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Effect of high density *Eucalyptus camaldulensis* and *Melia azedarach* plantation on soil nutrients at different planting density

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Abstract
The field experiment was conducted during 2012-13 at Agroforestry Research Centre, Haldi, of G. B. Pant University of Agriculture and Technology, Pantnagar (U. S. Nagar), Uttarakhand to study the effect of different planting density of *Eucalyptus camaldulensis and Melia azedarach* on nutrient accumulation in soil. The experiment was laid out in split design with four subplots i.e., 3.0 m × 1.0 m, 3.0 m × 1.5 m, 3.0 m × 2.0 m and 3.0 m × 2.5 m of spacing replicated thrice. Maximum soil organic carbon content (1.73 and 1.79%) in *Eucalyptus* and *Melia*, respectively was recorded with greater planting density at 0-30cm depth, whereas, maximum NPK (356.6, 37.85 and 289.5 kg/ha, respectively) was obtained with wider spacing at the same depth. Annual litterfall affect the nutrient storage in soil which was found in the order: N>K>P. The nutrient shows the decreasing trend with increase in the depth of soil from 0-30 to 60-90cm.The nutrient (NPK) show significant relation with respect to planting density.

Keywords: Planting density, carbon content, soil nutrient, litterfall

1. Introduction

Agroforestry is an important component of the 'evergreen revolution' movement in the country (Puri and Nair, 2004) [21]. In the light of combating the challenges of hunger, diseases, climate change and environmental degradation agroforestry, or woody perennial based intercropping systems, has proved itself as a key component of sustainable agriculture (Garrity, 2004) [8]. According to Gibson (1978) [10], short rotation forestry has considerable advantages over conventional forestry, including higher yield per unit area of land, increasing nutrient efficacy and increased labour productivity.

Eucalyptus camaldulensis, the river red gum, is a tree of the genus Eucalyptus. It is one of around 800 species within the genus. It is a plantation species in many parts of the world, but is native to Australia, where it has the most widespread natural distribution of *Eucalyptus* in Australia, especially beside inland water courses (Colloff and Matthew 2014) [6]. *Eucalyptus* spp. is the tree that grows extremely fast in warm and humid climates. Because of their great environmental adaptability, excellent form and rapid growth, they are the most widely planted industrial exotic plants (Jairus *et al*., 2011) [14]. Another tree species, *Melia azedarach* is now becoming increasingly common under high density, short-rotation mixed plantations for site amelioration and may have the potential to increase crop yields, maintain soil fertility, also provides fuel wood and fodder.

According to Rigbelis and Nahas (2004) [22], the most important soil nutrient supply to the forest soil environment is the one derived from litter decomposition by actions of organism under conditions of high air temperature and soil moisture content. Soil being one of the most complex and heterogeneous environments, contains significant microbial diversity (Tiedje *et al*., 1999) [26]**.** Exotic plantation species have the characteristics of fast growth rate and thereby take up nutrient at a fast rate from the soil, leading to reduced soil fertility. It is worthwhile to determine the density and nutrient levels of different fast growing tree plantations that will maximize productivity. The macro-nutrients (N, P and K) are a major limiting factor in agriculture, as well as in forest production (Lodhiyal, Singh and Singh, 1994) [16]**.**

The majority of nutrients required for plant production are made available through the decomposition of litter and other plant remains (Waring and Schlessinger, 1985) [29]. The key to the survival of any forest ecosystem lies in its efficient nutrient cycling. Accumulation of organic matter, produced by litter fall and its decomposition, is an important factor in both soil formation and nutrient cycling processes (Van Wesemael, 1993) [27].

Highly effective mechanisms for recycling nutrients include dense and deep root systems that allow soil exploration, and an internal translocation of nutrients prior to leaf fall (Chandler, 1985) [4]. Therefore, the nutrient economy of short rotation plantations greatly influences its economic and energetic performance, and its acceptance in plantation forestry. It is reasonable to consider how the density and species of high density plantation affects the nutrient present in soil.
Previously, few investigations have been carried out on nutrient study in man-made plantations in the central Himalayas. From the point of sustainability, studies on aspects of nutrient use by species harvested in short cycles are important for the management of plantation forestry.

2. Material and Methods
The field experiment was carried or conducted during 2012-13 at Agroforestry Centre, Haldi of G. B. Pant University of Agriculture and Technology, Pantnagar (U. S. Nagar), Uttarakhand. The centre is located at 29^0 North latitude, $79^0 30'$ East longitude and at an altitude of 243.84 m above the mean sea level, which lies in the foothills of the Shivalik range of the Himalayas in the narrow strip called 'Tarai'. The soils are weakly developed with mollic epipedons and horizons and are classified as Mollisols. The soil of experiment plot was silty clay loam with soil pH 7.6, organic carbon content of 1.53%, available nitrogen of 256.6 kg/ha, available phosphorus of 32.32 kg/ha and available potassium of 176.5 kg/ha. The experiment was laid out in split plot design comprising six year old of two tree species as main plot and four spacing (*i.e.* tree densities) as sub-plot.
The experimental site was divided into three replications and soil samples were collected at 0-30cm, 30-60cm and 60-90cm depth of profile before harvesting of tree species. The soil samples were air-dried and ground with the help of wooden roller. Thereafter, each sample was passed through 2mm sieve and stored in labeled polythene bags for their analysis. The particle size analysis was made to find out the relative percentage of sand, silt and clay and was carried out by Bouycous hydrometer method (Bouycous, 1962) [3]. The pH was determined in 1:2.5 soil: water ratio and after half hour of equilibrium, the pH was determined with the help of glass electrode on microprocessor based pH meter (Jackson, 1967) [13].

Estimation of organic carbon percentage
Organic carbon was determined by the method given by Walkley and Black (1934) [28]. In this method soil samples were taken and excess of potassium dichromate was added in soil in presence of sulphuric acid which forms chromic acid and oxidize organic carbon in soil. The amount of organic carbon oxidized was the amount of carbon in soil.

$$\%\ \text{organic carbon} = \frac{(\text{B - S}) \times 0.003 \times 0.5 \times 100 \times 1.3}{1}$$

Where,
B = Volume of ferrous ammonium sulfate (FAS) in blank
S = Volume of FAS in sample
Normality of FAS = 0.5 Organic matter was converted to organic carbon using VAN BEMMELEAN factor (1.724).
Organic matter = Organic carbon x 1.724.

Estimation of available soil nitrogen
Available soil nitrogen in soil was determined by alkaline potassium permanganate method (Subbiah and Asija, 1956) [24]. Twenty-gram soil was taken in a distillation flask and 20 ml of water was added. Then 100 ml of 0.32% $KMnO_4$ and 100 ml of 2.5% NaOH solutions were added and the distillation flask was immediately fitted in to distillation apparatus. Then 25 ml of 4% boric acid containing mixed indicator, adjusted to pH 4.5, was taken in a conical flask and the delivery tube of distillation apparatus was dipped in it. Distilled ammonia gas from the distillation flask, collected in boric acid, was back titrated with 0.02 N standards H_2SO4. Amount of nitrogen in soil was determined by the micro-kjeldahl technique. Available nitrogen was calculated by using following formula:

Available nitrogen (kg/ha) = (S-B) x 31.36
Where,
S = Sample titration (ml standard acid)
B = Blank titration (ml standard acid)

Estimation of available soil phosphorus
Available phosphorus was extracted by sodium bi-carbonate extractant (0.5 M $NaHCO_3$) adjusted to pH 8.5 as per method of (Olsen *et al*., 1954) [18]. Soil sample was taken (2.5g) in 150 ml conical flask. Fifty ml of sodium bicarbonate and one pinch of carbon black (activated charcoal) were added to the soil and shaken well for 30 minutes on mechanical shaker. For colour development Ascorbic Acid Method was used.
Then the contents were filtered with Whatman No. 42 filter paper. Then 5 ml of filtered aliquot was taken in 25 ml volumetric flask. Add 5 ml of ammonium molybdate solution and then add p-nitrophenol for colouring and H_2SO_4 for decolourizing and dilute up to the mark. Blue colour appears measures the intensity of colour in absorption spectrophotometer.

Estimation of exchangeable soil potassium
Available potassium was determined by neutral ammonium acetate method adjusted to pH 7.0 outlined by Hanway and Heidel (1952) [12]. 5.0 gram of soil was taken in 150 ml conical flask. Then 25 ml of the neutral 1.0 N ammonium acetate solution was added and shaken for 5 minutes on mechanical shaker. Then contents were filtered through Whatman No. 1 filter paper. The concentration of K in the filtrate was measured by using flame photometer. The concentration of potassium was worked out with the help of standard curve.

Statistical Analysis
The data obtained during the course of investigation was analyzed using standard statistical procedure for split-plot design in which the two factorial was used. Significance of treatment means was tested by, "F-test" (Panse and Sukhatme, 1967) [19]. The critical difference at 5 percent level of significance was calculated and used to compare the two treatment means as per the design.

3. Results and Discussion
The results obtained are presented in appropriate tables and figures and discussed under suitable headings as follows:

Soil Nutrients
Organic carbon
The data regarding the soil organic carbon shows that with decrease in planting density, soil organic carbon also decreases with each increasing depth (Fig. 1). The soil organic carbon (SOC) percentage decreased with increase in

depth in both tree species i.e. *Eucalyptus* and *Melia*. Maximum (1.79%) SOC in *Melia* was recorded under 0-30cm depth with narrow spacing of 3.0m x 1.0m which was higher than *Eucalyptus* (1.63%). Similarly, the same pattern was followed under 30-60cm and 60-90cm depth.

Higher carbon content in 0-30cm depth and with 3.0m x 1.0m spacing may be attributed to more accumulation of leaf litter in upper soil layer which on decomposition releases CO_2 during mineralization of organic carbon and accumulate only resistant products *viz.*, humus in soil and this is the reason for the significant changes observed from 0-30 cm than in 30-60cm and 60-90cm soil depth. Similar findings were reported by Kumar (2006) [15] and Singh and Sharma (2007) [23]. The accumulation of more roots in upper layer of soil give access to moisture and nutrients available in top soil which is also evident from the present study, where more organic carbon was reported in 0-30cm soil layer. The results are further with findings of Dhyani *et al.* (1990) [7], Mohsin *et al.* (2000) [17] and Chaturvedi and Das (2002) [5].

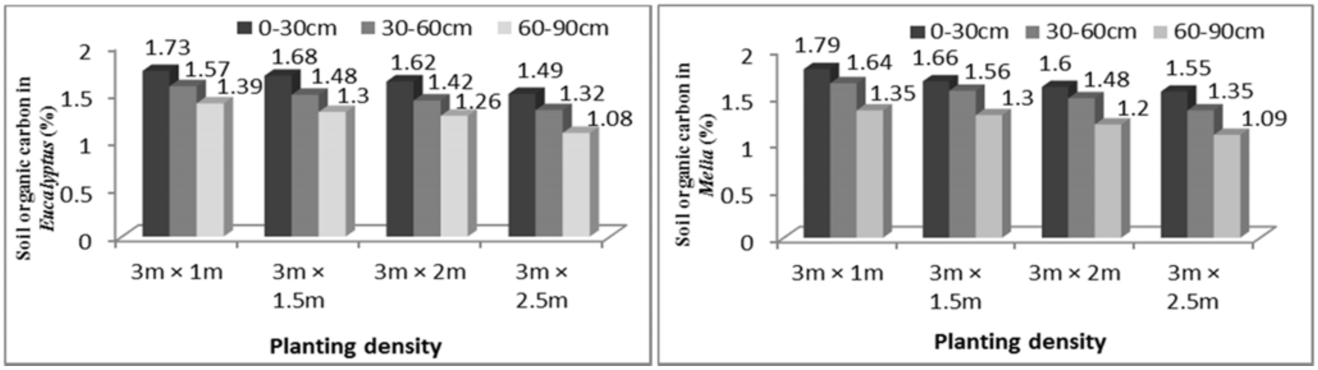

Fig 1: Effect of planting density of *E. camaldulensis* and *M. azedarach* on organic carbon content (%) at different soil depth

Available nitrogen, phosphorus and exchangeable potassium

The declining trend of NPK as shown in Table 1 was observed from lesser planting density (3.0m x 2.5m) to more density of plants (3.0m x 1.0m). Among the different depth, the maximum soil available N, P, K (kg/ha) was found to be greater in surface soil (0-30cm) layer due to more turn-over of organic residue on the surface soil whereas lowest was recorded in the lower most soil layer of 60-90cm depth. This result is supported by findings of Bhardwaj *et al.* (2001) [2] and Swami *et al.* (2008) [25]. The present study showed the significant decrease for soil available nutrient with the decrease in tree spacing. This may be due to more nutrient uptake per unit area since more roots exerted in the wider tree spacing in comparison to close spacing. These results are in conformity with the findings of Bhardwaj *et al.* (2001) [2]. The level of nutrients in a given soil is the net outcome of the inputs and outputs of the system. In general, a greater proportion of nutrients occurred in surface soil, reflecting the massive input of nutrients to the soil through litter fall. Interaction among both tree species did not show any significant differences.

Table 1: Soil N, P and K (kg/ha) at 0-30cm, 30-60cm and 60-90cm depth under tree species and spacing under high density plantation

Treatments	Soil N(kg/ha)			Soil P(kg/ha)			Soil K(kg/ha)		
	0-30cm	**30-60cm**	**60-90cm**	**0-30cm**	**30-60cm**	**60-90cm**	**0-30cm**	**30-60cm**	**60-90cm**
A. Tree species									
Eucalyptus	289.1	224.4	197.5	32.45	30.17	27.03	202.4	159.9	151.4
Melia	304.4	263.5	218.8	35.97	32.66	28.68	212.2	158.6	145.8
SEd±	31.71	53.59	59.83	0.23	0.77	0.66	29.69	17.47	15.63
CD (P=0.05)	NS	NS	NS	0.96	NS	NS	NS	NS	NS
B.Tree spacing									
3m × 1m	234.2	191.1	151.2	30.60	28.16	24.36	141.2	116.2	112.3
3m × 1.5m	271.5	216.7	178.6	32.98	30.08	26.55	176.0	141.1	128.8
3m × 2m	324.8	262.2	229.7	35.41	32.41	29.19	222.6	176.3	162.1
3m × 2.5m	356.6	305.8	273.0	37.85	35.02	31.33	289.5	203.4	191.2
SEd±	11.94	10.20	15.9	0.45	0.73	0.60	19.28	6.57	6.88
CD (P=0.05)	26.01	22.23	34.82	0.98	161	1.32	41.90	14.32	15.00
Interaction (A x B)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Nutrient return through litter fall

The order of relative abundance of these nutrients through litterfall in the present study was N > K > P (Table 2), which agrees with the finding of Peterson and Rolfe (1982) [20]. The mean concentrations of nutrient elements in litter fall were always less than the mean concentrations in live foliage, as reported by Abate (2004) [1]. This reflects the immobility of this particular element in foliage (Gordon *et al*., 2000) [11]. On the unit area basis, the nutrient return through litterfall in earlier studies (George *et al*., 1982) [9] indicated that the leaf litter contributed a major portion of total N, P and K. The same was reported in the present study for both *Eucalyptus* and *Melia* species. The flux of nutrients from recently fallen litter to the soil will depend on amount of litterfall and litter characteristics.

Table 2: Monthly nutrients return through litter in soil (kg/ha) as influenced by tree species and spacing under high density plantation

Months	*Eucalyptus*			*Melia*		
	N	P	K	N	P	K
January	1.03	0.08	0.30	8.81	1.78	6.41
February	2.41	0.18	0.71	1.88	0.38	1.37
March	5.58	0.42	1.64	0.69	0.14	0.50
April	6.10	0.46	1.79	1.19	0.24	0.87
May	1.49	0.11	0.44	1.70	0.34	1.24
June	1.56	0.12	0.46	2.42	0.49	1.76
July	1.49	0.11	0.44	3.19	0.64	2.32
August	1.30	0.10	0.38	3.25	0.66	2.36
September	1.51	0.11	0.44	2.78	0.56	2.02
October	1.42	0.11	0.42	1.99	0.40	1.45
November	1.97	0.15	0.58	3.33	0.67	2.41
December	1.25	0.10	0.37	7.14	1.44	5.19

4. Conclusion

The study revealed that there is significancy in achieving different nutrient (kg/ha) with respect to different planting density. Wider spacing was found superior to accumulate the maximum amount of NPK at minimum depth (0-30cm) because of amount of litterfall. Among both tree species, *Melia azedarach* was found more suitable for storing greater amount nutrients in soil as compare to *Eucalyptus camaldulensis* because of its deciduous nature.

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