

Original Research Article

Growth and Biomass models for three fast-growing tree species under High-density Plantation

Abstract

Three fast-growing trees, viz., *Populus deltoides* (Poplar), *Eucalyptus spp.* (Eucalyptus) and *Casuarina equisetifolia* (Casuarina) were studied, in high-density plantation at village Padilla, in Prayagraj, Uttar Pradesh with three different spacings, viz., 1×1 m, 1.2×1.2 m and 1.5×1.5 m. The trial was established in year 2021 and data was collected after one year. The maximum height was found after one year in T₂: Eucalyptus (1×1m) 3.81 m followed by T₅: Eucalyptus (1.2×1.2 m) 3.78 m, T₈: Eucalyptus (1.5×1.5 m) 3.40 m which was at par with each other and minimum in T₉: Casuarina (1.5×1.5 m) 2.42 m whereas the maximum girth was found in T₄: Poplar (1.2×1.2 m) 6.91 cm followed by T₂: Eucalyptus (1×1m) 6.61cm, T₅: Eucalyptus (1.2×1.2m) 6.16 cm, T₁: Poplar (1×1m) 5.91 cm which was at par with each other and minimum in T₉: Casuarina (1.5×1.5 m) 3.22 cm. Various (27) linear function were attempted to predict biomass based on GBH (G) and Height (H). Prediction accuracy of Height, girth model was slightly better than the height and girth model. Linear model ($Y=a + bH + cG$), where Y denotes dependent variable (biomass) and H and G denotes independent variable (Height or Girth), performed better (than the remaining tested models) in terms of estimation precision and prediction accuracy. The AGB was maximum was found in T₂: Eucalyptus (1×1m) 0.676kg tree⁻¹ followed by T₅: Eucalyptus (1.2×1.2 m) 0.598 kg tree⁻¹ and minimum in T₉: Casuarina (1.5×1.5 m) 0.214kg tree⁻¹. After completion of one year Eucalyptus (1×1m) showed best growth among all treatments.

Key words: Growth, Biomass, Linear model, Fast-growing tree species, High-density plantation

Introduction

Fast-growing species to assess productivity thresholds looked to be particularly apparent following the large establishment of wood plantations in developing countries, with the main objective of delivering as much wood as possible in a short length of time¹. Over the world, efforts are being made to establish plantations of fast-growing tree species as a means of achieving objectives like boosting the wood-based industry's demand for timber^{2,3}.

High-density plantation systems have the advantages of higher yield and production per unit area⁴. High-density planting, a novel cultivation technique, enables the accommodation of more plants per unit space than is possible with conventional planting density⁵. High-density plantations allow for the planting of more trees in a smaller space, increasing productivity per square foot. To provide fuelwood and raw materials for the industrial process, high-density plantations are built. Forest plantations also provide non-wooden forest products and advantages as a result of the trees planted or other ecosystem characteristics, they aid in establishing.

A proportional change from one part of an organism to another is known as an allometry⁶. Regression methods can be used to determine an allometric relationship between tree dimension and biomass⁷. For both practical forestry difficulties and scientific reasons, it is crucial to quantify the biomass of trees and forests. The interest in using biomass and the worth of trees and forests has increased with the rising economic value of wood, bark, roots, and leaves⁸. Forest biomass is crucial for research into the productivity of ecosystems, energy flow, and dynamics of nutrients and carbon, in addition to being used for commercial purposes⁹. Also, the standing biomass indicates the forest's potential production and gives a sense of the types of products that can be harvested. For process-based individual tree growth models, the tree biomass models may be crucial. Many allometric models exist in different parts of the world that link biomass to tree dimensions^{7,10,11}.

Material and methods

The experiment was established at Padilla, Prayagrajin year 2021 and the data was collected after one year (2022). The GPS location of site longitude (25.54° N) and latitude (81.89° E). The experiment was conducted for evaluation of growth performance of three fast-growing tree species under high-density plantation. In this experiment three fast growing species viz., Poplar (*Populus deltoides*), Eucalyptus(*Eucalyptus spp.*) and Casuarina (*Casuarina equisetifolia*) was established in randomized block design (RBD) with 9 treatments and 3 replication with following treatments T₁: Poplar (1×1m), T₂: Eucalyptus (1×1m), T₃: Casuarina (1×1m), T₄: Poplar (1.2×1.2 m), T₅: Eucalyptus (1.2×1.2 m), T₆: Casuarina (1.2×1.2 m), T₇: Poplar (1.5×1.5 m), T₈: Eucalyptus (1.5×1.5 m) and T₉: Casuarina (1.5×1.5 m).

Height (m) of the tree was recorded with help of clinometer and girth (cm) was recorded above 1.37 m ground level with help of measuring tape.

Stem biomass (kg tree⁻¹)

Weighing at the stem was done on the twenty selected trees. To reduce root damage, a few carefully chosen trees were chopped down. To make estimating biomass easier, the stem was cut into logs and split 20 cm above the ground. The fresh weight of the logs was then instantly determined by weighing them on an electronic scale in the field. To achieve the appropriate weight, a representative sample was taken from the stem of each tree and placed in an oven set at 100 ± 2 0C. Dry matter content was calculated by using the formula:

$$\text{Stem Dry matter content (\%)} = \frac{DS_1 + DS_2 + DS_3}{FS_1 + FS_2 + FS_3} \times 100$$

Where:

DS_1, DS_2, DS_3 = Dry weight of sample one, two and three, respectively.

FS_1, FS_2, FS_3 = Fresh weight of sample one, two and three, respectively.

Total stem dry weight (kg)

The total fresh weight of the stem part was multiplied by the dry matter content to obtain the total dry weight using the following equation:

$$\text{Total stem dry weight} = \text{Total stem fresh weight} \times \text{Stem dry matter content (\%)}$$

Branches biomass (kg tree⁻¹)

The branch biomass in the absence of leaves was calculated for twenty randomly selected trees. After the branches were cut off from the shoots, they were promptly weighed in the field using an electronic scale to determine their present weight. Three randomly selected branch samples from different parts of were dried in an oven (100 ± 2 0C) to determine the oven dry weight of the branch biomass. The weight achieved remained consistent. Dry matter content was calculated by using the formula:

$$\text{Dry matter content (\%)} = \frac{DB_1 + DB_2 + DB_3}{FB_1 + FB_2 + FB_3} \times 100$$

Where:

DB_1, DB_2, DB_3 = Dry weight of branch one, two and three, respectively.

FB_1, FB_2, FB_3 = Fresh weight of branch one, two and three, respectively.

Total branch dry weight (kg)

The total fresh weight of each tree branch was multiplied by the dry matter content using the following calculation to determine the total branch dry weight:

$$\text{Total branch dry weight} = \text{Total branch fresh weight} \times \text{Branch dry matter content (\%)}$$

Leaf biomass (kg tree⁻¹)

The chosen trees' leaves were separated from their branches in the field, and the newly weighted leaves were then immediately weighed using an electronic balance there.

Four representative leaf samples were dried until the leaf biomass achieved a constant weight in an oven set at 70 ± 2 °C. Leaves dry matter content was calculated by using the following formula:

$$\text{Leaves Dry matter content (\%)} = \frac{DL_1 + DL_2 + DL_3 + DL_4}{FL_1 + FL_2 + FL_3 + FL_4} \times 100$$

Where:

DL_1, DL_2, DL_3, DL_4 = Dry weight of branch one, two, three and four respectively.

FL_1, FL_2, FL_3, FL_4 = Fresh weight of branch one, two, three and four respectively.

Total leaves dry weight (kg)

Using the following calculation, the fresh weight of each tree's leaves was multiplied by the amount of dry matter in each tree to determine total leaf dry weight:

$$\text{Total leaves dry weight} = \text{Total leaves fresh weight} \times \text{Branch dry matter content (\%)}$$

Above ground biomass (kg tree⁻¹)

For the calculation of above ground biomass (AGB) addition of dry biomass of bole. Branches and leaves.

$$\text{AGB} = \text{Bole biomass} + \text{Branches biomass} + \text{Leaves Biomass}$$

Biomass expansion factor (BEF): The BEF was calculated by Above ground biomass divided by the bole biomass¹³.

$$\text{BEF} = \frac{\text{Above ground biomass (Bole + branches + leaves biomass)}}{\text{Bole biomass}}$$

Statistical analysis: MS-Excel and online software WASP, OPSTAT statistical software was used for computation of descriptive statistics and appropriate of linear/non-linear models. The best fir tree biomass models were evaluated using twenty-seven distinct equations (Table 2) in an effort to determine their estimation accuracy using the coefficient of determination, or $R^{2(\text{Ref}; 14,15,16)}$.

Result and discussion

The maximum height was found after one year (2022) in T_2 : Eucalyptus (1×1m) 3.81 m followed by T_5 : Eucalyptus (1.2×1.2 m) 3.78 m, T_4 : Poplar (1.2×1.2 m) 3.53 m which was at par with each other and minimum in T_9 : Casuarina (1.5×1.5 m) 2.42 m whereas the maximum girth was found after one year (2022) in T_4 : Poplar (1.2×1.2 m) 6.91 cm followed by T_2 : Eucalyptus (1×1m) 6.61 cm and minimum in T_9 : Casuarina (1.5×1.5 m) 3.22 cm shown in table 1. Similarly, the maximum height was found in the first year was found in T_2 (3.76 m; Casuarina 1 × 1 m) followed by T_6 (3.66 m; Casuarina 1.2 × 1.2 m) whereas maximum girth was found in T_6 (7.34 cm; Casuarina 1.2 × 1.2 m) followed by T_1 (7.18 cm; Eucalyptus

1 × 1 m)¹⁷. The maximum height was documented in 3018 (12.55 m), followed by P-32 (12.29 m), P-23 (11.89 m) and P-13 (11.77 m) and lowest in clone 413 (9.99 m), 288 (9.95 m) and 2136 (9.28 m)¹⁸. The maximum height was recorded in poplar clone L-200-84 (9.98 m) followed by Udai (9.57 m) at Prayagraj¹⁹. The growth performance of 20 clones of Eucalyptus on parameters height and DBH. The height range varied from 18.5 to 23.6 m whereas DBH varied 11.47 to 16.07 cm²⁰.

Table 1: Height (m) and girth (cm) of fast-growing species under HDP

Treatment	Height (m)	Girth (cm)
T ₁ : Poplar (1×1m)	3.19 ^{cd}	5.91 ^{cd}
T ₂ : Eucalyptus (1×1m)	3.81 ^a	6.61 ^{ab}
T ₃ : Casuarina (1×1m)	2.70 ^{ef}	3.42 ^e
T ₄ : Poplar (1.2×1.2 m)	3.53 ^{ab}	6.91 ^a
T ₅ : Eucalyptus (1.2×1.2 m)	3.78 ^a	6.16 ^{bc}
T ₆ : Casuarina (1.2×1.2 m)	2.68 ^{ef}	3.53 ^e
T ₇ : Poplar (1.5×1.5 m)	2.91 ^{de}	5.57 ^d
T ₈ : Eucalyptus (1.5×1.5 m)	3.40 ^{bc}	5.63 ^d
T ₉ : Casuarina (1.5×1.5 m)	2.42 ^f	3.22 ^e
SEm	0.10	0.16
CD (0.05)	0.29	0.48
CV %	5.23	5.31

Means followed by the letter are not significantly different at a 5% probability level.

Linear regression model of bole, branches, leaves and above ground biomass of tree was shown in table 2. The regression model for bole biomass maximum R² for height and grith was found in T₁: Poplar (1×1m) 0.874 followed by T₂: Eucalyptus (1×1m) 0.773 and minimum in T₃: Casuarina (1×1 m) 0.456. The R²for height was maximum found in T₁: Poplar (1×1m) 0.839 followed by T₇: Poplar (1.5×1.5 m) 0.688 and minimum in T₃: Casuarina (1×1 m) 0.076. The R²forgrith was maximum found in T₂: Eucalyptus (1×1m) 0.727 followed by T₅: Eucalyptus (1.2×1.2 m) 0.649 and minimum in T₁: Poplar (1×1m) 0.018. The branches biomass the R²for height and grith was maximum in T₄: Poplar (1.2×1.2 m) 0.947 followed by T₆: Casuarina (1.2×1.2 m) 0.754 and minimum in T₁: Poplar (1×1m) 0.317. The R²for height was maximum found in T₄: Poplar (1.2×1.2 m) 0.843 followed by T₇: Poplar (1.5×1.5 m) 0.621 and minimum in Casuarina (1.5×1.5 m) and T₂: Eucalyptus (1×1m) 0.002. The R²forgrith was maximum found in T₂: Eucalyptus (1×1m) 0.526; T₃: Casuarina (1×1m) 0.526 followed by T₃: Casuarina (1×1m) 0.408 and minimum in T₅: Eucalyptus (1.2×1.2 m) 0.044. The leaves biomass R²for height and grith was maximum in T₈: Eucalyptus (1.5×1.5 m) 0.793 followed by T₆: Casuarina (1.2×1.2 m) 0.779 and minimum in

T₁: Poplar (1×1m) 0.370. The R² for height was maximum found in T₇: Poplar (1.5×1.5 m) 0.698 followed by T₄: Poplar (1.2×1.2 m) 0.646 and minimum in T₁: Poplar (1×1m) 0.003.

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Table 2: Regression model of Bole, branches, leaves and above ground biomass of fast-growing species under HDP

Treatment	Variable	Parameters	Dry bole biomass	R ²	Dry branches biomass	R ²	Dry leaves biomass	R ²	Above ground biomass	R ²
T ₁ : Poplar (1×1m)	W=a + bH + cG	a, b, c	-0.154, 0.096, 0.018	0.874	0.089, 0.008, -0.009	0.317	0.220, 0.001, -0.023	0.370	0.153, 0.105, -0.013	0.841
	W=a + bH	a, b	-0.043, 0.095	0.839	0.036, 0.008	0.136	0.080, 0.002	0.003	0.072, 0.106	0.799
	W=a + cG	a, c	0.160, 0.012	0.018	0.113, -0.009	0.200	0.222, -0.023	0.370	0.495, -0.019	0.031
T ₂ : Eucalyptus (1×1m)	W=a + bH + cG	a, b, c	-0.188, 0.041, 0.057	0.773	-0.060, -0.001, 0.023	0.526	-0.069, 0.009, 0.042	0.651	-0.318, 0.049, 0.122	0.776
	W=a + bH	a, b	0.124, 0.056	0.083	0.069, 0.004	0.002	0.160, 0.020	0.018	0.353, 0.080	0.040
	W=a + cG	a, c	-0.055, 0.058	0.727	-0.065, 0.023	0.526	-0.040, 0.042	0.648	-0.160, 0.124	0.761
T ₃ : Casuarina (1×1m)	W=a + bH + cG	a, b, c	-0.033, 0.006, 0.032	0.456	0.016, -0.002, 0.005	0.548	0.002, 0.0034, 0.025	0.599	-0.014, 0.007, 0.062	0.672
	W=a + bH	a, b	0.050, 0.024	0.076	0.028, 0.001	0.010	0.065, 0.018	0.092	0.143, 0.043	0.099
	W=a + cG	a, c	-0.022, 0.033	0.458	0.013, 0.004	0.526	0.008, 0.026	0.596	-0.0003, 0.063	0.670
T ₄ : Poplar (1.2×1.2 m)	W=a + bH + cG	a, b, c	-0.396, 0.082, 0.059	0.714	-0.188, 0.052, 0.014	0.947	-0.301, 0.084, 0.024	0.737	-0.884, 0.218, 0.097	0.835
	W=a + bH	a, b	-0.065, 0.105	0.424	-0.111, 0.057	0.843	-0.167, 0.093	0.646	-0.342, 0.255	0.652
	W=a + cG	a, c	-0.213, 0.073	0.470	-0.071, 0.022	0.294	-0.112, 0.038	0.244	-0.396, 0.133	0.406
T ₅ : Eucalyptus (1.2×1.2 m)	W=a + bH + cG	a, b, c	0.081, -0.002, 0.036	0.651	-0.005, 0.026, -0.002	0.507	-0.174, 0.072, 0.020	0.688	-0.096, 0.095, 0.055	0.804
	W=a + bH	a, b	0.346, -0.016	0.031	-0.016, 0.026	0.501	-0.029, 0.064	0.495	0.301, 0.075	0.253
	W=a + cG	a, c	0.072, 0.036	0.649	0.098, -0.004	0.044	0.111, 0.014	0.093	0.28, 0.046	0.407
T ₆ : Casuarina (1.2×1.2 m)	W=a + bH + cG	a, b, c	0.020, 0.010, 0.014	0.716	-0.048, 0.019, 0.012	0.754	-0.091, 0.027, 0.035	0.779	-0.118, 0.056, 0.061	0.824
	W=a + bH	a, b	0.058, 0.014	0.406	-0.018, 0.022	0.632	0.0001, 0.037	0.471	0.040, 0.073	0.548
	W=a + cG	a, c	0.034, 0.017	0.537	-0.022, 0.018	0.345	-0.054, 0.045	0.558	-0.042, 0.080	0.541
T ₇ : Poplar (1.5×1.5 m)	W=a + bH + cG	a, b, c	-0.249, 0.099, 0.044	0.743	0.009, 0.020, 0.0003	0.621	-0.010, 0.023, 0.008	0.735	-0.250, 0.143, 0.052	0.884
	W=a + bH	a, b	-0.102, 0.141	0.688	0.010, 0.020,	0.621	0.015, 0.030	0.698	-0.078, 0.192	0.834
	W=a + cG	a, c	-0.274, 0.0979	0.578	0.004, 0.011	0.328	-0.016, 0.020	0.537	-0.287, 0.129	0.661
T ₈ : Eucalyptus (1.5×1.5 m)	W=a + bH + cG	a, b, c	-0.058, 0.047, 0.025	0.601	0.001, 0.009, 0.008	0.461	-0.057, 0.022, 0.016	0.793	-0.114, 0.077, 0.048	0.734
	W=a + bH	a, b	0.002, 0.067	0.505	0.020, 0.015	0.335	-0.017, 0.035	0.608	0.005, 0.116	0.589
	W=a + cG	a, c	0.005, 0.043	0.435	0.013, 0.011	0.386	-0.028, 0.025	0.634	-0.010, 0.079	0.588
T ₉ : Casuarina (1.5×1.5 m)	W=a + bH + cG	a, b, c	0.065, 0.011, -0.002	0.676	0.048, 0.0007, -0.006	0.413	0.110, 0.006, -0.008	0.575	0.223, 0.018, -0.015	0.566
	W=a + bH	a, b	0.057, 0.012	0.669	0.023, 0.003	0.173	0.075, 0.010	0.429	0.154, 0.025	0.478
	W=a + cG	a, c	0.118, -0.009	0.273	0.051, -0.006	0.408	0.138, -0.011	0.465	0.307, -0.027	0.399

The R^2 for girth was maximum found in T₂: Eucalyptus (1×1m) 0.648 followed by T₈: Eucalyptus (1.5×1.5 m) 0.634 and minimum in T₅: Eucalyptus (1.2×1.2 m) 0.092. The above ground biomass R^2 for height and girth maximum in T₇: Poplar (1.5×1.5 m) 0.884 followed by T₁: Poplar (1×1m) 0.841 and minimum in T₉: Casuarina (1.5×1.5 m) 0.566. The R^2 for height, the maximum found in T₇: Poplar (1.5×1.5 m) 834 followed by T₁: Poplar (1×1m) 0.799 and minimum in T₂: Eucalyptus (1×1m) 0.040. The R^2 for girth maximum found in T₂: Eucalyptus (1×1m) 761 followed by T₃: Casuarina (1×1m) 670 and minimum in T₁: Poplar (1×1m) 0.031.

The biomass of bole, branches, leaves and above ground biomass (AGB) was shown in table 3. The bole biomass (kg tree⁻¹) maximum found after one year (2022) in T₂: Eucalyptus (1×1m) 0.345kg tree⁻¹ followed by T₄: Poplar (1.2×1.2 m) 0.302kg tree⁻¹ and minimum in T₉: Casuarina (1.5×1.5 m) 0.085kg tree⁻¹. The branches biomass maximum found in T₄: Poplar (1.2×1.2 m) 0.093 kg tree⁻¹ followed by T₂: Eucalyptus (1×1m) 0.088kg tree⁻¹ and minimum in T₃: Casuarina (1×1m) 0.028kg tree⁻¹. The leaves biomass maximum found in T₂: Eucalyptus (1×1m) 0.243kg tree⁻¹, followed by T₅: Eucalyptus (1.2×1.2 m) 0.222 kg tree⁻¹ and minimum in T₉: Casuarina (1.5×1.5 m) 0.099kg tree⁻¹.

Table 3: Stem, branches, leaves and AGB (kg tree⁻¹) of fast-growing species under HDP

Treatment	Bole (Kg tree ⁻¹)	Branches (Kg tree ⁻¹)	Leaves (Kg tree ⁻¹)	AGB (Kg tree ⁻¹)
T ₁ : Poplar (1×1m)	0.258 ^c	0.061 ^d	0.087 ^e	0.407 ^d
T ₂ : Eucalyptus (1×1m)	0.345 ^a	0.088 ^a	0.243 ^a	0.676 ^a
T ₃ : Casuarina (1×1m)	0.093 ^d	0.028 ^f	0.097 ^{de}	0.217 ^e
T ₄ : Poplar (1.2×1.2 m)	0.302 ^b	0.093 ^a	0.162 ^c	0.556 ^b
T ₅ : Eucalyptus (1.2×1.2 m)	0.295 ^b	0.081 ^b	0.222 ^b	0.598 ^b
T ₆ : Casuarina (1.2×1.2 m)	0.096 ^d	0.045 ^e	0.105 ^d	0.246 ^e
T ₇ : Poplar (1.5×1.5 m)	0.286 ^b	0.069 ^c	0.101 ^{de}	0.456 ^c
T ₈ : Eucalyptus (1.5×1.5 m)	0.243 ^c	0.077 ^b	0.108 ^d	0.427 ^{cd}
T ₉ : Casuarina (1.5×1.5 m)	0.085 ^d	0.030 ^f	0.099 ^{de}	0.214 ^e
S Em	0.01	0.001	0.01	0.01
CD (0.05)	0.03	0.01	0.02	0.04
CV %	6.77	6.92	6.71	5.98

Means followed by the letter are not significantly different at a 5% probability level.

The AGB was maximum was found in T₂: Eucalyptus (1×1m) 0.676kg tree⁻¹ followed by T₅: Eucalyptus (1.2×1.2 m) 0.598 kg tree⁻¹ and minimum in T₉: Casuarina (1.5×1.5 m) 0.214kg tree⁻¹. Similarly, the highest biomass was found in the first year was found in T₆ (*Casuarina* 1.2 × 1.2 m; 15.51 t ha⁻¹), followed by T₁ (*Eucalyptus* 1 × 1 m; 14.71 t ha⁻¹) and lowest in T₁₂ (*Melia* 1.5 × 1.5 m; 0.66 t ha⁻¹)¹⁷. The total assessed AGB production of *E. camaldulensis* coppice is 18.21 t ha⁻¹ at 3 years of age²¹. The stems, branches, leaves and total dry biomass after one year growth was the minimum 2.92, 0.86, 1.36 and 5.15 t ha⁻¹ (Ref. 22). The poplar biomass was higher in agroforestry trees (1,223 kg tree⁻¹) than in monoculture plantation trees (1,102 kg tree⁻¹)²³. The *P. deltoides* clones, where the total biomass reached from 48.5 Mg ha⁻¹ to 62.2 Mg ha⁻¹ at Chhattisgarh²⁴.

The Biomass Expansion Factor (BEF) of fast-growing species under high density plantation are presented in Table 4. the maximum BEF after first year was found in T₆: Casuarina (1.2×1.2 m) 2.55 followed by T₃: Casuarina (1×1m) 2.34 and minimum in T₁: Poplar (1×1m) 1.58. Similarly, the BEF value for *Ailanthus excelsa* plantation was 1.23 at Uttarakhand¹³. The BEF of 7-year-old Poplar was 1.47 and *E. hybrid* at age of 18, 28 and 30 years 1.93, 1.23 and 1.31 respectively at Punjab²⁵. The BEF value of *E. globulus* 0.77 at Portugal reported by Soares and Tome²⁶.

Table 4: Biomass Expansion Factor of fast-growing species under HDP

Treatment	BEF
T ₁ : Poplar (1×1m)	1.58
T ₂ : Eucalyptus (1×1m)	1.96
T ₃ : Casuarina (1×1m)	2.34
T ₄ : Poplar (1.2×1.2 m)	1.84
T ₅ : Eucalyptus (1.2×1.2 m)	2.02
T ₆ : Casuarina (1.2×1.2 m)	2.55
T ₇ : Poplar (1.5×1.5 m)	1.60
T ₈ : Eucalyptus (1.5×1.5 m)	1.76
T ₉ : Casuarina (1.5×1.5 m)	2.16

The correlation matrix of height, girth, biomass of bole, branches, leaves and AGB per tree was showed in table 5. The height was significantly positively correlated with girth 0.902, bole biomass 0.880, branch biomass 0.909, leaves biomass 0.812 and AGB 0.941. The

girth was significantly positively correlated with bole biomass 0.976, branch biomass 0.961, leaves biomass 0.611 and AGB 0.936. The bole biomass was significantly positively correlated with branch biomass 0.940, leaves biomass 0.644 and AGB 0.960. The branches biomass was significantly positively correlated with leaf biomass 0.672 and AGB 0.942. The leaves biomass was significantly positively correlated with AGB 0.830.

Table 5: Correlation matrix of height, girth, biomass of stem, branches, leaves and AGB

Parameters	Height	Girth	Bole biomass tree ⁻¹	Branches biomass tree ⁻¹	Leaves biomass tree ⁻¹	ABG tree ⁻¹
Height	1.000					
Girth	0.902	1.000				
Bole biomass tree ⁻¹	0.880	0.976	1.000			
Branches biomass tree ⁻¹	0.909	0.961	0.940	1.000		
Leaves biomass tree ⁻¹	0.812	0.611	0.644	0.672	1.000	
ABG tree ⁻¹	0.941	0.936	0.960	0.942	0.830	1.000

Conclusion

Fast-growing tree species under HDP after one year showed that the maximum height was found in Eucalyptus (1×1m) spacing whereas the maximum girth was found in Poplar (1.2×1.2 m) spacing. The maximum bole, leaves and above ground biomass was found in Eucalyptus (1×1m) spacing whereas branches biomass was maximum in Poplar (1.5×1.5 m) spacing. The biomass expansion factor was maximum found in Casuarina (1.5×1.5 m) spacing. After one year among the three species recommend the Eucalyptus planted in (1×1m) spacing for better growth and biomass production.

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