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Comparison of Fine Root Biomass Stand of Three Tree Species (Eucalyptus Camaldulensis, Accacia Abyssinica and Cordia Africana) at Bahirdar University, Peda Campus

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Abstract
Even though fine roots consist of a small fraction (<5%) of the total biomass of a standing crop, fine root production represents a large proportion (30%–65%) of annual net primary production in forest ecosystems. Therefore, investigation into the fine root dynamics of different tree species could provide information on the role of each species in the nutrient cycle, carbon cycle, and carbon sequestration in their ecosystems. Furthermore, understanding fine-root biomass production and turnover enhances sustainable management practices in forest ecosystems. In this study, three tree species (*A. abyssinica, C. africana, and E. camaldulensis*) were selected to investigate the fine root biomass stand at the Peda Campus of Bahir Dar University. These three species were compared for their total fine root biomass. The depth-wise distribution of fine root biomass was investigated for these three tree species. *E. camaldulensis* showed significantly (P<0.05) the highest fine root biomass compared to *A. abyssinica and C. africana*. Fine root biomass observations for *A. abyssinica, C. Africana, and E. camaldulensis* were 281.5 ±20.5, 286.6±12.2, and 755.4±28.2, respectively, in g/m2 (mean±SE). 74% of fine root biomass for both of *A. abyssinica* and *E. camaldulensis* and 79% of fine root biomass for *C. africana* were concentrated at the upper soil profile to a depth of only 20 cm. The results suggest that *E. camaldulensis* is a much more important species in the carbon cycle, nutrient cycle, and carbon sequestration. The depth-wise reduction of fine root biomass in all three species indicates that soil moisture and organic matter are much more available at the upper soil profile and decrease when the depth increases. Nutrient content and other traits of the fine roots must be studied further so as to use the data for the management of forest ecosystems or plantations of the selected species.

Keywords: fine root; *acacia abyssinica; cordia african; eucalyptus camaldulensis*; depth class; fine root biomass

Introduction

The belowground part of a tree can be roughly seen as a mirror image of the aboveground system, with its specific morphology and function in the soil environment. The root system of a plant or a tree serves both mechanical and biological functions. A tree root system consists of course and fine branches (the coarse roots and the fine root). Fine, small and coarse roots are the major components of belowground biomass (Vogt, K.A. and Person 1991), and their vertical distribution defines the extent to which they modify soil physical and biological properties at depth. Coarse or woody roots provide support and anchorage, persist well through time and can absorb small amount of water and nutrient. On the other hand, those roots that are the most active in absorption of water, nutrient and mycorrhizal formation are the ephemeral fine roots (Brundrett, M., Murase, G. and Kendrick 1990). The fine roots are usually the high-order laterals that make up most of the surface area of the root system. A symbiotic association between non-woody fine root and mycorrhizal fungi forms the main nutrient-absorbing organ in most trees (Smith, S. E. and Read 1997). According to (Fogel 1990), fine root are small but functionally important fractions of tree biomass. Fine root (with diameter < 2 mm) represent a dynamic portion of belowground biomass, nutrient capital and a significant part of net primary production in native and managed ecosystems (Harris, W.F., Jr kinerson, R.S. and Edwards 1997).

Mostly tree roots are classified based on the diameter classes. Some authors specify fine root as a diameter class ranging from 0-1 mm (Pregitzer, K. S., DeForest, J. L., Burton, A. J., Allen, M. E, Ruess, R. W., and Hendrick 2002) while the majority are in favor of the widely accepted diameter class ≤ 2 mm (Hendrick, R.L. and Pregitzer 1993; Tufekcioglu, A., Raich, J.W., Isenhart, T.M. and Schultz 1994; Puttsepp 2004; Yang, Y.S., Guo, J.F., Chen, G.S., Xie, J.S., Cai, L.P. and Lin 2004). The rationale behind classifying fine root (≤ 2 mm) as one group is based on the idea that all roots in this diameter class are structurally and functionally identical (Kosola, K.R., Eissensat D.M. and Graham 1995). Most of the competitions among plants take place underground. Root competition can be more intense and involves many neighbors than shoot competition (Wilson 1998). In contrast to aboveground competitions that primarily involves a single resource, light; plants compete for a broad range of soil resources, including water in the belowground.

Forests play an important role in the global carbon cycle because 80% of the carbon stored in terrestrial vegetation is in forest biomass (Olson, J.S., Wattes, J.A. and Allison 1985). Forest soil contains around 70% of the total carbon globally (Post, W.M., Emanuel, W.R., Zinke, P.J. and Strangenberger 1992). Fine root constitutes the most dynamic portion of the belowground component and tend to show high turnover rate. For example, the annual loss of fine root in forest ecosystems estimated in the ranges from 40-72% of the standing crop (Fogel 1990). Even though fine root constitutes a small fraction (< 5%) of a total standing biomass (Gill, R.A. and Jackson 2000) their production represents a large proportion of total net primary production in most forest ecosystems (Nadelhoffer, K.J. and Raich 1992; Jackson, R.B., Money, H.A. and Schultz 1997). Based on 253 fine root biomass field studies in a wide range of ecosystems, (Fahey, T.J. and Hughes 1994) estimated that approximately 33% of global net primary production is used for fine root production. Fine root production has been found to be equivalent to, or greater than, aboveground litter fall in a number of forests, and may constitute more than half of the net primary production (Fenta Nigate, Camp, V.M, Alemu Yenehun, Ashebir Sewale, and Walraevens 2020). Hence, a good understanding of plant root dynamics and quantifying fine root production is crucial to the understanding of ecosystem structure and function. However, little is known about the dynamics of tropical forest fine root in general. More specifically, tree fine root study is in its infancy stage in Ethiopia. The present study originated in recognition of these deficiencies and aimed to investigate the difference in fine root biomass stand between the species and the depth wise distribution of fine roots among the three common tree species (*Acacia abyssinica*, *Cordia africana*, and *Eucalyptus camaldulensis*) at Bahir Dar University, Peda Campus.

Materials and Methods

Description of the Study area

The study was conducted at Bahir Dar University, Peda Campus (figure. 1). Bahir Dar University is located at Bahir Dar town, the capital of Amhara National Regional State. The university came into existence by merging two former higher educational institutions: Polytechnic Institute (1963) and Bahir Dar Teachers College (1972) in the year 2000. Currently, there are over 40,000 students attending their studies in various programs. The university has now 2481 academic staff of which 369 are females. The geographic coordinate of the study site is 11°34'21" north and 37°23'51" east. It is situated at about 1800 meters above the sea level (masl.) elevation. The geology is made up of volcanic rocks, mainly basalts. While most of the Tana basin is covered by tertiary volcanic rocks, in the study area, young, quaternary, and highly vesicular basalt prevails. The occurrence of the recent quaternary basalt in the Tana basin is restricted to a rather small part to the south of Lake Tana (Berhanu Abraha, Ali Seid 2006), where the study area is situated. The average annual temperature of the study area is 19.6°C while the minimum and maximum temperatures are 12.3°C and 26.8°C, respectively. The average precipitation of the study area is 118.3 mm with 2 mm of minimum rainfall at February and 428 mm of maximum rainfall registered at August (figure. 2). The vegetation of the study area consists of exogenous and indigenous tree and shrub species such as *Ficus spp*., *Cordia africana*, *Eucalyptus camldulensis*, *Jacaranda mimosofolia*, *Pinus radiata*, *Garavilla rubosta*, *Syzigium guinensis*, *Mangifera indica*, *Psidium Gujava*, *Lucenia leucocephala*, *Carissa edulis*, *Calpurina aurea*, *Citrus Spp*., *Terminalia mantaly*, *Coffea Arabica* and *Acacia Spp*. which protect the ecosystem from degradation and also are edible to animals (Jonsson, K., Fidjeland, L., Maghembe, J.A. and Hogberg 2019).

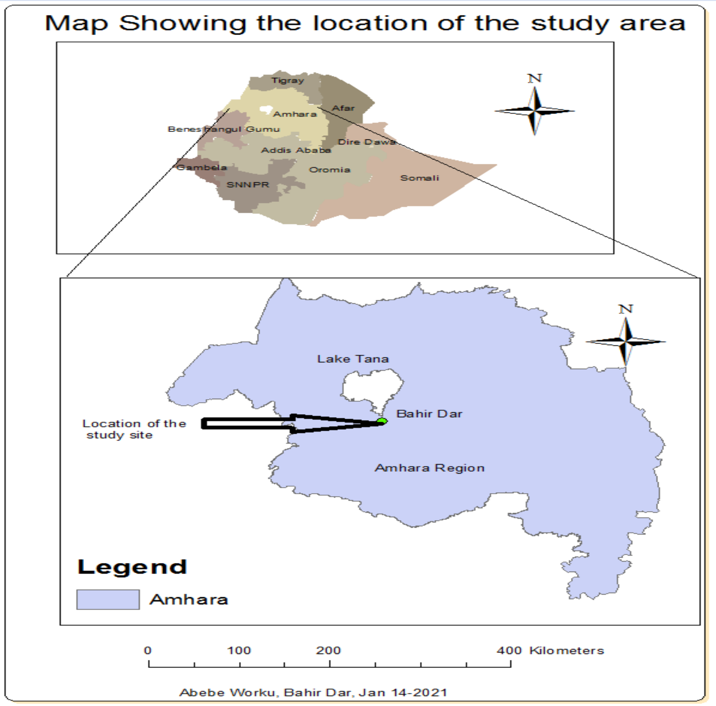

Figure 1: The location of the study area in relation to Ethiopia, Amhara regional state, Bahirdar town, and Lake Tana.

Study Species

Three tree species were selected for the present study. Two of them are indigenous and one exotic species. *Acacia abyssinica* and *Cordia africana* are indigenous while *Eucalyptus camldulensis* is the exotic one. *Acacia abyssinica* (Fabaceae) is known for its nitrogen fixing character and it is important species in agro forestry practice in Ethiopia. *Cordia africana* (Boraginaceae) is an endangered and protected by low species known for its high-quality timber and edible fruits. *Eucalyptus camaldulensis* (Myrtaceae) is one of the successful exogenous tree species especially in plantations near towns as it is highly needed for a lot of purposes like timber, construction, fire wood and so on. The fine roots of Acacia abyssinica are smooth in texture, nearly yellowish color, and produces prominent smell when crushed. Fine root of *Cordia africana* is smoothly textured, black in colour. *Eucalyptus camaldulensis* produce fine roots with rough texture, spiral coiling shape, black colour. Dead fine roots are recognized when floating over the soaking water during washing and easily breakable; cannot withstand little bending force.

Sample Collection, Processing, and Storage Method

After the sampling trees have been selected purposively by considering their health and ground condition two circles drawn by centering the stem, the first only 1 m far from the stem and the second 2m far from the stem. 5 core sampling spots were assigned along each of the circles giving 10 sampling spots per tree and 30 sampling spots for the three study species. Three depth classes (0-10 cm, 10-20 cm, 20-40 cm) were considered at each of the sampling spots. Therefore, 90 root core samples were collected, washed, dried and weighed. A conventional sequential soil scorer with 2 cm inner diameter and 25 cm length with a sharpened tip was driven into the ground to the desired sampling depth using a plastic hammer weighing 5 kg.

Processing soon followed sample collections. In case of delay, roots were stored in a refrigerator at about 4 ^{0}C to reduce respiration rate and delaying time of root death. Fine root was separated from the soil by soaking in water and then gently washing them over a series of sieves with a mesh size of 2.8, 2, 1 and 0.5 mm. All roots that were 2 mm or less in diameter were considered to represent fine root class in this study. Separation into live and dead fractions in the lab was done using a combination of visual and mechanical techniques based on the elasticity of their tissue and the color of the cortex. Live roots are usually pale-colored, elastic, and are free of decay whereas dead roots are black, broken easily, and in various stage of decay. The separated live and dead fine roots were oven dried at 70 ^{0}C to constant weight and dry weight was recorded. Results were calculated in dry mass per square meter basis. And the area was calculated as πr^2; where, r is the interior radius of the soil corer (1 cm).

Result and Discussion

Fine root biomass observation for *A. abyssinica, C. Africana, and E. camaldulensis* were; 281.5 ±20.5, 286.6±12.2, and 755.4±28.2, respectively in g/m^2. The range of fine root biomass readings of the three study species in the present study *281.5 - 755.4* g/m^2 was in between the global average (0.2 – 5Kg/m^2) (Jackson, R.B., Canadell, J., Ehleringer, J.R., Mooney, H.A., Sala, O.E., Schulze, E.D. 1996). *E. camaldulensis* showed significantly ($P<0.05$) greatest fine root biomass stand than the two indigenous tree species; *A. abyssinica* and C. *Africana* (Fig 2).

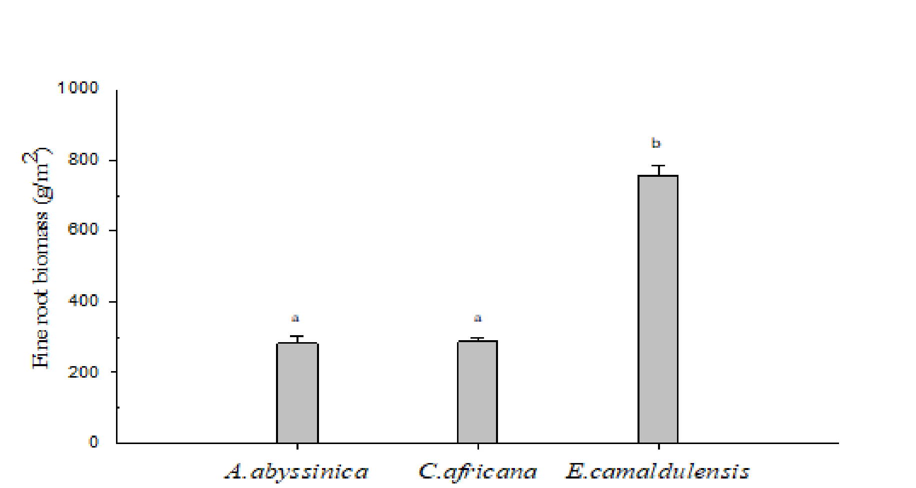

Figure 2: Comparison of fine root biomass of the study species; similar letters on the top of the bar indicate there is no significant difference while different letters on top of bars indicate significant difference.

The finding of the present study on the fine root biomass of *E. camaldulensis* (755.4±28.2 g/m^2) is almost similar to the report of (Pierret, A., Maeght, J.l., Clement, C., Montoroi, J.P., Hartmann, C. and Hamde 2016) on fine root biomass of *Eucalyptus tereticornis* from eastern Australia (678 ± 96.9 g/m^2). On the contrary, (Germon, A., Guerrini , A., Bordron 2018) reported only 646±101 kg/ha or 64.6±10 g/m^2 of fine root biomass for *E. camaldulensis* from Tanzania which is very small as compared to the result of the present study. The finding of the present study on the major portion of the fine root system found in the upper 20 cm was in agreement with global research findings. According to (Germon, A., Guerrini , A., Bordron 2018) who reviewed depth wise distribution of fine roots of several ecosystems concluded that 80-90% of roots were in the top 20 cm of soil in tundra, boreal forest, and temperate grasslands. The finding of the present study, 74 % of the fine roots of *A.abyssinica* and *E.camaldulensis* concentrated in the first 20 cm soil depth and 79 % of fine roots of C. *africana* were found from the same soil depth (fig 3), was in agreement with the global record from different corners of the world (Hueso O.R . Juan Pineiro, J., Power 2019). The result also in agreement with (Van Do 2020) in which 70 % of the fine roots of *Cupressus leustanica* found to be concentrated in the upper soil profile to a depth of 20 cm. Fine root investigation on *Eucalyptus tereticornis* and *Eucalyptus camaldulensis* by (Grier, C.C., Vogt, K.A., Keyyes, M.R. and Edmopnds, R.L. 1981) also showed that major portion of the fine root system was confined in the 0–0.3 m depth. Another study also reported the majority of fine roots were located within the upper soil horizons, and fine root biomass decreased with depth from Tanzania(De Anglelis, D.L., Gardner, R.H. and Shugar 1991). 78% of the fine roots of Acacia plantation in Vietenam were distributed in the 0–20 cm soil layer while less than 4.0% were distributed in the 50–80 cm (Zeleke Asaye and Solomon Zewdie 2013). This can be explained by the fact that fine-roots physiologically capture and transport water and nutrients to support the survival and growth of a tree (Zeleke Asaye and Solomon Zewdie 2013) and the surface layer of soil has the highest fertility and moisture content in the soil profile (Schulze, E. D., Mooney, H. A., Sala, O. E., Jobbagy, E., Buchmann, N., Bauer 1996).

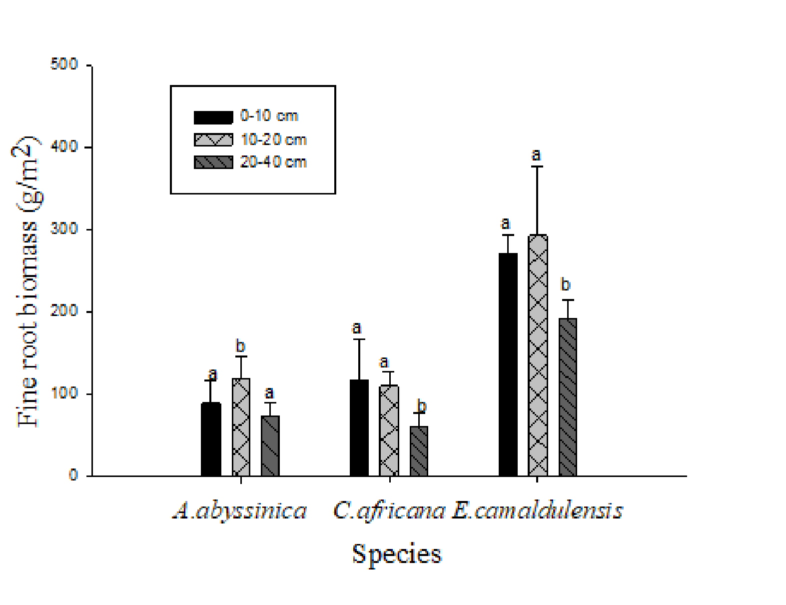

Figure 3: Depth wise distribution of fine root biomass for the three study species; different letters on the top of the bars for respective species indicate that there is significant difference while similar letter indicate there is no significant difference.

Conclusion and recommendations

Comparison on fine root biomass between species depicted that *E. camaldulensis* had significantly higher fine root biomass than the two indigenous species i.e., *A. abyssinica* and *C. africana*. Since fine roots are important in nutrient cycle, carbon cycle, carbon sequestration, water uptake and various ecophysiological activities of plants the result of the present study showed that *E. camaldulensis* is one of the most important tree species in nutrient cycle, carbon cycle, carbon sequestration, and water absorption functions. However, the root exudates and nutrient content of these species need to be investigated in the future so as to be clear which species is advantageous. By investigating the vertical distribution of fine roots, scientists are capable of recommending the time and space to apply fertilizer for plantation. In all of the three study species majority of fine roots were found to be concentrated in the upper 20 cm soil depth. This indicates application of fertilizer should not go beyond the 20 cm soil profile and further study is required to fully understand the seasonal variation of the fine roots of these study species.

Declarations

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Conflict of Interest

The authors declare that they do not have a conflict of interest

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