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Waghaye Pawan Ashok
Research Scholar, Department of Agroforestry, Forest College and Research Institute, Mettupalyam, Tamil Nadu, India

R Jude Sudhagar
Associate Professor Forestry, Department of Agroforestry, Forest College and Research Institute, Mettupalyam, Tamil Nadu, India

I Sekar
Professor (Forestry), O/o. The Controller of Examinations, TNAU, Coimbatore, Tamil Nadu, India

S Umesh Kanna
Forestry, Directorate of Planning and Monitoring, TNAU, Coimbatore, Tamil Nadu, India

Corresponding Author:
R Jude Sudhagar
Associate Professor Forestry, Department of Agroforestry, Forest College and Research Institute, Mettupalyam, Tamil Nadu, India

Root distribution pattern studies to assess the foraging zone in *Melia dubia* Cav.

Waghaye Pawan Ashok, R Jude Sudhagar, I Sekar and S Umesh Kanna

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Abstract
Melia dubia is one of the important tree species in agroforestry models across India owing to its multifarious utilities, compatibility with various agricultural, horticultural and forage crops. Inspite of its pan India prevalence, research data pertaining to the spatial distribution of its root system is scarce which is primarily responsible for determination of the capacity to absorb water and nutrients preferentially over other allied crops. Belowground competitions are the major constraints to successful intercropping in woody/agroforestry ecosystems and thus spatial distribution of tree roots assumes paramount importance. The root distribution pattern of selected trees in a twelve-year-old Malabar neem (*Melia dubia* Cav.) plantation grown at 4 m x 4 m spacing was studied using the logarithmic spiral trench technique to assess the level of competitive/complementary impacts of the root system. Root intensity decreased steadily as the root diameter classes increased with function to soil depth as well as lateral distance. It was observed that 65.07 % of the total roots observed on the profile wall of the trench were fine roots (size class <2.5 mm) followed by medium sized roots (24.70%; size class >2.5 to<5.00 mm) and the lowest values were recorded for the coarse roots (10.22%; size class>5.0 mm). Major share of the fine roots occupied near to the base of tree and 60.14% of fine roots were found to be accumulated in upper 20 cm layer of soil. In terms of lateral distance, maximum number of fine roots were recorded near the tree at 0.26 m with root intensity 431.1 m^{-2}, and 65.85% of fine roots were found to be concentrated within 80 cm lateral distance from the tree.

Keywords: Logarithmic spiral trenching, root distribution and root intensity

Introduction
Melia dubia, commonly known to as Malabar Neem, is a multipurpose tree with a strong potential that is ideal for agroforestry and farm forestry to increase yields per unit of land. *Melia dubia* is naturally found in tropical wet deciduous forests between 1500 and 1800 metres above mean sea level in the Sikkim Himalayas, North Bengal, upper Assam, parts of Odisha, and the Western Ghats (Gamble, 1992) [5]. *Melia dubia* is one of fast growing tree sometimes regarded as a short rotation money-making tree due to its high demand in the pulpwood, plywood, and lumber sectors. It is an efficient producer of both fuel and fodder. *Melia dubia* also has a wide range of medical, pharmacological, traditional, ethnomedical, and other qualities and applications. (Goswami *et al.*, 2020) [6]. *Melia dubia* is now being pushed as a source of industrial plywood and pulpwood through contract farming as well as different agroforestry methods, as pulpwood and plywood species, in response to the rising demand for both materials (Parthiban *et al.*, 2009) [11].

There is an inherent conflict in agroforestry between the anticipated beneficial impacts of tree root systems, such as soil fertility and nutrient cycling, and competition between tree and crop roots (Schroth, 1998) [13]. A fundamental tenet of agroforestry is the complementary use of soil resources. A fundamental knowledge of belowground interactions is necessary since many agroforestry systems' production has been lower than expected as a result of net water competition (Fernándeze *et al.*, 2008). Different species exhibit different patterns of root activity around them. Understanding these patterns may help in deciding proper spacing and fertilizer distribution, additionally it is possible to prevent excessive competition and unnecessary nutrient losses in agroforestry systems. The majority of agroforestry systems depend heavily on the distribution and rooting pattern of the tree and crop to decide better acquisition of water and minerals with the least amount of loss. When resources are limited, identifying and sustaining differential zones of water and mineral absorption—which eventually serves to restrict interspecific competition—is a key function of both the superficial root system and the deep root system (Kumar *et al.*, 2018) [9].

Materials and Methods
Study Area
The research experiment was conducted in'J' block of Forest College and Research Institute, Mettupalayam, in Silvi-mediculture field trial (11º19'21" N latitude and 76º56'16" E longitude with an elevation of 313 m above MSL) during January-February 2022. In the study area, wet season is oppressive and overcast while the dry season is humid and partly cloudy. Over the course of the year, temperature typically varies from 20°C to 36°C and is rarely below 17°C or above 38°C.The rainy period of the year lasts for approximately nine months, from March to December with an average of 30 -45 rainy days. The month of October is generally observed to be with the maximum rain with an average rainfall of 120 mm.The rainless period of the year lasts for fourmonths from December to March. The month with the least rain is January with an average rainfall of 5 mm. *Melia dubia* was planted in the experimental area in December2009. Ramets raised through mini clonal technology wereused for establishing the plantation. The trees were planted at the standard recommended spacing (4 x 4 m). Three trees were randomly selected for the present study and root distribution pattern studies were conducted.

Root distribution pattern studies using logarithmic spiral trench method
Three trees were randomly selected for this investigation,. Table 1 contains information on the biometric properties of the selected trees. Each selected tree's root system was partially dug up using the logarithmic spiral trenching method (Huguet, 1973; Tomlinson *et al.*, 1998; Ramanan and Kunhamu, 2021) [7, 18, 12]. The crown radius of the selected tree was measured by projecting the crown edges to the ground. The dimensions of the trench were calculated using the formulas below, and the tree was partially excavated to observe soil the profile wall and perform root studies.

$x = 1.5\,(d)$

$y = [1\text{n}\,(\frac{r}{d})]/\pi$

$z = xe^{y\Theta}$

Where
d = tree diameter in m
r = average of the crown radius at four cardinal points in m
x = distance of the starting point of the spiral from the tree in m
y = natural logarithm of the ratio of crown radius to the diameter of the tree divided by π
z = distance of any point on the spiral from the tree base in m and
$\Theta = 0^0, 22.5^0, 45^0, 67.5^0, 90^0, 112.5^0, 135^0, 157.5^0$ and 180^0.

The trajectory of the trench was laid down on the field using marking powder by calculating the distance 'x' on the north side from the tree, which was the origin and further extension was done in the spiral clockwise direction thus sampling a 180° sector of the root system. The nine coordinates of the inner trench—OA, OB, OC, OD, OE, OF, OG, OH, and OI—as shown in fig. 1—were obtained by assigning θ as 0°, 22.5° (π/8), 45° (π/4), 67.5° (3π/8), 90° (π/2), 112.5° (5π/8), 135° (3π/4), and 157.5° (π). The coordinates for the external side of the trench were set to give OA′, OB′, OC′, OD′, OE′, OF′, OG′, OH′, and OI′ by expanding the coordinates for the internal side by 60 cm.

Table 1: Biometric parameters of selected *Melia dubia* trees

DBH at 1.37m (cm)	Height (m)	Average crown radius at four cardinal points (m)
17.83	9.38	1.88
16.40	8.96	1.63
16.76	9.02	1.73

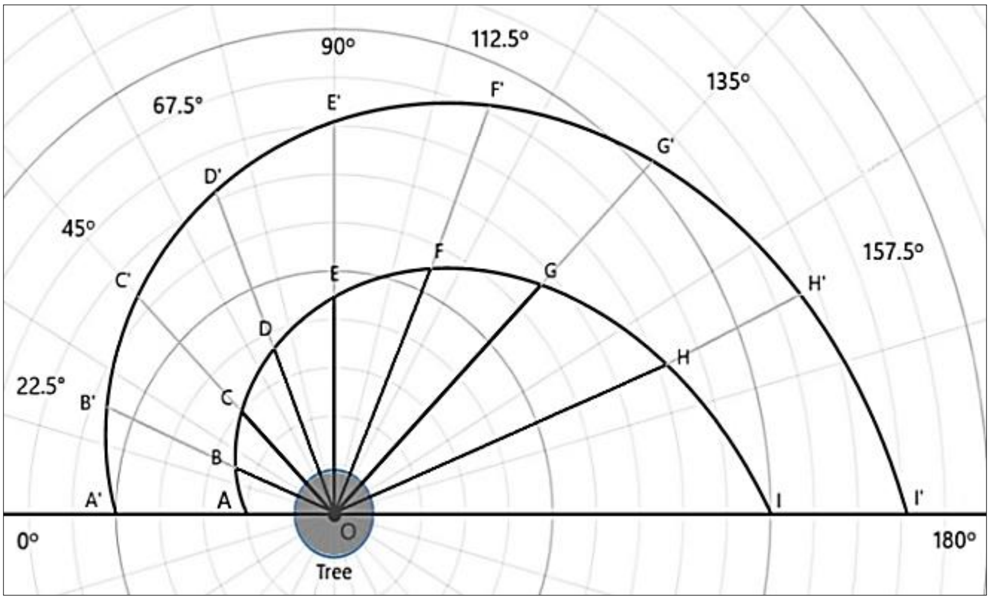

Fig 1: Diagram showing co-ordinates of the logarithmic spiral trench where O-origin of the spiral at a north-facing point on *Melia dubia* OA, OB, OC, OD, OE, OF, OG, OH and OI are co-ordinates of the internal spiral at θ = 0°, 22.5°, 45°, 67.5°, 90°, 112.5°,135°,157.5° and 180°.

The trench was manually excavated to a depth of 60 cm and a width of 60 cm, with special attention paid to keeping the trench's sides intact. To count the number of cut roots exposed on both sides of the trench's interior and exterior walls, a 50x50 cm quadrat was put against the walls' vertical sides. In accordance with the angle of the trench from the tree, the quadrats were positioned along the spiral trench at predetermined lateral distances up to the end of the trench. The roots of *Melia dubia* were distinguishable from other herbaceous roots by their distinctive purple-brown colouring. Based on diameter, the roots were categorised into three sizes: 2 mm, 2–5 mm, and >5 mm. The number of roots in each size class was counted in 10 cm soil layers to a maximum depth of 50 cm from the soil surface. Root counts were converted into root intensity (number of roots m^{-2}) (Bohm, 1979).

Result and Discussion

A) Vertical distribution of roots

Vertical root distribution of various root diameter classes for *Melia dubia*is presentedin Table 2. There was a gradual reduction in the mean root intensity with increasing soil depth for fine roots (<2.5 mm). Mean root intensity at 0-10 cm depth for fine roots was observed as 373.33 roots m^{-2} with a gradual reduction over increasing depth. Minimum root intensity was found to be 90.40 m^{-2} at 40-50 cm of soil depth. Findings of the study are in consonance with the findings of Kumar *et al.* (2018) [9] who reported that the mean root intensity decreased with increasing soil depth and the value ranged between 886.67roots m^{-2}at 50-60 cmto 1666.67 at 0-10 cm in *Swietenia macrophylla*. For medium sized roots (2.5 to 5.0 mm), the trend of rootintensity was similar as fine roots. Maximum medium root intensity was observed at 0-10 cm depth with 129.61roots m^{-2} with a decreasing trend in the lower depths of the profile trench. Inconsistency was observed in root intensity as a function of soil depth in coarse roots (>5.0 mm). Considering coarse root distribution with respect to increasing soil depth, maximum number of roots were recorded in 30-40 cm depth with root intensity of 51.71 roots m^{-2}.

Root intensity for coarse roots was less in upper layer of soil as compared to lower layer of the excavated trenches. Similar were reported by Swamy *et al.* (2003) [16] in *Gmelina arborea* where the authors observed most of the coarse roots to be distributed in the top 40 cm of soil whereas fine roots were concentrated in the top20 cm. Among all root diameters taken into consideration, maximum root intensity was observed for fine roots (1071.40 m^{-2}) followed by medium roots (406.76 m^{-2}) and lastly coarse roots (168.33 m^{-2}). In this present study, 65.07% of the total roots observed on the profile wall of trench were fine roots in *Melia dubia***.** There was a gradual decrease in total root intensity with increasing depth. 32.28% of total roots were found in upper 10 cm layer of soil. Minimum total root intensity was found in 40-50 cm soil layer which was only 10.10% of total root intensity. Divakara *et al.* (2001) [3] observed similar results in *Bambusa arundinacea* where in it was reported that nearly 30% of total roots of were found in 10-20 cm layer.

Table 2: Root intensity of *Melia dubia*as a function of soil depth

Root intensity as a function of soil depth				
Soil Depth (cm)	Root intensity (number m^{-2}) in different root diameter classes (mm)			Total
	<2.5	2.5 to 5.0	>5.0	
0-10	373.33	129.61	28.60	531.54
10-20	257.38	86.93	31.86	376.18
20-30	201.75	74.56	32.03	308.34
30-40	148.54	63.81	51.71	264.06
40-50	90.40	51.84	24.12	166.37
Total	1071.40	406.76	168.33	1646.48

B) Lateral Distribution of root

Changes in root intensity of *Melia dubia* for various root diameter classes (<2.5mm, 2.5-5.0 mm and >5.0 mm) as a function of lateral distance (0.26 m, 0.76 m, 1.20 m, 1.43 m, 1.82 m and 2.40 m) from the tree are presentedin Table 3. Total root intensity as function of lateral distance was found to be decreasing from 627.35 roots $m^{-2}$to 60.43 roots $m^{-2}$with increasing lateral distance. 38.10 % of total roots were found 0.26 m away from tree bole which was the starting point of the trench. For fine roots, root intensity ranged between 28.10 m^{-2}(2.40 m) to 443.15 m^{-2} (0.26 m). Similar trend was found for medium roots (2.5 - 5.0mm) wherein the highest root intensity (119.99 m^{-2}) was found near the tree bole and minimum (24.27 m^{-2}) at the end of trench. For coarse roots (>5 mm), root intensity at 0.26 m was 64.21 m^{-2} which was maximum for current diameter class. Minimum root intensity recorded for coarse root was 8.06 m^{-2} at 2.40 m lateral distance from tree. This finding was supported by earlier work by Tomlinson *viz.* (1998) [18] where they found that mean root intensity was 350 m^{-2} at 1 m from the trunk reaching a minimum of 94 roots m^{-2} at 10 m from the trunk. Srinivasan *et al*. (2004) [15] reported the foraging zone for *Hevea brasiliensis* at 300 cm lateral distance from the base of tree and at 30 cm soil depth. Jamaludheen *et al.* (1997) [8] conducted similar studies in *Artocarpus hirsutus* where it was observed that maximum feeder root concentration was upto 2.25 m in the lateral distance from tree and at 30 cm soil depth. Thakur *et al.* (2015) [17] reported similar results for Silver oak wherein it was reported that 74-78% of roots were concentrated at 1.55 m lateral distance and within 30cm soil depth and it was concluded that the active foraging zone for Silver oak lies within 150cm lateral distance and at 30 cm depth.

Table 3: Root intensity as function of lateral distance from *Melia dubia*

Root intensity as function of lateral distance from the tree				
Lateral distance (m)	**Root intensity (numberm^{-2}) in different root diameter classes (mm)**			**Total**
	<2.5	**2.5 to 5.0**	**>5.0**	
0.26	443.15	119.99	64.21	627.35
0.46	267.52	78.79	44.50	390.80
0.80	145.95	74.18	35.57	255.70
1.39	123.21	56.34	7.97	187.53
1.82	63.48	53.18	8.02	124.68
2.40	28.10	24.27	8.06	60.43
Total	1071.40	406.76	168.33	1646.48

C) Fine root (<2.5 mm) distribution of *Melia dubia*

Root intensity pattern of fine roots as function of soil depth and lateral distance are shown in Fig 2. Root intensity for fine roots showed decreasing trend with increasing soil depth and lateral distance from tree. Root intensity for fine roots was observed maximum near the tree (0.26m) at 0-10 cm soil depth which was observed 129.7 roots m^{-2} while minimum root intensity was observed as zero at 2.4 m away from the tree base and at lower soil depth of the profile trench. 60.14% of fine roots were found to be accumulated in the upper 20 cm layer of soil. Considering the lateral distance, maximum quantity of fine roots were observed near the tree at 0.26 m with root intensity 431.1 m^{-2}and 65.85% of fine roots were found to be accumulated within 80 cm lateral distance from the tree. Minimum root count at 0-60 cm soil depth and distal distance (2.4 m) accounted forless than 3% of the total root intensity. From these results,it is concluded that the probable zone offoragingin 12-years-old *Melia dubia* would be under 1.0 m lateral distance from the tree base where almost 80% of the feeder roots are concentrated. In a similar study, Kunhamu *et al.* (2010) [10] reported 25 cmlateral distance as ideal fertilizer application zone for two-year-old *Acacia mangium*.

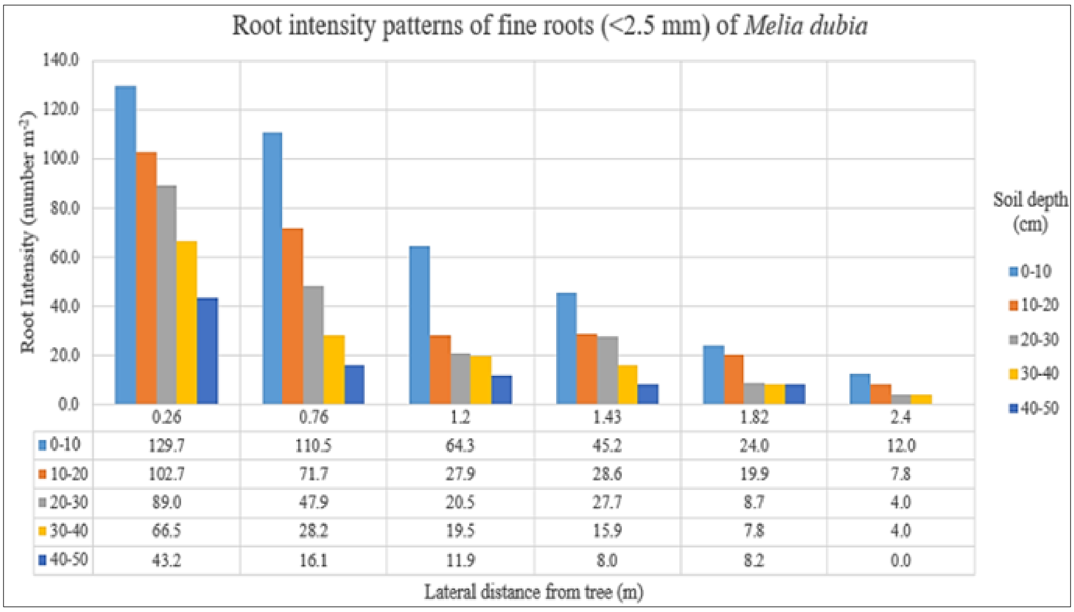

Fig 2: Root intensity pattern of fine roots of *Melia dubia*

Conclusion

Studies on the root distribution pattern of *Melia dubia* indicate that 65.07% of total roots observed on profile wall of trench were fine roots and major share of the fine roots were found to occupy near to the base of the tree and 60.14% of fine roots were found to be accumulated in the upper 20 cm layer of soil. In terms of lateral distance, maximum quantum of fine roots were recorded near the tree at 0.26 m with root intensity of 431.1 m^{-2} and 65.85 percent of fine roots were found to be concentrated within 80 cm from the tree base. Fine root count at 0-60 cm soil depth and at 2.4 m distal distance accounted for less than 3% of the overall root intensity. Based on these findings, the authors conclude that the likely foraging zone of 12-year-old *Melia dubia* is less than 1.0 m in the lateral distance from the tree base where almost 80% of the feeder roots are distributed.

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