		10-20	1.25	0.06	12
		20-30	1.20	0.03	12
		Total	1.29	0.12	36
	Total	0-10	1.54	0.15	36
		10-20	1.42	0.17	36
		20-30	1.28	0.11	36
		Total	1.41	0.18	108

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table - 6

Analysis of Variance of fine root nitrogen (%)

Site	Source	d. f	F-value	P-value
I	Season	2	67.79	<0.01
	Depth	2	69.05	<0.01
	Season * Depth	4	2.62	<0.05
	Error	99		
II	Season	2	157.64	<0.01
	Depth	2	110.87	<0.01
	Season * Depth	4	3.81	<0.01
	Error	99		

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

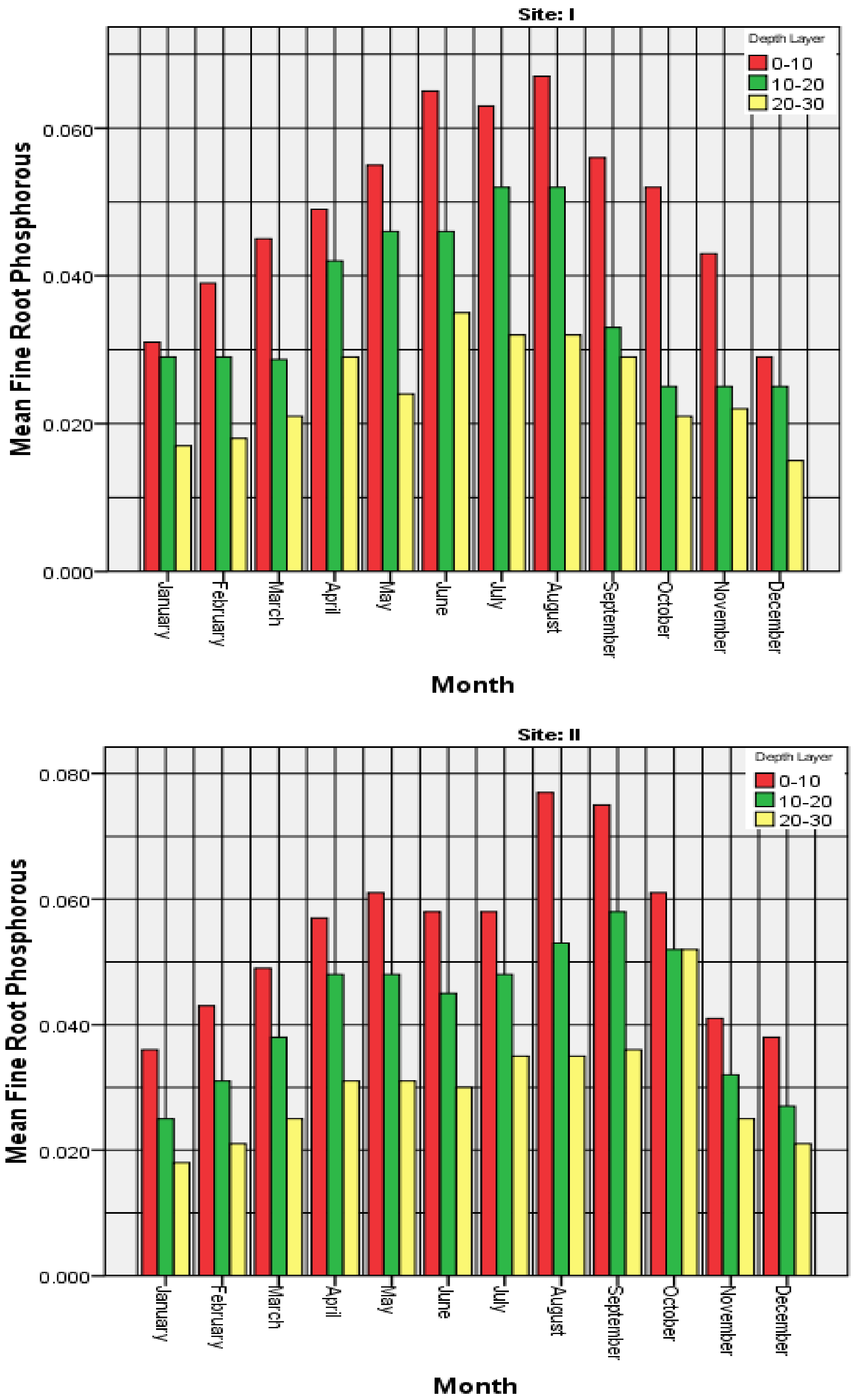


Figure - 5: Monthly variation in fine root Phosphorus concentration (%) at different soil depth

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table - 7

Variation in Phosphorus concentration (%) in fine root at different soil depth

Site	Season	Depth layer	Mean	S. D	N
I	Summer	0-10	0.050	0.005	9
		10-20	0.039	0.009	9
		20-30	0.025	0.004	9
		Total	0.038	0.012	27
	Rainy	0-10	0.655	0.748	15
		10-20	0.546	0.629	15
		20-30	0.720	0.587	15
		Total	0.640	0.647	45
	Winter	0-10	0.698	0.694	12
		10-20	0.640	0.638	12
		20-30	0.601	0.610	12
		Total	0.646	0.631	36
	Total	0-10	0.518	0.671	36
		10-20	0.450	0.588	36
		20-30	0.507	0.580	36
		Total	0.492	0.610	108
II	Summer	0-10	0.056	0.006	9
		10-20	0.045	0.005	9
		20-30	0.029	0.003	9
		Total	0.043	0.012	27
	Rainy	0-10	0.066	0.009	15
		10-20	0.051	0.005	15
		20-30	0.038	0.008	15
		Total	0.052	0.014	45
	Winter	0-10	0.040	0.003	12
		10-20	0.029	0.003	12
		20-30	0.021	0.003	12
		Total	0.030	0.008	36
	Total	0-10	0.055	0.013	36
		10-20	0.042	0.011	36
		20-30	0.030	0.009	36
		Total	0.042	0.015	108

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table - 8

Analysis of Variance of fine root phosphorous (%)

Site	Source	d. f	F-value	P-value
I	Season	2	11.45	<0.01
	Depth	2	.098	>0.05
	Season * Depth	4	.152	>0.05
	Error	99		
II	Season	2	143.99	<0.01
	Depth	2	156.02	<0.01
	Season * Depth	4	3.15	<0.05
	Error	99		

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

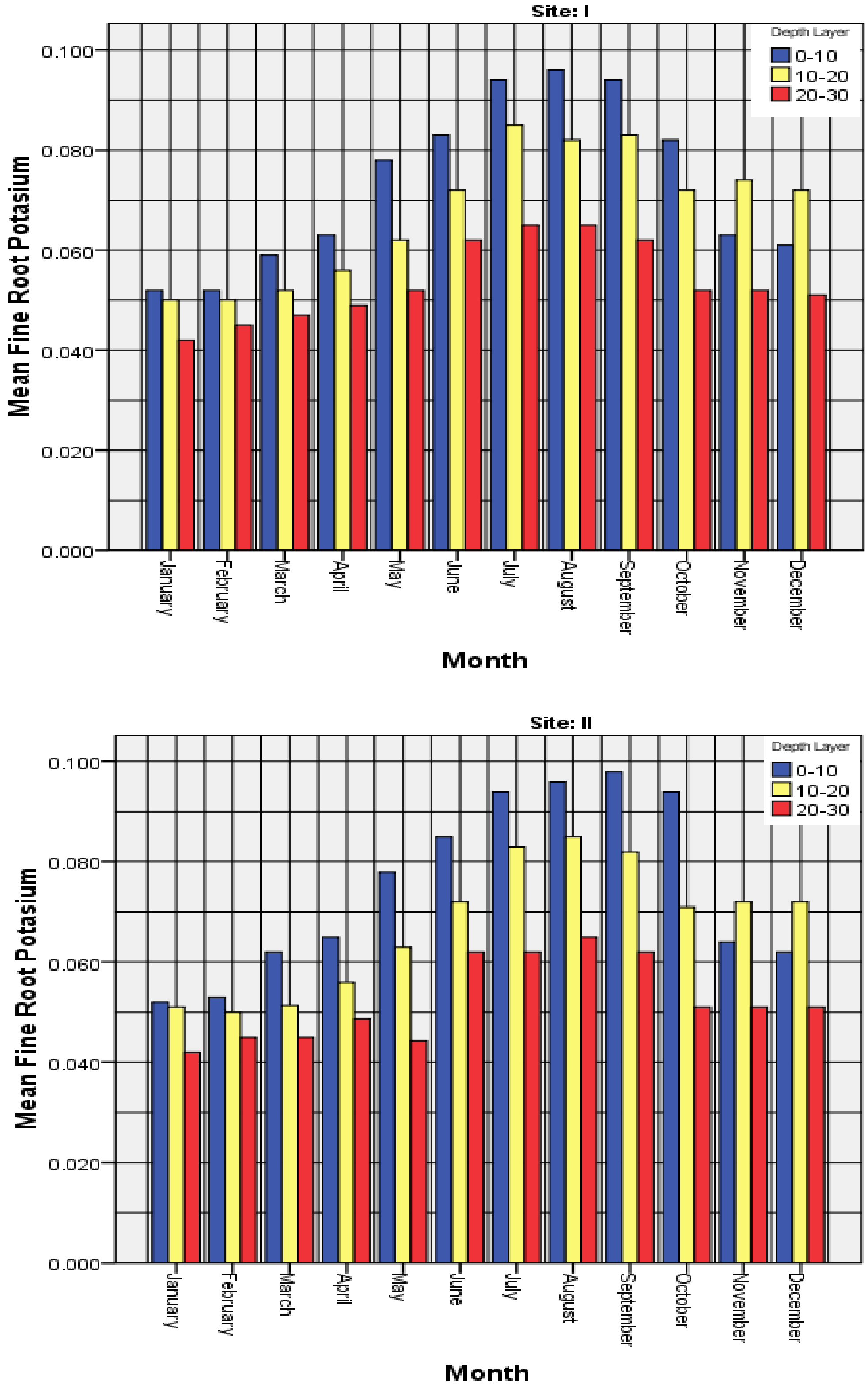


Figure - 6: Monthly variation in fine root Potasium concentration (%) at different soil depth

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table - 9

Variation of Potasium concentration (%) in fine root at different soil depth

Site	Season	Depth layer	Mean	S. D	N
I	Summer	0-10	0.067	0.009	9
		10-20	0.057	0.005	9
		20-30	0.049	0.003	9
		Total	0.058	0.009	27
	Rainy	0-10	0.090	0.006	15
		10-20	0.079	0.006	15
		20-30	0.061	0.005	15
		Total	0.077	0.013	45
	Winter	0-10	0.057	0.006	12
		10-20	0.062	0.012	12
		20-30	0.048	0.005	12
		Total	0.055	0.010	36
	Total	0-10	0.073	0.016	36
		10-20	0.068	0.013	36
		20-30	0.054	0.008	36
		Total	0.065	0.015	108
II	Summer	0-10	0.068	0.008	9
		10-20	0.057	0.005	9
		20-30	0.046	0.003	9
		Total	0.057	0.011	27
	Rainy	0-10	0.093	0.005	15
		10-20	0.079	0.006	15
		20-30	0.060	0.005	15
		Total	0.077	0.015	45
	Winter	0-10	0.058	0.006	12
		10-20	0.061	0.011	12
		20-30	0.047	0.004	12
		Total	0.055	0.010	36
	Total	0-10	0.075	0.017	36
		10-20	0.067	0.013	36
		20-30	0.052	0.008	36
		Total	0.065	0.016	108

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

Table 10

Analysis of Variance of fine root potassium (%)

Site	Source	d. f	F-value	P-value
I	Season	2	118.70	<0.01
	Depth	2	67.52	<0.01
	Season * Depth	4	8.91	<0.01
	Error	99		
II	Season	2	146.34	<0.01
	Depth	2	104.26	<0.01
	Season * Depth	4	12.38	<0.01
	Error	99		

11: Fine root biomass in various forests of the world

Sl.No	Forest type	Location	Diameter (mm)	Forest root biomass gm^{-2}	Authors
1	Hardwood forest	USA	<2mm	471	Fahey and Hughes, 1994
2	Scot pine forest	Sweden	<2mm	145-656	Pearson et al, 1995
3	Tropical forest	India	<2mm	309	Sundarapandian et al, 1966
4	Cove hardwood forest	Coweeta	<2mm	468	Davis, 1997
5	Low elevation mixed oak	Coweeta	<2mm	793	Davis, 1977
6	High elevation mixed oak forest	Coweeta	<2mm	765	Davis,1997

http://dx.doi.org/10.29322/IJSRP.10.12.2020.p10804

7	Nothern hardwood forest	Coweeta	<2mm	657	Davis, 1997
8	Scot pine forest	Finland	<2mm	220-408	K.Mokkonin, 2001
9	Pine forest	Manipur, India	<2mm	132-236	Uma et al, 2002
10	Oak forest	Manipur India	<2mm	115-225	Uma et al, 2002
11	Pine forest	Norway	<2mm	250	Muukkonaen et al, 2006
12	Moist tropical forest	Florida	<2mm	433	OJ Valver de Barrentes et al, 2007
Sl.No	Forest type	Location	Diameter (mm)	Forest root biomass gm^{-2}	Authors
13	Lowland forest	Florida	<2mm	433	Oscar et al, 2014
14	Deciduous temperate forest	USA	<2mm	357.96	Oscar et al, 2015
15	Picca abies forest	China	<2mm	278-366	Z.Y.Yuan 2017,2018
16	Sub tropical forest i. Forest site I ii. Forest siteII	 Manipur, India Manipur, India	 <2mm <2mm	 31.89-169.82 36.92-180.88	 Present study Present Study