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ORIGINAL ARTICLE

Comparative study of soil properties in three Fast-growing tree species under High-density Plantation

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ABSTRACT

A two-year old high-density plantation experiment was established in year 2021 and soil sample data was collected in 2022 and 2023 in three different depths viz., 0-15 cm, 15-30 cm and 30-60 cm at Padilla, Prayagraj, Uttar Pradesh. In this experiment three fast-growing tree species Poplar (Populus deltoides), Eucalyptus (Eucalyptus spp.) and Casuarina (Casuarina equisetifolia) were planted in different spacing viz., 1×1 m, 1.2×1.2 m and 1.5×1.5 m. The result indicated that soil pH, electrical conductivity (dsm^{-1}), organic carbon (%), available nitrogen, phosphorus and potassium (Kg ha^{-1}) were found higher at soil depth 0-15 cm as compared to 15-30 cm and 30-60 cm due to addition of organic carbon residue on the surface soil. Soil OC, available N, P and K in 0-15 cm, 15-30 cm as well as 30-60 cm profile was found statistically significant. It protestive showed an increase from initial value in all the treatments in 2022 and 2023. The result indicates soil properties was more increase in Casuarina (1×1 m) spacing in both the years.
Keywords: *High-density plantation, Soil properties, Poplar, Eucalyptus, Casuarina*

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INTRODUCTION

Trees in general provide a number of environmental benefits and play an important role in ecosystem services. Tree plantation is known to bring changes in edaphic, micro-climate, floral and other components of ecosystem recovery process through bio-recycling of mineral elements, micro-climate modification, changes in vegetation composition etc [1]. Including certain tree species in agricultural systems can improve soil physical and chemical qualities as well as optimise nutrient recycling. Studies have demonstrated that planting trees enhanced numerous physico-chemical characteristics of the soil [2].

These patterns may serve as a key predictor of stability or the likelihood of desertification in such areas [3-4]. Through N fixation, litter fall and subsequent decomposition, root decay, and decreased nutrient loss via wind erosion and leaching under plantation sites, trees on agricultural fields can enhance the physico-chemical characteristics of the soil [5, 6]. Through litter fall and recycling, significant amounts of nutrients are added to the soil under trees, improving the soils' nutrient reserves. Additionally, the impact of diverse tree plantations to improve nutrient status depends on a number of variables, including the composition of leaf litter, the behaviour of nutrients, the structure of soils, the buildup of organic matter, microbial activity, and the quantity of minerals that are rich in nutrients [7]. One of the most effective strategies to battle and control desertification is through the planting of tree species. Poplar (*Populus deltoides*), Eucalyptus (*Eucalyptus spp.*), and Casuarina (*Casuarina equisetifolia*) tree species may flourish on soils with little fertility, inadequate precipitation, and high soil temperatures. The purpose of the current study is to assess how various tree species affect the physicochemical characteristics of soils in arid environments.

MATERIAL AND METHODS

The high-density plantation experiment was established in July 2021 at Padilla, Prayagraj Uttar Pradesh. The GPS location of site (25.54° N) latitude, (81.89° E) longitude and at an altitude of 98 m above mean sea level. In this experiment three fast growing species *viz.,* Poplar (*Populus deltoides*), Eucalyptus

(*Eucalyptus spp.*) and Casuarina (*Casuarina equisetifolia*) were planted in different spacing *viz.,* 1×1 m, 1.2×1.2 m and 1.5×1.5 m. The experiment design adopted was Randomized Block Design (RBD) with nine treatments and three replications *viz.,* T_1: Poplar (1×1m), T_2: Eucalyptus (1×1m), T_3: Casuarina (1×1m), T_4: Poplar (1.2×1.2 m), T_5: Eucalyptus (1.2×1.2 m), T_6: Casuarina (1.2×1.2 m), T_7: Poplar (1.5×1.5 m), T_8: Eucalyptus (1.5×1.5 m) and T_9: Casuarina (1.5×1.5 m). In this experiment 135 trees of each species were planted in different spacing and replication. The soil sample was collected after end of first (June 2022) and second (June 2023). The soil sample was collected in depth of 0-15 cm, 15-30 cm and 30-60 cm. The sample was collected in each treatment and replication.

The experimental site was medium land with shallow to medium soil depth. On July, 2021 the experimental site was divided into different representative points to collect the soil samples from 0-15 cm, 15-30 cm and 30-60 cm profile depths. After air drying of samples stones were removed and the soil was passed through 2 mm sieve. A composite sample was created next, and 500 g of soil was chosen from this composite sample after being properly processed in accordance with standard procedure.

RESULT

The pH found after one (2022) and second year (2023) minimum in 0- 15 cm, in T_3: Casuarina (1×1m) 7.56 and 7.55 followed by T_1: Poplar (1×1m) 7.57 and 7.56 respectively. In depth of 15-30 cm first year (2022) and second year (2023) the minimum pH was found in T_3: Casuarina (1.5×1.5 m) 7.76 and 7.75 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 7.77 and 7.76 respectively. In depth of 30-60 cm minimum pH found in first year (2022) T_3: Casuarina (1×1m) 7.92 followed by T_1: Poplar (1×1m), T_4: Poplar (1.2×1.2 m), T_9: Casuarina (1.5×1.5 m) 7.93 whereas in second year (2023) the minimum pH was found in T_3: Casuarina (1×1m) 7.91 followed by T_1: Poplar (1×1m), T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m), T_6: Casuarina (1.2×1.2 m), T_9: Casuarina (1.5×1.5 m) 7.92 was shown in table 1. *Eucalyptus tereticornis* plantation sodic soil pH declined at Sultanpur district, Uttar Pradesh [8]. Eucalyptus five different species of soil pH, reduced after one year of harvesting in all species at Panjab [9]. *E. tereticornis* clonal soil pH levels up to 10.0 and high sodium adsorption ratio field plantations. In comparison to normal soil, tree volume fell by 20% in the pH range of 8.21-8.70 and 60% in pH levels more than 8.71 at Kurukshetra in Haryana [10].

Table 1: pH of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2023	2022	2023
T_1: Poplar (1×1m)	7.57	7.56	7.77	7.76	7.93	7.92
T_2: Eucalyptus (1×1m)	7.58	7.57	7.78	7.77	7.94	7.92
T_3: Casuarina (1×1m)	7.56	7.55	7.76	7.75	7.92	7.91
T_4: Poplar (1.2×1.2 m)	7.59	7.58	7.78	7.77	7.93	7.92
T_5: Eucalyptus (1.2×1.2 m)	7.59	7.58	7.79	7.78	7.95	7.94
T_6: Casuarina (1.2×1.2 m)	7.58	7.57	7.77	7.76	7.94	7.92
T_7: Poplar (1.5×1.5 m)	7.59	7.57	7.79	7.78	7.94	7.93
T_8: Eucalyptus (1.5×1.5 m)	7.59	7.58	7.80	7.79	7.95	7.94
T_9: Casuarina (1.5×1.5 m)	7.58	7.57	7.79	7.77	7.93	7.92
Sem ±	0.14	0.13	0.14	0.14	0.15	0.15
CD (p=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	3.17	3.08	3.21	3.17	3.35	3.23
Initial	7.60		7.80		7.95	

The EC found after one year (2022) in the minimum in 0-15 cm was found in T_3: Casuarina (1×1m) 0.116 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.117 whereas in second year (2023) the minimum was found in T_3: Casuarina (1×1m), T_1: Poplar (1×1m) and T_6: Casuarina (1.2×1.2 m) 0.115 followed by T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m) and T_9: Casuarina (1.5×1.5 m) 0.116 In depth of 15-30 cm first year (2022) minimum EC found in T_3: Casuarina (1×1m) and T_6: Casuarina (1.2×1.2 m) 0.129 followed by T_1: Poplar (1×1m) 0.130 whereas in second year (2023) the minimum EC was found T_3: Casuarina (1×1m) 0.127 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.128. In depth of 30-60 cm first year (2022) minimum EC was found in T_3: Casuarina (1×1m) 0.139 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.140 whereas in second year (2023) the minimum was found in T_3: Casuarina (1×1m) 0.137 followed by T_1: Poplar (1×1m) 0.138 shown in table 2. *E. tereticornis* plantation electrical conductivity (EC) declined at Sultanpur district, Uttar Pradesh [8]. Eucalyptus five different species of electric conductivity reduced after one year of harvesting in all species at Panjab [9]. Addition of organic residue on the surface soil, electrical conductivity (dsm^{-1}), higher at the soil's 0–15 cm depth than at 15–30 cm under Gamhar-based agroforestry system Ranchi, Jharkhand's [11].

Table 2: EC (dsm^{-1}) of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2023	2022	2023
T_1: Poplar (1×1m)	0.117	0.115	0.130	0.128	0.140	0.138
T_2: Eucalyptus (1×1m)	0.118	0.116	0.131	0.129	0.141	0.139
T_3: Casuarina (1×1m)	0.116	0.115	0.129	0.127	0.139	0.137
T_4: Poplar (1.2×1.2 m)	0.118	0.116	0.132	0.130	0.141	0.139
T_5: Eucalyptus (1.2×1.2 m)	0.119	0.117	0.133	0.130	0.142	0.140
T_6: Casuarina (1.2×1.2 m)	0.117	0.115	0.129	0.128	0.140	0.138
T_7: Poplar (1.5×1.5 m)	0.119	0.117	0.132	0.130	0.143	0.140
T_8: Eucalyptus (1.5×1.5 m)	0.120	0.118	0.133	0.131	0.144	0.141
T_9: Casuarina (1.5×1.5 m)	0.118	0.116	0.131	0.129	0.141	0.139
Sem ±	-	-	-	-	0.01	-
CD (p=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	5.06	4.71	5.84	5.90	6.35	5.74
Initial	0.121		0.134		0.146	

The OC found after first year (2022) in depth 0-15 cm the maximum was found in T_3: Casuarina (1×1m) 0.56 followed by T_1: Poplar (1×1m) 0.55, T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m), T_6: Casuarina (1.2×1.2 m) 0.54, T_5: Eucalyptus (1.2×1.2 m) 0.53 which was at par to each other whereas in second year (2023) maximum was found in T_3: Casuarina (1×1m) 0.58 followed by T_1: Poplar (1×1m) 0.57, T_2: Eucalyptus (1×1m), T_6: Casuarina (1.2×1.2 m), T_2: Eucalyptus (1×1m) 0.56 which was at par to each other. In depth of 15-30 cm the maximum OC was found first year (2022) in T_3: Casuarina (1×1m) 0.46 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.45, T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m) 0.44 which was at par to each other whereas in second year (2023) maximum found in T_3: Casuarina (1×1m) 0.48 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.47, T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m), T_9: Casuarina (1.5×1.5 m) 0.46 which was at par to each other. In depth of 30-60 cm the maximum OC was found first year (2022) in T_3: Casuarina (1×1m) 0.36 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.35, T_2: Eucalyptus (1×1m), T_4: Poplar (1.2×1.2 m), T_9: Casuarina (1.5×1.5 m) 0.34 which was at par to each other whereas in second year (2023) maximum was found in T_3: Casuarina (1×1m) 0.39 followed by T_1: Poplar (1×1m), T_6: Casuarina (1.2×1.2 m) 0.37 which was at par to each other are shown in table 3.

The soils under *Prosopis cineraria, Acacia senegal* and *Tecomella undulata* showed a significant increase in soil organic carbon 0.12 to 0.27% [12]. Eucalyptus five different species of soil organic carbon reduced after one year of harvesting in all species at Panjab [9]. Addition of organic residue on the surface soil, organic carbon (%) higher at the soil's 0–15 cm depth than at 15–30 cm under Gamhar-based agroforestry system Ranchi, Jharkhand's [11]. *Albizia lebbeck* (145%), *Acacia nilotica* (129%), and *E. tereticornis* (101%) showed an increase in soil OC stock in the surface soil [13].

Table 3: Organic Carbon (%) of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2022	2023	2022
T_1: Poplar (1×1m)	0.55^{ab}	0.57^{ab}	0.45^{ab}	0.47^{ab}	0.35^{abc}	0.37^{ab}
T_2: Eucalyptus (1×1m)	0.54^{ab}	0.56^{abc}	0.44^{abc}	0.46^{abc}	0.34^{abcd}	0.36^{bc}
T_3: Casuarina (1×1m)	0.56^{a}	0.58^{a}	0.46^{a}	0.48^{a}	0.36^{a}	0.39^{a}
T_4: Poplar (1.2×1.2 m)	0.54^{ab}	0.56^{abcd}	0.44^{abc}	0.46^{ab}	0.34^{abc}	0.36^{bc}
T_5: Eucalyptus (1.2×1.2 m)	0.53^{abc}	0.54^{bcd}	0.43^{bc}	0.45^{bc}	0.33^{bcd}	0.35^{bc}
T_6: Casuarina (1.2×1.2 m)	0.54^{ab}	0.56^{abcd}	0.45^{ab}	0.47^{ab}	0.35^{ab}	0.37^{ab}
T_7: Poplar (1.5×1.5 m)	0.52^{bc}	0.54^{cd}	0.43^{c}	0.45^{bc}	0.33^{cd}	0.35^{bc}
T_8: Eucalyptus (1.5×1.5 m)	0.51^{c}	0.53^{d}	0.42^{c}	0.44^{c}	0.32^{d}	0.34^{c}
T_9: Casuarina (1.5×1.5 m)	0.52^{bc}	0.54^{bcd}	0.43^{bc}	0.46^{ab}	0.34^{abcd}	0.36^{bc}
Sem ±	0.01	0.01	0.01	0.01	0.01	0.01
CD (p=0.05)	0.03	0.03	0.03	0.03	0.02	0.02
CV (%)	3.42	3.29	3.43	3.15	3.82	3.80
Initial	0.50		0.41		0.31	

Mean followed by the same letter are not significantly from each other at 5 % level

The nitrogen found after first year (2022) and second year (2023) in depth 0-15 cm the maximum was found in T_3: Casuarina (1×1m) 212.30 and 215.94 Kg ha^{-1} followed by T_1: Poplar (1×1m) 210.40 and 214.63 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 207.38 and 211.32 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 206.64 and 210.72 Kg ha^{-1} which was at par to each other, respectively. In depth of 15-30 cm the maximum nitrogen was found first year (2022) and second year (2023) in T_3: Casuarina (1×1m) 183.03 and 186.03 Kg ha^{-1} followed by T_1: Poplar (1×1m) 180.93 and 184.18 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 176.43 and 178.51 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 173.45 and 178.19 Kg ha^{-1} which was at par to each other, respectively. In depth of 30-60 cm the maximum nitrogen was found first year (2022) and second year (2023) in T_3: Casuarina (1×1m) 165.49 and 167.97 Kg ha^{-1} followed by T_1: Poplar (1×1m) 163.03 and 165.86, T_6: Casuarina (1.2×1.2 m) 163.21 and 165.49 Kg ha^{-1}, T_9: Casuarina (1.5×1.5 m) 162.35 and 165.00 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 161.54 and 164.97 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 160.92 and 163.43 Kg ha^{-1}, T_7: Poplar (1.5×1.5 m) 160.84 and 164.06 Kg ha^{-1} which was at par with each other, respectively are shown in table 4. The *P. deltoides* total nitrogen reserve in branch and bole was maximum 1005.6 kg ha^{-1} at 60 x 60 cm and 765.4 kg ha^{-1} at 120 x 120 cm spacing, respectively [14]. The largest amount of nutrient is present at 0–20 cm, and it decreases with soil depth. After 6 years, under different poplar clones, N increased from 14.9 to 24.1% [15]. *E. tereticornis* plantation, as compared to the control system's 223 kg ha^{-1} nitrogen level, the silvipasture system's nitrogen content was 278.4 kg ha^{-1} [16].

Table 4: Nitrogen (Kg ha^{-1}) of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2023	2022	2023
T_1: Poplar (1×1m)	210.40^{ab}	214.63^{ab}	180.39^{ab}	184.18^{ab}	163.03^{ab}	165.86^{a}
T_2: Eucalyptus (1×1m)	206.79^{abcd}	211.01^{abcd}	176.43^{abc}	178.51^{abc}	160.92^{ab}	163.43^{abc}
T_3: Casuarina (1×1m)	212.30^{a}	215.94^{a}	183.03^{a}	186.03^{a}	165.49^{a}	167.97^{a}
T_4: Poplar (1.2×1.2 m)	206.64^{abcd}	210.72^{abcd}	172.51^{bc}	176.02^{bc}	161.54^{ab}	164.97^{ab}
T_5: Eucalyptus (1.2×1.2 m)	204.05^{bcd}	207.36^{cd}	169.89^{c}	172.97^{c}	158.92^{bc}	160.09^{bc}
T_6: Casuarina (1.2×1.2 m)	207.39^{abc}	211.32^{abc}	173.45^{abc}	178.19^{abc}	163.21^{ab}	165.49^{a}
T_7: Poplar (1.5×1.5 m)	202.95^{cd}	207.13^{cd}	169.89^{c}	172.69^{c}	160.84^{ab}	164.06^{abc}
T_8: Eucalyptus (1.5×1.5 m)	200.66^{d}	204.36^{d}	167.45^{c}	169.72^{c}	155.44^{c}	159.37^{c}
T_9: Casuarina (1.5×1.5 m)	205.52^{bcd}	208.33^{bcd}	170.24^{c}	173.53^{c}	162.35^{ab}	165.00^{ab}
Sem ±	2.22	2.29	3.22	3.1	1.75	1.7
CD (p=0.05)	6.66	6.85	9.66	9.3	5.25	5.11
CV (%)	3.86	3.92	4.21	4.04	3.88	3.8
Initial	200.10		166.40		154.35	

Mean followed by the same letter are not significantly from each other at 5 % level

Table 5: Phosphorus (Kg ha^{-1}) of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2023	2022	2023
T_1: Poplar (1×1m)	15.74^{a}	16.04^{ab}	13.72^{a}	13.90^{a}	11.63^{a}	11.87^{a}
T_2: Eucalyptus (1×1m)	14.72^{b}	15.09^{bc}	13.63^{a}	13.78^{a}	11.50^{a}	11.59^{ab}
T_3: Casuarina (1×1m)	15.73^{a}	16.17^{a}	13.79^{a}	14.02^{a}	11.69^{a}	11.92^{a}
T_4: Poplar (1.2×1.2 m)	14.65^{b}	14.91^{c}	12.82^{ab}	13.48^{ab}	10.85^{ab}	11.23^{abc}
T_5: Eucalyptus (1.2×1.2 m)	14.44^{b}	14.75^{c}	12.74^{abc}	13.36^{abc}	10.77^{ab}	11.15^{abc}
T_6: Casuarina (1.2×1.2 m)	14.68^{b}	14.94^{c}	12.92^{ab}	13.51^{ab}	10.99^{ab}	11.30^{abc}
T_7: Poplar (1.5×1.5 m)	14.53^{b}	14.79^{c}	11.80^{bc}	12.64^{bc}	10.37^{b}	10.84^{bc}
T_8: Eucalyptus (1.5×1.5 m)	14.28^{b}	14.61^{c}	11.53^{c}	12.49^{c}	10.23^{b}	10.71^{c}
T_9: Casuarina (1.5×1.5 m)	14.63^{b}	14.94^{c}	12.23^{bc}	12.76^{bc}	10.40^{b}	10.92^{bc}
Sem ±	0.33	0.35	0.41	0.3	0.31	0.27
CD (p=0.05)	0.99	1.05	1.24	0.9	0.94	0.81
CV (%)	3.88	4.02	5.61	3.89	4.99	4.13
Initial	14.20		12.05		9.85	

Mean followed by the same letter are not significantly from each other at 5 % level

The phosphorus found after first year (2022) in T_1: Poplar (1×1m) 15.74 Kg ha^{-1} followed by T_3: Casuarina (1×1m) 15.73 Kg ha^{-1} whereas in second year (2023) in depth 0-15 cm the maximum was found in T_3: Casuarina (1×1m) 16.17 Kg ha^{-1} followed by T_1: Poplar (1×1m) 16.04 Kg ha^{-1}. In depth of 15-30 cm the maximum phosphorus was found first year (2022) and second year (2023) in T_3: Casuarina (1×1m) 13.79 and 14.02 Kg ha^{-1} followed by T_1: Poplar (1×1m) 13.72 and 13.90 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 13.63 and 13.78 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 12.92 and 13.51 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 12.82 and 13.48 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 12.74 and 13.36 Kg ha^{-1} which was at par to each, respectively. In depth of 30-60 cm the maximum phosphorus was found first year (2022) and second year (2023) in T_3: Casuarina (1×1m) 11.69 and 11.92 Kg ha^{-1} followed by T_1: Poplar (1×1m) 11.63 and 11.87 Kg ha^{-1} T_2: Eucalyptus (1×1m) 11.50 and 11.59 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 10.99 and 11.30 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 10.85 and 11.23 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 10.77 and 11.15 Kg ha^{-1} which was at par to each other, respectively are shown in table 5. The *P. deltoides* total P were 18.47 kg ha^{-1} at 60 x 60 cm and 13.5 kg ha^{-1} at 120 x 120 cm, respectively [14]. The largest amount of nutrient at 0–20 cm, and it decreases with soil depth. After 6 years, different poplar clones, P increased from 17.2 to 23.3% [15].

The potassium found after first year (2022) and second year (2023) in depth 0-15 cm the maximum was found in T_3: Casuarina (1×1m) 117.97 and 120.21 Kg ha^{-1} followed by T_1: Poplar (1×1m) 117.91 and 119.00 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 117.81 and 118.42 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 114.11 and 116.09 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 114.21 and 115.23 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 114.00 and 114.64 Kg ha^{-1} which was at par with each other, respectively. In depth of 15-30 cm the maximum potassium was found first year (2022) and second year (2023) in T_3: Casuarina (1×1m) 102.92 and 105.78 Kg ha^{-1} followed by T_1: Poplar (1×1m) 102.56 and 104.75 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 102.11 and 104.32 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 101.79 and 103.26 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 101.41 and 102.51 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 100.67 and 102.13 Kg ha^{-1} which was at par with each other, respectively. In depth of 30-60 cm the maximum potassium was found first year (2022) in T_1: Poplar (1×1m) 86.66 Kg ha^{-1} followed by T_3: Casuarina (1×1m) 86.64 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 86.53 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 85.77 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 85.72 Kg ha^{-1}, T_6: Casuarina (1.2×1.2 m) 85.71 Kg ha^{-1} which was at par with each other whereas in second year (2023) the maximum potassium was found in T_3: Casuarina (1×1m) 89.07 Kg ha^{-1} followed by T_6: Casuarina (1.2×1.2 m) 88.68 Kg ha^{-1}, T_1: Poplar (1×1m) 88.05 Kg ha^{-1}, T_2: Eucalyptus (1×1m) 87.62 Kg ha^{-1}, T_4: Poplar (1.2×1.2 m) 87.52 Kg ha^{-1}, T_5: Eucalyptus (1.2×1.2 m) 86.11 Kg ha^{-1} which was at par to each other are shown in table 6. The *P. deltoides* total K were 895.7 kg ha^{-1} at 60 x 60 cm and 011.9 kg ha^{-1} at 120 x 120 cm, respectively [14]. The largest amount of nutrient found at 0–20 cm, and it decreases with soil depth. After 6 years, different poplar clones, K increased from 3.1 to 5.1% [15].

Table 6: Potassium (Kg ha^{-1}) of fast-growing species under HDP

Treatment	0-15 cm		15-30 cm		30-60 cm	
	2022	2023	2022	2023	2022	2023
T_1: Poplar (1×1m)	117.91^{a}	119.00^{a}	102.56^{a}	104.75^{a}	86.66^{a}	88.05^{ab}
T_2: Eucalyptus (1×1m)	117.81^{a}	118.42^{a}	102.11^{ab}	104.32^{ab}	86.53^{ab}	87.62^{ab}
T_3: Casuarina (1×1m)	117.97^{a}	120.21^{a}	102.92^{a}	105.78^{a}	86.64^{a}	89.07^{a}
T_4: Poplar (1.2×1.2 m)	114.21^{ab}	115.23^{ab}	101.41^{abc}	102.51^{abcd}	85.77^{abc}	87.52^{ab}
T_5: Eucalyptus (1.2×1.2 m)	114.00^{ab}	114.64^{ab}	100.67^{abcd}	102.13^{abcd}	85.72^{abc}	86.11^{abc}
T_6: Casuarina (1.2×1.2 m)	114.11^{ab}	116.09^{ab}	101.79^{ab}	103.26^{abc}	85.71^{abc}	88.68^{a}
T_7: Poplar (1.5×1.5 m)	110.54^{b}	111.17^{b}	96.18^{cd}	98.25^{cd}	80.47^{cd}	82.11^{bc}
T_8: Eucalyptus (1.5×1.5 m)	110.43^{b}	110.95^{b}	95.44^{d}	97.69^{d}	78.82^{d}	80.00^{c}
T_9: Casuarina (1.5×1.5 m)	110.60^{b}	111.69^{b}	96.88^{bcd}	99.28^{bcd}	80.84^{bcd}	81.73^{bc}
Sem ±	1.98	2.16	1.81	1.83	1.93	2.12
CD (p=0.05)	5.94	6.48	5.44	5.47	5.8	6.36
CV (%)	4.01	4.25	4.14	4.1	3.98	4.29
Initial	110.05		95.60		80.00	

Mean followed by the same letter are not significantly from each other at 5 % level

Multiple correlation of pH, EC, OC, N, P and K in both years *viz.,* 2022 and 2023 in different depth shown *viz.,* 0-15 cm, 15-30 cm and 30-60 cm in table 7. Soil pH had significantly positively with EC and negative correlated with, OC, N, P and K at 0-15, 15-30 and 30-60 cm depth in both years. Soil EC had significantly negatively correlated with OC, N, P and K at 0-15, 15-30 and 30-60 cm depth in both years. OC had significantly positively correlated with NPK at 0-15, 15-30 and 30-60 cm depth in both years. N had significantly positively correlated with PK at 0-15, 15-30 and 30-60 cm depth in both years. P had significantly positively correlated with K at 0-15, 15-30 and 30-60 cm depth in both years.

Table 7: Multiple correlation of EC, OC, N, P and K in both year in different depth

Parameters			pH						EC						OC						N						P						K					
Depth			0-15 cm		15-30 cm		30-60 cm		0-15 cm		15-30 cm		30-60 cm		0-15 cm		15-30 cm		30-60 cm		0-15 cm		15-30 cm		30-60 cm		0-15 cm		15-30 cm		30-60 cm		0-15 cm		15-30 cm		30-60 cm	
		Year	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
pH	0-15 cm	2022	1.000																																			
		2023	0.960**																																			
	15-30 cm	2022	0.811**	0.779*																																		
		2023	0.855**	0.822**	0.933**																																	
	30-60 cm	2022	0.776*	0.735*	0.728*	0.839**																																
		2023	0.720*	0.680*	0.876**	0.921**	0.898**																															
EC	0-15 cm	2022	0.888**	0.787*	0.960**	0.977**	0.809**	0.888**																														
		2023	0.781*	0.689*	0.923**	0.935**	0.728*	0.849**	0.969**																													
	15-30 cm	2022	0.767*	0.708*	0.821**	0.839**	0.585N	0.835**	0.863**	0.840**																												
		2023	0.943**	0.857**	0.918**	0.931**	0.708*	0.816**	0.964**	0.925**	0.890**																											
		2023	-0.922**	-0.830**	-0.943**	-0.896**	-0.730*	-0.784*	-0.923**	-0.876**	-0.743*	-0.906**	-0.889**	-0.924**	0.953**	0.967**	0.952**	0.924**	0.924**	0.923**	0.976**	0.986**	0.989**															
	30-60 cm	2022	-0.782*	-0.754*	-0.867**	-0.912**	-0.840**	-0.883**	-0.945**	-0.929**	-0.810**	-0.905**	-0.917**	-0.947**	0.793*	0.823**	0.877**	0.947**	0.946**	0.923**	0.891**	0.873**	0.769*	0.819**														
		2023	-0.762*	-0.762*	-0.829**	-0.876**	-0.901**	-0.926**	-0.906**	-0.884**	-0.783*	-0.840**	-0.844**	-0.906**	0.733*	0.811**	0.839**	0.906**	0.906**	0.887**	0.849**	0.846**	0.749*	0.792*	0.962**													
P	0-15 cm	2022	-0.931**	-0.863**	-0.829**	-0.806**	-0.759*	-0.686*	-0.830**	-0.765*	-0.570NS	-0.833**	-0.775*	-0.831**	0.839**	0.859**	0.836**	0.830**	0.830**	0.846**	0.911**	0.912**	0.943**	0.946**	0.745*	0.747*												
		2023	-0.952**	-0.876**	-0.823**	-0.799**	-0.755*	-0.685*	-0.822**	-0.741*	-0.580NS	-0.834**	-0.768*	-0.823**	0.838**	0.855**	0.828**	0.822**	0.822**	0.850**	0.907**	0.904**	0.952**	0.945**	0.727*	0.726*	0.996**											
	15-30 cm	2022	-0.760*	-0.612NS	-0.850**	-0.794*	-0.548NS	-0.676*	-0.817**	-0.809**	-0.659NS	-0.785*	-0.859**	-0.817**	0.941**	0.907**	0.856**	0.817**	0.817**	0.792*	0.899**	0.910**	0.908**	0.907**	0.691*	0.597NS	0.777*	0.785*										
		2023	-0.701*	-0.555NS	-0.871**	-0.783*	-0.509NS	-0.636NS	-0.805**	-0.793*	-0.625NS	-0.751*	-0.846**	-0.806**	0.964**	0.920**	0.876**	0.806**	0.806**	0.784*	0.884**	0.902**	0.882**	0.892**	0.667*	0.572NS	0.746*	0.749*	0.984**									
	30-60 cm	2022	-0.803**	-0.679*	-0.862**	-0.779*	-0.537NS	-0.660NS	-0.801**	-0.773*	-0.665NS	-0.788*	-0.809**	-0.802**	0.939**	0.923**	0.868**	0.801**	0.801**	0.791*	0.892**	0.916**	0.949**	0.938**	0.658NS	0.593NS	0.828**	0.838**	0.981**	0.965**								
		2023	-0.845**	-0.720*	-0.886**	-0.817**	-0.605NS	-0.682*	-0.842**	-0.806**	-0.657NS	-0.824**	-0.845**	-0.842**	0.958**	0.941**	0.895**	0.842**	0.842**	0.836**	0.933**	0.949**	0.971**	0.967**	0.709*	0.647NS	0.886**	0.892**	0.974**	0.960**	0.991**							
	0-15 cm	2022	-0.712*	-0.571NS	-0.798**	-0.699*	-0.449NS	-0.575NS	-0.721*	-0.698*	-0.574NS	-0.694*	-0.749*	-0.721*	0.915**	0.881**	0.806**	0.721*	0.721*	0.710*	0.832**	0.861**	0.898**	0.880**	0.562NS	0.486NS	0.757*	0.770*	0.977**	0.972**	0.988**	0.969**						
		2023	-0.784*	-0.636NS	-0.876**	-0.786*	-0.525NS	-0.653NS	-0.812**	-0.777*	-0.669*	-0.784*	-0.828**	-0.812**	0.958**	0.932**	0.885**	0.812**	0.812**	0.807**	0.894**	0.914**	0.933**	0.928**	0.655NS	0.581NS	0.799**	0.811**	0.982**	0.984**	0.992**	0.984**	0.987**					

K				N			O C							
30-60 cm		15-30 cm		15-30	0-15 cm		30-60 cm		15-30 cm		0-15 cm		30-60 cm	
2023	2022	2023	2022	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022
-0.566NS	-0.516NS	-0.728*	-0.597NS	-0.929**	-0.877**	-0.909**	-0.921**	-0.886**	-0.888**	-0.849**	-0.824**	-0.795*	0.889**	0.836**
-0.439NS	-0.368NS	-0.575NS	-0.438NS	-0.835**	-0.780*	-0.794*	-0.830**	-0.782*	-0.784*	-0.759*	-0.724*	-0.684*	0.793*	0.695*
-0.872**	-0.782*	-0.880**	-0.842**	-0.905**	-0.955**	-0.953**	-0.950**	-0.957**	-0.957**	-0.993**	-0.960**	-0.949**	0.961**	0.933**
-0.771*	-0.690*	-0.801**	-0.752*	-0.853**	-0.924**	-0.944**	-0.955**	-0.970**	-0.973**	-0.939**	-0.896**	-0.873**	0.983**	0.953**
-0.444NS	-0.380NS	-0.516NS	-0.438NS	-0.719*	-0.782*	-0.811**	-0.819**	-0.803**	-0.803**	-0.710*	-0.739*	-0.672*	0.810**	0.769*
-0.611NS	-0.522NS	-0.654NS	-0.590NS	-0.760*	-0.834**	-0.839**	-0.864**	-0.884**	-0.884**	-0.814**	-0.818**	-0.740*	0.889**	0.869**
-0.793*	-0.710*	-0.827**	-0.773*	-0.879**	-0.953**	-0.969**	-0.983**	-0.999**	-1.000**	-0.965**	-0.923**	-0.899**	1.001**	0.979**
-0.805**	-0.732*	-0.809**	-0.783*	-0.812**	-0.923**	-0.930**	-0.908**	-0.970**	-0.971**	-0.926**	-0.883**	-0.855**	0.970**	0.969**
-0.639NS	-0.521NS	-0.665NS	-0.597NS	-0.713*	-0.755*	-0.759*	-0.846**	-0.864**	-0.864**	-0.827**	-0.752*	-0.689*	0.865**	0.821**
-0.712*	-0.634NS	-0.780*	-0.699*	-0.869**	-0.904**	-0.926**	-0.956**	-0.964**	-0.965**	-0.923**	-0.850**	-0.833**	0.966**	0.930**
-0.836**	-0.785*	-0.866**	-0.831**	-0.841**	-0.935**	-0.959**	-0.947**	-0.979**	-0.979**	-0.931**	-0.899**	-0.899**	0.980**	
-0.794*	-0.711*	-0.827**	-0.773*	-0.879**	-0.954**	-0.970**	-0.984**	-1.000**	-1.000**	-0.966**	-0.923**	-0.900**		
0.933**	0.898**	0.964**	0.936**	0.935**	0.968**	0.954**	0.896**	0.899**	0.899**	0.957**	0.980**			
0.884**	0.822**	0.921**	0.880**	0.951**	0.984**	0.962**	0.916**	0.923**	0.923**	0.970**				
0.878**	0.789*	0.889**	0.850**	0.912**	0.967**	0.956**	0.956**	0.965**	0.965**					
0.793*	0.711*	0.827**	0.773*	0.879**	0.954**	0.969**	0.983**	1.000**						
0.793*	0.711*	0.827**	0.773*	0.879**	0.954**	0.969**	0.983**							
0.754*	0.668*	0.807**	0.737*	0.893**	0.940**	0.960**								
0.823**	0.779*	0.892**	0.833**	0.950**	0.992**									
0.848**	0.797*	0.905**	0.852**	0.964**										
0.770*	0.736*	0.884**	0.797*											
0.810**	0.763*	0.896**	0.824**											
0.681*	0.598NS	0.683*	0.636NS											
0.577NS	0.466NS	0.583NS	0.527NS											
0.615NS	0.583NS	0.744*	0.648NS											
0.605NS	0.577NS	0.749*	0.644NS											
0.906**	0.926**	0.983**	0.948**											
0.958**	0.964**	0.997**	0.984**											
0.870**	0.873**	0.963**	0.910**											
0.862**	0.860**	0.958**	0.901**											
0.878**	0.903**	0.965**	0.927**											
0.909**	0.906**	0.985**	0.944**											
0.986**	0.989**	0.983**												
0.958**	0.958**													
0.975**														
1.000														

** Significant at 1 % level of probability   * Significant at 5 % level of probability

CONCLUSION

Fast-growing tree species in high-density plantations showed improved results for all soil parameters, including pH, EC, soil organic carbon, available N, P, and K. As a result of the breakdown of leaf litter, tree species increased the soil's fertility. The pH and EC were showing decreasing in Casuarina (1×1 m) spacing in all depth 0-15 cm 0.66 % 4.91 %, 15-30 cm 0.69 % and 5.24 % 30-60 cm 0.46 % and 6.31 % respective after two years. The maximum increment in soil organic carbon, available N, P and K was recorded in Casuarina (1×1 m) spacing which was 14.29, 7.34, 12.16, 8.45 percent respectively, compared to initial in 0-15 cm soil depth, 15.17, 10.55, 14.05, 9.62 percent respectively, compared to initial in 15-30 cm soil depth and 20.51, 8.11, 17.62, 10.19 percent respectively, compared to initial in 30-60 cm soil depth after two years of experimentation.

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