Biomass estimation models for three fast-growing tree species at Prayagraj, Uttar Pradesh (country?).

Abstract

A field experiment was conducted ~~for~~ to develop the regression models of biomass ~~of~~ for three fast-growing trees, *viz.,Populus deltoides* (Poplar), *Eucalyptus spp.* (Eucalyptus) and *Casuarina equisetifolia* (Casuarina) in high-density plantation after two years at three different spacings, *viz.*, 1m×1m, 1.2m×1.2m and 1.5m×1.5m in village Padilla, Prayagraj, Uttar Pradesh (country?). The trial was established in year 2021 and data was collected after two years. The result indicated~~s~~ the maximum height range was found in T_2: Eucalyptus (1m×1m) 7.5m followed by T_8: Eucalyptus (1.5m×1.5m) 5.3m whereas the maximum girth range was found in T_2: Eucalyptus (1m×1m) 12.5cm followed by T_7: Poplar (1.5m×1.5m) 11.7cm. The bolelinear function ~~showed~~ for height and ~~grith~~girth in 2nd year maximum R^2 was found in T_8: Eucalyptus (1.5m×1.5m) 0.969 followed by T_6: Casuarina (1.2m×1.2m) 0.958 whereas the branch's linear function ~~showed~~ for ~~for~~ height and g~~r~~i~~r~~th was maximum R^2 in 2nd year maximum in T_2: Eucalyptus (1m×1m) 0.947 followed by T_4: Poplar (1.2m×1.2m) 0.838. The leaves' linear function ~~showed~~ for height and g~~r~~i~~r~~th was maximum R^2 in 2nd year maximum found in T_9: Casuarina (1.5m×1.5m) 0.903 followed by T_5: Eucalyptus (1.2m×1.2m) 0.861 whereas the AGB linear function ~~showed~~ for height and ~~grith~~girth was maximum R^2 in 2nd year maximum found in T_2: Eucalyptus (1m×1m) 0.976 followed by T_6: Casuarina (1.2m×1.2m) 0.965. The bole biomass maximum found after 2nd year T_4: Poplar (1.2m×1.2m) 2.801kgtree^{-1} followed by T_2: Eucalyptus (1m×1m) 2.801kgtree^{-1} whereas in 2nd year branch biomass maximum found in T_8: Eucalyptus (1.5m×1.5m) 1.130 kgtree^{-1} followed by T_4: Poplar (1.2m×1.2m) 0.982 kgtree^{-1}. The leaves biomass maximum found in 2nd year maximum found in T_8: Eucalyptus (1.5m×1.5m) 1.950 kgtree^{-1} followed by T_2: Eucalyptus (1m×1m) 1.617kgtree^{-1} whereas in 2nd year AGB maximum in T_2: Eucalyptus (1m×1m) 5.285 kgtree^{-1} followed by T_8: Eucalyptus (1.5m×1.5m) 4.803 kgtree^{-1}.

Key words: Regression model,Biomass, Fast-growing tree species, Height, Girth

Introduction

Fast-growing wood species have been frequently used in plantation forests and community forests to improve the woods' long-term viability. ~~They~~ These wood species can be used to bridge the gap between supply and demand for wood [1]. Planting density has a major impact on each individual tree's available growing resources and crown features[2],

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affecting wood volume growth, biomass increment, and wood quality [3,4].Trees have a critical role in the environment[5] and are also ~~trees are~~ visible and quantifiable indicators of ecological health. Trees transform and alter the environment in which they grow, making them important ecosystem engineers [6]. Trees also provide a variety of ecosystem services such as water purification, ~~erosion~~ prevention of soil erosion, flood defence, carbon sequestration, air temperature regulation and air quality regulation [7].

Based on diameter at breast height (DBH) and height data, biomass estimation equations, also known as allometric equations or regression models, are used to estimate the biomass or volume of above-ground tree components. These equations are generated from sample trees' measured tree weights in relation to their DBH and height. Estimating the biomass of tree species present in a forest or plantation using biomass equations is a standard and cost-effective method [8]. Direct and indirect methods, as well as remote sensing methods, can be used to estimate biomass. Destructive sampling is the most accurate method for estimating tree biomass [9~~,10,11,12~~, 10, 11, 12]. This direct method permits allometric equations to be developed, which may be utilised to translate ground-based observations into biomass [9~~,10~~, 10].

Material and methods

The experiment was established at Padilla, Prayagrajin year July, 2021 and the data was collected after two year (June, 2023). The GPS location of site longitude (25.54° N) and latitude (81.89° E). The experiment was conducted ~~for~~ to evaluat~~eion of~~ the growth performance and develop the regression equation of biomass ~~of~~ for three fast-growing tree species under high-density plantation. In this experiment plantations of three fast growing species *viz.*, Poplar (*Populus deltoides*), Eucalyptus(*Eucalyptus spp.*) and Casuarina (*Casuarina equisetifolia*) w~~e~~ar~~es~~ established in Randomized Block Design (RBD) with 9 treatments and 3 replication with the following treatments *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).

Height (m)

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

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Stem biomass (kg tree^{-1})

The weight of the twenty trees ~~that were~~ chosen ~~were~~ was weighed at the stem. The s~~S~~elected trees were carefully cut, minimising root damage. The stem was chopped into logs for ease of biomass estimate and separated 20 cm above the ground level. 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 ^{0}-C, and dried until a constant weight was attained. Dry matter content was calculated by using the ~~formula~~[formula [13]:

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

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)

Using the following formula, the total dry weight of the stem portion was calculated by multiplying its total fresh weight by its dry matter content:

Total stem dry weight = Total stem fresh weight × Stem dry matter content (%)

Branches biomass (kg tree^{-1})

Twenty randomly chosen trees were used to compute the branch biomass without leaves. The branches were ~~then~~ immediately detached from the shoots and weighed in the field with an electronic scale to obtain the current weight. To obtain the oven dry weight of the branch biomass, three randomly chosen branch samples from various portions of the tree were taken, dried in an oven at ~~(~~100±2 ^{0}-C~~)~~, ~~and~~ until a constant ~~the~~ weight was attained ~~remained constant~~. Dry matter content was calculated ~~by~~ using the ~~formula~~[formula [13]:

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

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 following formula was used to get the total branch dry weight for each tree branch: total fresh weight multiplied by dry matter content:

Total branch dry weight = Total branch fresh weight × Branch dry matter content (%)

Leave biomass (kg tree^{-1})

Leaves of selected trees were detached from the branches in the field and weighed instantly with the help of electronic balance in the field to get the fresh weight. In an oven set at 70±2 ^{0}C, four representative leaf samples were dried until the leaf biomass reached a consistent weight. Leaves dry matter content was calculated by using the following formula [13]:

$$Leaves\ Dry\ matter\ content\ (\%) = \frac{DL_1 + DL_2 + DL_3 + DB_4}{FL_1 + FL_2 + FL_3 + FL_4} \times 100$$

Where:

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

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

Total leaves dry weight (kg)

The total dry weight of the leaves on each tree was calculated by multiplying their fresh weight by the dry matter content of each tree:

Total leaves dry weight = Total leaves fresh weight ×Leaves 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.

AGB= Bole biomass + Branches biomass+ Leaves Biomass

Statistical analysis

With the assistance of MS-Excel and the web programme WASP, the regression equation for the stem, branches, leaves, and aboveground biomass was created. OPSTAT statistical software was utilised to compute descriptive statistics and determine which linear and non-linear models were appropriate. Twenty-seven different equations (Table 2) were used to assess the biomass models of fast-growing tree species in an attempt to calculate the estimation accuracy of each model using the coefficient of determination, or R^2 [14,15,16, 15, 16].

Result and discussion

Range of height and girth wasRanges of height and girth are shown in table 1. The maximum height range of 7.5 m was found in T_2: Eucalyptus (1 m × 1 m), 7.5 m followed by 5.3 m in T_8: Eucalyptus (1.5 m × 1.5 m) 5.3 m and minimum of 2.1 m in T_1: Poplar (1 m × 1 m) 2.1 m whereas the maximum girth range of 12.5 cm was found in T_2: Eucalyptus (1 m ×1 m) 12.5 cm followed by 11.7 cm in T_7: Poplar (1.5 m × 1.5 m) 11.7 cm and minimum of 3.5

Comment [E5]: How many leaves? How were thy selected?

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Comment [E9]: Plase explain this statement well-likike **Range of height (m) and girth (cm) of fast-growing tree species under HDP are shown in table 1.**

cm in T_3: Casuarina (1 m ×1 m) ~~3.5 cm~~. Similarly, results were –reported in Poplar clone maximum height in Udai clone (11.57 ± 0.23 m) followed by L - 87 (10.22 ± 0.42 m) and minimum in Bahar (6.74 ± 0.19 m) at age of four years [17]. In first year the maximum height of 3.76 m was ~~reported~~ recorded in T_2 (~~3.76 m;~~ *Casuarina* 1 m ×1 m) followed by 3.66 m in T_6 (~~3.66 m;~~ *Casuarina* 1.2 m ×1.2 m) whereas maximum girth 7.34 cm was ~~found~~ recorded in T_6 (~~7.34 cm;~~ *Casuarina* 1.2 m × 1.2 m) followed by 7.18 cm in T_1 (~~7.18 cm;~~ *Eucalyptus* 1 m ×1 m) [18]. The *E. tereticornis* height and DBH ranges varied from 11.20-18.70 m and 8.59-18.13 cm, respectively [19]. The maximum height of 12.55 m was documented in 3018 ~~(12.55 m)~~, followed by 12.29 m recorded in P-32 ~~(12.29 m)~~, 11.89 m in P-23 ~~(11.89 m)~~ and 11.77 m in P-13 ~~(11.77 m)~~. The ~~and~~ lowest height was recorded in clone 413 (9.99 m), 288 (9.95 m) and 2136 (9.28 m) [20].The maximum height was recorded in Poplar clone L-200-84 (9.98 m) followed by Udai (9.57 m) at Prayagraj [21].

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

Treatment	Range of height (m)	Range of girth (cm)
T_1: Poplar (1 m × 1 m)	5.1-7.2	9.8-13.8
T_2: Eucalyptus (1 m × 1 m)	5.0-12.5	8.5-21.0
T_3: Casuarina (1 m ×1 m)	3.5-5.9	5.0-8.5
T_4: Poplar (1.2 m × 1.2 m)	5.3-8.0	10.0-19.5
T_5: Eucalyptus (1.2 m× 1.2 m)	4.5-9.0	8.0-19.1
T_6: Casuarina (1.2 ×1.2 m)	2.8-6.1	5.0-10.5
T_7: Poplar (1.5 m × 1.5 m)	3.8-9.0	6.8-18.5
T_8: Eucalyptus (1.5 m × 1.5 m)	4.0-9.3	6.5-14.9
T_9: Casuarina (1.5 m × 1.5 m)	2.5-5.8	3.8-9.8

Linear regression model of bole, ~~branches,~~branches, leaves and above ground biomass of tree ~~was~~ is shown in table 2**.** The bole linear function showed for height and ~~grith~~girth in 2nd year maximum R^2 was 0.969 ~~found~~ in T_8: Eucalyptus (1.5 m× 1.5 m) ~~0.969~~ followed by 0.958 in T_6: Casuarina (1.2 m × 1.2 m) ~~0.958~~ and minimum of 0.755 in T_7: Poplar (1.5 m × 1.5 m) ~~0.755~~ whereas a maximum height ~~was maximum~~ R^2 of 0.842 was found in 2nd year T_6: Casuarina (1.2 m × 1.2 m) ~~0.842~~ followed by 0.808 in T_4: Poplar (1.2 m ×1.2 m) ~~0.808~~ and minimum of 0.485 in T_3: Casuarina (1 m × 1 m) ~~0.485~~. The bole linear function ~~showed~~ for ~~grith~~girth was maximum R^2 of 0.956 ~~found in 2nd year~~ in T_2: Eucalyptus (1 m × 1 m) ~~0.956~~ followed by 0.950 in T_6: Casuarina (1.2 m × 1.2 m) ~~0.950~~ and minimum of 0.597 in T_7: Poplar (1.5 m × 1.5 m) ~~0.597~~. Similarly, result reported in allometric equations for *E. camaldulensis* for biomass height calculated R^2 values were for bole (0.94) [22]. The bole biomass of *C. equisetifolia* regression equation displayed maximum correlation with dbh R^2 =

Comment [E10]: Range should show the first lowest value to the last highest value fo example 3-7 or 10-24. one value is either an average of a number

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Comment [E12]: What is the reference for?

Comment [E13]: The term "maximum height" in third last sentence and last sentence are confusing.

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0.97 [23]. The *E. tereticornis* adjusted R^2 for fitted functions varied from 0.911 to 0.995 for different components [24].The logarithmic Black willow and eastern cottonwood model that used square of dbh then multiplied by height was the best fitting model (Adj. $R^2 = 0.982$) for the single tree AGB. Whereas a model that used dbh and total stem height as separate predictors was the best fitting model (Adj. $R^2 = 0.954$) for eastern cottonwood [25].

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 m × 1 m)	W=a + bH + cG	a. b. c	-4.20, - 0.026, 0.483	0.905	-0.443, 0.150, 0.012	0.740	-0.338, -0.007, 0.067	0.607	-4.981, 0.117, 0.562	0.912
	W=a + bH	a, b	-3.847, 1.034	0.641	-0.434, 0.176	0.733	-0.289, 0.140	0.424	-4.570, 1.350	0.687
	W=a + cG	a, c	-4.232, 0.475	0.905	-0.262, 0.061	0.590	-0.346, 0.065	0.607	-4.840, 0.600	0.910
T_2: Eucalyptus (1m×1m)	W=a + bH + cG	a. b. c	-4.081, -0.137, 0.60	0.951	-0.249, 0.078, 0.038	0.947	0.014, 0.149, 0.007	0.854	-4.316, 0.090, 0.645	0.976
	W=a + bH	a, b	-7.858, 1.807	0.708	-0.487, 0.200	0.850	-0.030, 0.172	0.849	-8.376, 2.180	0.763
	W=a + cG	a, c	-4.466, 0.568	0.956	-0.03, 0.056	0.918	0.434, 0.042	0.704	-4.062, 0.667	0.976
T_3: Casuarina (1m×1m)	W=a + bH + cG	a. b. c	-1.213, 0.037, 0.239	0.774	-0.086, 0.074, 0.009	0.700	0.091, 0.075, 0.004	0.644	-1.208, 0.186, 0.252	0.835
	W=a + bH	a, b	-0.714, 0.387	0.485	-0.067, 0.088	0.688	0.099, 0.081	0.642	-0.682, 0.555	0.632
	W=a + cG	a, c	-1.185, 0.253	0.772	-0.030, 0.039	0.494	0.149, 0.033	0.409	-1.066, 0.325	0.805
T_4: Poplar (1.2m×1.2m)	W=a + bH + cG	a. b. c	-3.02, 0.591, 0.148	0.885	-0.450, 0.139, 0.27	0.838	-0.155, 0.084, 0.009	0.772	-3.624, 0.814, 0.184	0.927
	W=a + bH	a, b	-2.388, 0.901	0.808	-0.335, 0.196	0.786	-0.116, 0.103	0.752	-2.838, 1.200	0.857
	W=a + cG	a, c	-2.44, 0.304	0.731	-0.313, 0.064	0.662	-0.072, 0.031	0.550	-2.822, 0.399	0.753
T_5: Eucalyptus (1.2m×1.2m)	W=a + bH + cG	a. b. c	-3.037, 0.174, 0.314	0.914	-0.027, 0.027, 0.042	0.805	0.067, 0.045, 0.049	0.861	-3.00, 0.246, 0.406	0.925
	W=a + bH	a, b	-2.610, 0.790	0.741	0.030, 0.109	0.661	0.134, 0.142	0.731	-2.446, 1.041	0.756
	W=a + cG	a, c	-2.851, 0.378	0.905	0.002, 0.052	0.793	0.116, 0.066	0.840	-2.733, 0.496	0.914
T_6: Casuarina (1.2m×1.2m)	W=a + bH + cG	a. b. c	-1.295, 0.127, 0.196	0.958	-0.080, 0.111, -0.004	0.826	-0.050, 0.093, 0.026	0.816	-1.425, 0.331, 0.218	0.965
	W=a + bH	a, b	-1.389, 0.559	0.842	-0.078, 0.101	0.825	-0.062, 0.151	0.789	-1.529, 0.811	0.892
	W=a + cG	a, c	-1.179, 0.243	0.950	0.021, 0.037	0.641	0.035, 0.061	0.759	-1.123, 0.340	0.937
T_7: Poplar (1.5m×1.5m)	W=a + bH + cG	a. b. c	-0.570, 0.138, 0.076	0.755	-0.256, 0.091, 0.019	0.712	-0.29, 0.018, 0.036	0.688	-1.114, 0.248, 0.131	0.834
	W=a + bH	a, b	-0.025, 0.219	0.507	-0.117, 0.112	0.634	-0.029, 0.057	0.260	-0.171, 0.387	0.568
	W=a + cG	a, c	-0.294, 0.104	0.597	-0.074, 0.038	0.382	-0.252, 0.040	0.667	-0.619, 0.181	0.652
T_8: Eucalyptus (1.5m×1.5m)	W=a + bH + cG	a. b. c	-2.913, 0.292, 0.271	0.969	-0.072, 0.080, 0.020	0.772	-0.428, 0.231, 0.005	0.837	-3.413, 0.603, 0.296	0.962
	W=a + bH	a, b	-2.364, 0.746	0.668	-0.031, 0.114	0.696	-0.418, 0.240	0.836	-2.813, 1.100	0.771
	W=a + cG	a, c	-2.181, 0.350	0.913	0.128, 0.042	0.584	0.152, 0.067	0.409	-1.901, 0.458	0.835
T_9: Casuarina (1.5m×1.5m)	W=a + bH + cG	a. b. c	-0.519, -0.033,0.185	0.912	-0.115, 0.047, 0.032	0.709	-0.064, 0.048, 0.046	0.903	-0.698, 0.061, 0.262	0.921
	W=a + bH	a, b	-0.428, 0.315	0.683	-0.10, 0.106	0.652	-0.041, 0.134	0.811	-0.569, 0.556	0.757
	W=a + cG	a, c	-0.537, 0.171	0.910	-0.09, 0.051	0.681	-0.038, 0.066	0.882	-0.665, 0.287	0.919

Where, a= Intercept; b and c= slope

The branch's linear function showed for height and ~~grith~~girth was maximum R^2 in 2^{nd} year found in T_2: Eucalyptus (1 m × 1 m) 0.947 followed by T_4: Poplar (1.2 m × 1.2 m) 0.838 and minimum in T_9: Casuarina (1.5 m × 1.5 m) 0.709 whereas height was shown maximum R^2 found in 2^{nd} year in T_2: Eucalyptus (1 m × 1 m) 0.850 followed by T_6: Casuarina (1.2 m × 1.2 m) 0.825 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.634. The branch's linear function showed for ~~grith~~girth was maximum R^2 found 2^{nd} year in T_2: Eucalyptus (1 m × 1 m) 0.918 followed by T_5: Eucalyptus (1.2 m × 1.2 m) 0.793 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.382. Similarly, result of allometric equations for *E. camaldulensis* for biomass height calculated R^2 values were for branch 0.95 [22]. The *C. equisetifolia* regression equation for branches displayed maximum R^2 value of 0.92 [23].

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The leaves' linear function showed for height and ~~grith~~girth was maximum R^2 in 2^{nd} year maximum found in T_9: Casuarina (1.5 m × 1.5 m) 0.903 followed by T_5: Eucalyptus (1.2 m × 1.2 m) 0.861 and minimum in T_1: Poplar (1 m × 1 m) 0.607 whereas height was shown maximum R^2 found in 2^{nd} year in T_2: Eucalyptus (1 m × 1 m) 0.849 followed by T_8: Eucalyptus (1.5 m × 1.5 m) 0.836 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.260. The leaves' linear function showed for ~~grith~~girth was maximum R^2 found in 2^{nd} year T_9: Casuarina (1.5 m × 1.5 m) 0.882 followed by T_5: Eucalyptus (1.2 m ×1.2 m) 0.840 and minimum in T_3: Casuarina (1 m ×1 m) and T_8: Eucalyptus (1.5 m × 1.5 m) 0.409. Similar~~,~~ result of allometric equations for *E. camaldulensis* for height calculated R^2 values were for leaves biomass 0.97 [22].

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The AGB linear function showed for height and ~~grith~~girth ~~was~~ of maximum R^2 in 2^{nd} year maximum found in T_2: Eucalyptus (1 m × 1 m) 0.976 followed by T_6: Casuarina (1.2 m × 1.2 m) 0.965 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.834 whereas height ~~was~~ shown maximum R^2 found in 2^{nd} year maximum in T_6: Casuarina (1.2 m × 1.2 m) 0.892 followed by T_4: Poplar (1.2 m × 1.2 m) 0.857 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.568. The AGB linear function showed for ~~grith~~girth ~~was~~ maximum R^2 found in 2^{nd} year T_2: Eucalyptus (1 m × 1 m) 0.976 followed by T_6: Casuarina (1.2 m × 1.2 m) 0.937 and minimum in T_7: Poplar (1.5 m × 1.5 m) 0.652. Similarly, result was reported the maximum R^2 value under Poplar 1.5m×1.5m spacing in both height and girth-based regression model after one year of plantation [13]. The AGB of *E. Tereticornis* adjusted R^2 for fitted functions varied from 0.911 to 0.995 [24].The R^2 = 0.982 for equation of AGB of Black willow and R^2 = 0.954 for eastern cottonwood are logarithmic model that used square of dbh and height [25].

Comment [E23]: You need to learn proper to discuss other studies' results compared with your results. All related studies may not always show similar results but trends and negative results depending on the treatments advanced in each. Discussing this in relation to your study treatments makes your work interesting and more sceintific.

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The bole biomass (kg tree^{-1}) maximum found after 2nd year T_4: Poplar (1.2_m_× 1.2_m) 2.885 kg tree^{-1} followed by T_2: Eucalyptus (1_m_×_1_m) 2.801_kg tree^{-1} and minimum in T_3: Casuarina (1_m_×_1_m) 0.471_kg tree^{-1} whereas branch biomass maximum found in T_2: Eucalyptus (1_m_× 1_m) 0.868 kg tree^{-1} followed by T_4: Poplar (1.2_m_× 1.2_m) 0.830 kg tree^{-1} and minimum in T_9: Casuarina (1.5_m_× 1.5_m) 0.291_kg tree^{-1}. The leaves biomass maximum found in 2nd-year maximum found in T_2: Eucalyptus (1_m_×_1_m) 1.277_kg tree^{-1} followed by T_8: Eucalyptus (1.5_m_× 1.5_m) 1.072_kg tree^{-1} and minimum in T_7: Poplar (1.5_m_× 1.5_m) 0.222_kg tree^{-1} whereas_ AGB maximum in T_2: Eucalyptus (1_m_×_1_m) 4.946_kg tree^{-1} followed by T_4: Poplar (1.2_m× 1.2_m) 4.233 kg tree^{-1} minimum in T_9: Casuarina (1.5_m_× 1.5 m) 1.236 kg tree^{-1} shown in table 3.

Comment [E27]: Make use of connectors to make the meaning of the sentense come out clear

Comment [E28]: Report this results well. Then find other studies that can compare with this result and discuss them

Table 3: Bole, branches, leaves_and AGB (kg tree^{-1}) of three fast-growing species under HDP

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Treatment	**Bole (kg tree^{-1})**	**Branches (kg tree^{-1})**	**Leaves (kg tree^{-1})**	**AGB (kg tree^{-1})**
T_1: Poplar (1_m_× 1_m)	1.039	0.582	0.369	1.990
T_2: Eucalyptus (1_m_× 1_m)	2.801	0.868	1.277	4.946
T_3: Casuarina (1_m_× 1_m)	0.471	0.318	0.468	1.256
T_4: Poplar (1.2_m_× 1.2_m)	2.885	0.830	0.517	4.233
T_5: Eucalyptus (1.2_m_× 1.2_m)	1.564	0.613	0.904	3.089
T_6: Casuarina (1.2_m_× 1.2_m)	0.719	0.408	0.572	1.699
T_7: Poplar (1.5_m_× 1.5_m)	1.085	0.482	0.222	1.797
T_8: Eucalyptus (1.5_m_× 1.5_m)	1.723	0.637	1.072	3.431
T_9: Casuarina (1.5_m_× 1.5_m)	0.520	0.291	0.436	1.236
S Em ±	0.08	0.01	0.02	0.11
CD (0.05)	0.25	0.04	0.06	0.33
CV %	10.01	4.46	5.15	7.27

Similarly, result was reported in *E. tereticornis* dry bole, branches, leaves and AGB 67.64, 5.17, 4.33 and 77.15 kg tree^{-1} respectively in a plantation of ~~after~~ four years ~~of plantation~~ [19]. The above-ground biomass production (kg tree^{-1}) was *Eucalyptus tereticornis* 24.1 >*A. excelsa* 21.8 >*M. azedarach* 12.6 >*Populus deltoides*clone G 48 8.3 >*Alstoniascholaris* 6.6>*Pongamia pinnata* 3.7 [26]. The_Poplar biomass was reported higher

Comment [E29]: You are fond of this term similary. Please find its meaning and use it correctly.

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Comment [E31]: This ststement does not make any sense in agroforestry trees (1,223 kg tree^{-1}) than in monoculture plantation trees (1,102 kg tree^{-1}) [27]. The AGB was maximum were found in T_2: Eucalyptus (1 m × 1 m) 0.676 kg tree^{-1} followed by T_5: Eucalyptus (1.2 m × 1.2 m) 0.598 kg tree^{-1} and minimum in T_9: Casuarina (1.5×1.5m) 0.214 kg tree^{-1} after one year [13].

Conclusion

Among the three fast growing tree species, Eucalyptus (1 m × 1 m) spacing shows maximum height, girth and biomass. Hence after two years of study Eucalyptus (1 m × 1 m) spacing showed better growth and biomass production, so this spacing is recommended. Among all the species and spacing the regression equation of bole, branches, leaves and AGB height and girth-based model was most suitable equation for estimation and prediction of biomass. Evaluation of biomass prediction equation on the criteria of coefficient of determination (R^2) estimated that multi-variable (including both the growth characteristics *viz.*, H and G) linear functions are much more precision and accuracy.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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Comment [E33]: Reference significance?

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Comment [E35]: Recommeded for growing Eucalyptus for certain objective or rotations, not all purpose. You should therefore specify here what rotation it was. It is clear that better girth and height in Eucalyptus plantation is obtained in 2.5 spacing. This spacing also allows for machanisation.

Comment [E36]: Revise the terms to align the meaning

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