The Pharma Innovation Journal 2022; 11(3): 1945-1951

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(3): 1945-1951

www.thepharmajournal.com
Received: 04-01-2022
Accepted: 09-02-2022

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Tree spacing effect on growth and yield of *Eucalyptus urophylla* S.T. Blake: Prominent species for pulp and paper industry

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Abstract
Paper being an essential commodity in day-to-day use, forms the core sector of our economy. *Eucalyptus urophylla* S.T. Blake is a fast-growing eucalypt species used primarily for pulp and paper boards due to their acceptable wood quality, rapid growth, and high volumetric yield. Spacing has a significant role in tree growth parameters and stand's yield. This study aims to know the influence of spacing on growth and yield parameters in five different spacing at six years. Spacing significantly affected growth traits (height, diameter at breast height, clear bole height, and crown width), total biomass, and pulpwood production. Individual tree growth and biomass were higher at wider spacing (3.00 m × 3.00 m), whereas the total biomass per stand was higher with closer spacing (2.00 m × 3.00 m). The current study reveals that pulpwood yield can be increased by 25 per cent higher in *E. urophylla* at the test site by following a close spacing of 2.00 m × 3.00 m compared to wider spacing (2.75 m × 3.00 m), even if the survival rate is slightly lower.

Keywords: Biomass, *Eucalyptus urophylla*, pulpwood, spacing, wood yield

Introduction
The paper industry occupies a vital position in the Indian economy for its extended role in industrialization and social sector development. Global pulpwood consumption is expected to increase dramatically in the decades ahead due to consumer demand. If not managed sustainably, this growth could further drive deforestation and affect tropical ecosystems. Elias and Boucher (2014) [9] predicted that the total consumption of all wood products is expected to be greater in 2060 compared to present-day consumption. Still, the most notable increases in projected wood product consumption by 2060 will be in pulp and paper. In India, the paper industry is forecasted to grow from $8.6 billion in 2018 to $13.4 billion by 2024 (Davidson, 2021) [8].

Indian forests have been under intense pressure from growing demand for alternative land use, pulpwood, and non-timber forest products. The imbalance between supply and demand for forest products is increasing that pulp and paper industry now source their raw material requirement on a sustainable basis from mostly the plantations outside forest land such as social and farm forestry plantation (Kulkarni, 2013) [18]. The pressure on land has increased in the last decade, and it is essential to increase productivity to satisfy the increasing wood demand. Silvicultural management affects growth and wood properties in tree species through the interaction between biological processes and environmental conditions such as temperature, precipitation, nutrients, and light (Guzmán *et al.*, 2017) [12]. Planting density and site preparation can influence tree growth and silvicultural practices like thinning and nutrient application. Spacing affects the rate of growth and stand productivity and the cost of management in short-rotation plantations. Therefore, the choice of optimum spacing usually involves a balance between the time needed to attain desired tree size, maximize biomass production, and reduce the cost of management and utilization.

When the Indian paper industry encountered an acute shortage of quality raw material, an initiative was taken to explore the possibility of paper production from alternative sources like eucalyptus, poplar, subabul, *etc.* Eucalyptus is widely raised in India due to its short-term tangible benefits (timber, fuel, and oil), fast growth rate, and can be made available for pulp production within four to five years after planting (Rana *et al.*, 2014) [24]. The increasing demand for the species partly results from the attractive economic return from the plantations.

Eucalyptus urophylla S.T. Blake is widely used for pulp production in high rainfall regions due to rapid growth, high wood yield (30-50 m^3 ha^{-1} yr^{-1} at 5 to 10 years of age), acceptable wood properties, and pulp yield (Kien *et al.*, 2009) [17]. A package of practice needs to be developed for *E. urophylla* concerning the optimum spacing, fertilizer requirement, and other management practices, which are essential for the successful cultivation of the species in India. This study evaluates the effect of spacing on growth and yield parameters of *Eucalyptus urophylla*.

Materials and Methods

The field trial was established with *Eucalyptus urophylla* clone EUB 31 of Mysore Paper Mills (MPM) in five different spacings at Ambutheertha, Bhadravathi in Shivamogga district of Karnataka state, India, in 2006 in a Randomized Complete Block Design (RCBD) with five replications (Table 1). Trees in the trial were evaluated for growth and survival after six years of planting. Growth traits such as diameter at breast height (cm), total height (m), clear bole length (m), and crown width (m) were recorded.

For biomass estimation, representative trees (three trees per replication) of mean diameter were selected in each treatment and harvested at stump height in each replication. Above ground portion (without stump), of the felled tree, was separated into bole wood, branch wood, bark, and foliage, and the fresh weight of each portion was recorded. Bole wood, branch wood, bark, and foliage (each weighing one kilogram) were collected in sealed polyethylene bags for laboratory analysis. In the laboratory, the samples were oven-dried - leaves at 70° C; bole wood, branch wood, and bark at 100° C for 72 hours. The biomass of the tree was estimated as the sum of the dry weight of different components - bole wood, branch wood, bark, and leaf. Biomass of the plot was calculated as the product of the number of surviving trees in each plot and the average tree biomass and then extrapolated to a per hectare basis. Total biomass for each treatment was computed as the sum of above-ground biomass and below-ground biomass. Below ground biomass was estimated as above-ground biomass per hectare × 0.26 (IPCC, 2006) [15]. Individual tree volume is the product of basal area (m^2), total height (m), and form factor (0.33) and extrapolated to per hectare basis (m^3 ha^{-1}). Mean annual increment in wood volume (m^3 ha^{-1} yr^{-1}) was obtained by dividing wood volume (m^3 ha^{-1}) by stand age. The pulpwood weight was calculated as the product of wood dry weight and the total number of trees in the plot. Wood weight per hectare (Mg ha^{-1}) and mean annual increment (Mg ha^{-1} yr^{-1}) were estimated based on pulpwood weight. Growth and yield parameters were analyzed using one-way analysis of variance (ANOVA), and allometric regression equations were developed to estimate the biomass and pulp yield by considering easily measurable parameters like height and DBH using GENSTAT software (Genstat 5 Release 3.2)

Table 1: Spacing regimes evaluated in *E. urophylla*

Treatments	Plot Area (m^2)	No. of trees in the plot	Trees ha^{-1}
T_1- 2.00 m × 3.00 m	240.00	40	1666
T_2- 2.25 m × 3.00 m	236.00	35	1481
T_3 - 2.50 m × 3.00 m	225.00	30	1333
T_4-2.75 m × 3.00 m	247.50	30	1212
T_5-3.00 m × 3.00 m	225.00	25	1111

Results and Discussion

Spacing effect on survival percentage

Tree spacing is an essential silvicultural tool that influences the sequence of future silvicultural treatments required and, ultimately, the stand attributes at harvesting age. Survival rate (%) is a parameter that influences the growth and development of forest stands. The survival rate among treatments in the present study did not differ significantly. Maximum survival rate was observed in 3.00 m × 3.00 m (100 %) followed by 2.25 m × 3.00 m showing 99.53 %. High survivals and volume growth are significant factors determining the overall wood yield from plantations. The prevailing survival rate in the present study was high. As seen in Table 2, different spacing regimes did not impact survival, with a high survival rate of 97-100 per cent in all treatments (2.00 m - 3.00 m spacing within rows and 3.00 m between rows). High survival indicates that competition between the trees for light and other resources was not severe at the harvest age of six years, even at a close spacing of 2.00 m x 3.00 m. This could be endorsed because the crown width of trees was less than 2.0 m in most treatments (Table 2). Due to the competition for available resources, mortality would be evident at close spacing only if trees are grown to longer rotations for timber. Akin to the present findings, Prasad *et al.* (2010) [23] opined that the tree survival was not significantly affected by spacing at a harvest age of four years in eucalyptus-based agroforestry plantations. Whereas Erasmus *et al.* (2018) [10] recorded low survival rates for *Pinus patula* in the closely spaced treatments, that is around 66 per cent survival against the 96 per cent in wider spacing.

Table 2: Effect of spacing on growth parameters

Treatments	Survival rate (%)	DBH (cm)	Height (m)	Clear Bole height (m)	Crown width (m)	Volume (m^3)
T_1	99.18 (84.8) $^{\Delta}$	16.03 ^{a}	16.88 ^{b}	15.13 ^{a}	1.15 ^{a}	0.12 ^{a}
T_2	99.53 (86.1) $^{\Delta}$	16.47 ^{ab}	16.45 ^{a}	15.35 ^{a}	1.16 ^{a}	0.12 ^{a}
T_3	97.28 (80.5) $^{\Delta}$	17.08 ^{c}	17.96 ^{d}	15.46 ^{b}	1.56 ^{b}	0.14 ^{c}
T_4	99.46 (85.8) $^{\Delta}$	16.92 ^{bc}	16.85 ^{ab}	15.14 ^{a}	1.70 ^{c}	0.13 ^{b}
T_5	100.00 (90.0) $^{\Delta}$	17.72 ^{d}	17.42 ^{c}	15.42 ^{a}	1.98 ^{d}	0.15 ^{d}
S. Em (±)	2.65	0.19	0.16	0.01	0.16	0.004
CD.(0.05)	NS	0.47	0.40	0.03	0.40	0.009

$^{\Delta}$ Parenthetical values are arc sine transformed;
Figures with similar letters as superscript do not differ significantly; CD- Critical Difference

Spacing effect on growth parameters

Stem diameter is the most common measure of secondary growth and is usually measured as diameter at breast height (DBH). Despite no significant variation in the survival rate, considerable variation was observed in diameter growth with different spacing (Table 2). DBH was highest (17.72 cm) with wide spacing (3.00 m × 3.00 m), the lowest (16.03 cm) with least spacing (2.00 m × 3.00 m), and intermediate for other treatments. This finding reveals that the diameter increment of an individual tree is not affected until the maximum utilizable growing space is reached, beyond which competition for available space influences diameter growth. A similar increase in mean stem diameter with increased spacing was recorded in *Acrocarpus fraxinifolius* (Kumar *et al.*, 2014) [19]. Zahabu *et al*. (2015) [26] stated that the increasing diameter with increasing spacing is because trees at wider spacing effectively utilize the advantage of having more growing space for crown and root development due to reduced competition and observed a similar trend for *Tectona grandis*. However, tree height did not follow the same trend as DBH (Table 2).

Maximum tree height was recorded for the spacing 2.50 m × 3.00 m (17.96 m), followed by the spacing 3.00 m × 3.00 m (17.42 m). It was least for the espacement 2.25 m × 3.00 m (16.45 m). Several parameters influence tree height, and some species exhibit slow height growth during the preliminary establishment years. Eucalypts are, however, capable of accomplishing very rapid height growth at an early age and the majority of eucalypts plantations achieve their most significant annual height increment before five years (Forrester *et al.*, 2010) [11]. Contrary to the present observations, Erasmus *et al*. (2018) [10] revealed that plant spacing had a highly significant effect on mean tree height wherein tree height decreased by eight per cent from wider spacing to closer spacing. Further, clear bole height (CBH) is a qualitative genetic trait less influenced by the environment than other growth traits. However, this trait is of great significance in clonal forestry, where the emphasis is on maximizing the volume of the main trunk. There was a significant difference in clear bole height and crown width for different spacing. The minimum values were observed in the closer spacing and maximum values in wider spacing (Table 2). A study conducted by Mohamed *et al.* (2018) [20] on *Hardwickia binate* revealed that maximum clear bole height recorded was in closer spacing (3 m × 5 m) while minimum in wider spacing (3 m × 10 m), which was in line with the present observation.

Tree crown in fast-growing young eucalypts is generally conical (Bhardwaj *et al.*, 2017) [4], but increased competition can result in skewed upward foliage distribution (Alcorn *et al.*, 2012) [1]. It was observed that the crown width increased with an increase in spacing. Maximum crown width was noticed with the widest spacing of 3.00 m × 3.00 m (1.98 m) and the least in the close spacing of 2.00 m × 3.00 m (1.15 m). The lower crown width in closer spacing might be due to the reduced light availability due to increased competition from neighboring trees. Similar results were also reported by Britt and Reynolds (2013) [5] for loblolly pine. Likewise, Khan and Chaudhry (2007) [16], observed a significant difference in crown width of *Populus deltoides* under different spacing regimes (3.7 m × 6.1 m, 3.7 m × 9.1 m, and 3.7 m × 12.1 m), a linear relationship between poplar tree densities and crown width prevailed revealing that with an increase in tree spacing crown width increased and vice versa.

Spacing significantly affected volume production per tree, varying from 0.12 m^3 to 0.15 m^3. Among the different spacing regimes, maximum volume (0.15 m^3) was produced with 3.00 m × 3.00 m spacing. Total volume increased per tree with wider spacing (Table 3), and the lowest volume (0.12 m^3) was recorded for 2.00 m × 3.00 m and 2.25 m × 3.00 m spacing. Since competition for growth resources is less in wider spacing, volume production is high. More significant diameter growth in wide spacing is a major contributing factor for increased volume production. The higher individual stem volume was obtained in the widest plantation spacing, which is in line with the results of studies conducted to know the effect of spacing on the wood volume of *Pinus taeda* (Cardoso *et al.*, 2018) and *Pinus ponderosa* (Zhang *et al.*, 2013) [27]. This could be ascribed to the fact that the light penetration in the plantation with the widest spacing will lengthen the survival of the lower branches so that their diameter and axial growth continue over a more extended period (Beaulieu *et al.*, 2011) [2].

Wood volume and mean annual increment (m^3 ha^{-1}) did not vary significantly across the different treatments (Table 3). However, it was noticed that the wood volume per stand decreased with increased spacing. A higher value for wood volume was recorded in 2.00 m × 3.00 m and, the lowest was noticed in 2.75 m × 3.00 m. Among the different spacing treatments, the highest mean annual increment of wood volume was recorded in 2.00 m × 3.00 m (31.56 m^3 ha^{-1} yr^{-1}), and the minimum increment was registered for 2.75 m × 3.00 m (27.24 m^3 ha^{-1} yr^{-1}). In the short rotation and no thinning in these pulpwood plantations, a significant gain in volume (180.30 m^3 ha^{-1}) was evident at six years of age from planting closer than the normal square spacing of closer spacing (2.00 m × 3.00 m). Penner *et al.* (2001) [22] also reported that close spacing (2.10 m spacing) would give the highest merchantable wood per unit area in *Pinus resinosa*. Close spacing can accommodate more trees per unit area, but sufficient care must be taken to prevent competition for resources and density-dependent mortality in stands.

Table 3: Effect of spacing on wood yield

Treatments	Wood Volume (m^3 ha^{-1})	MAI (m^3 ha^{-1} yr^{-1})	Pulp Wood Weight (Mg ha^{-1})	MAI (Mg ha^{-1} yr^{-1})
T_1	189.30	31.56	72.80 ^{b}	12.14 ^{b}
T_2	175.20	29.21	71.8 ^{b}	11.96 ^{b}
T_3	182.90	30.49	58.90 ^{a}	9.81 ^{a}
T_4	163.50	27.24	58.44 ^{a}	9.74 ^{a}
T_5	164.80	27.47	65.72 ^{ab}	10.95 ^{ab}
S. Em (±)	9.12	1.52	3.80	0.634
CD.(0.05)	NS	NS	11.46	1.91

Figures with similar letters as superscripts do not differ significantly
CD- Critical Difference; NS- Non-significant
MAI- Mean Annual Increment

Since pulpwood is procured in India on a weight basis, the spacing that gives maximum tonnage per unit area would ensure the best returns to the grower. As seen earlier, maximum pulpwood weight (Table 3) was obtained with the close spacing of 2.00 m × 3.00 m (72.80 Mg ha^{-1}), almost 25 per cent higher than that obtained with wider spacing of 2.75 m × 3.00 m (58.44 Mg ha^{-1}). Likewise, mean annual increment (pulpwood weight) also increased significantly with reduced spacing; 9.74 Mg ha^{-1} yr^{-1} (2.75 m × 3.00 m) to 12.14 Mg ha^{-1} yr^{-1} (2.00 m × 3.00 m). Pulpwood produced under the wider spacing (3.00 m × 3.00 m) was on par with closer spacing treatments (Table 2), which could be ascribable to a higher survival rate (100 %) of trees and higher pulpwood production by the individual tree (Table 3) under wider spacing. Similar to the present observation Hegde *et al.* (2015) [14] opined that for Acacia hybrid clones, optimum tree density of 1600 plants per ha (grown at the closer spacing of 2.50 m × 2.50 m) is ideal for maximum pulpwood production on a short rotation.

Spacing effect on biomass production

The influence of spacing on different biomass parameters of an individual tree was prominent in the current study. The biomass of an individual tree increased with increased spacing regimes. Bark dry weight for different spacing regimes varied significantly, and the mean values are presented in Table 4. Above-ground biomass and the biomass of each tree component (bark, branch wood, foliage, and pulpwood) varied significantly with spacing. The values for bark dry weight ranged from 6.99 kg to 8.82 kg. The estimated means were highest in treatment 3.00 m × 3.00 m, which was significantly superior over all the other treatments. Observations on the branch wood dry weight of different treatments were analyzed, and the estimated means significantly varied, with values ranging from 2.78 kg to 5.59 kg. The highest branch wood dry weight value was observed in 2.50 m × 3.00 m among the different spacing treatments. The pulpwood dry weight for different spacing treatments varied from 44.4 kg to 59.2 kg. The treatment 3.00 m × 3.00 m was superior to all the other treatments with an average mean of 72.8 kg of total dry weight and the least total dry weight (54.1 kg) recorded in 2.25 m × 3.00 m. Above-ground biomass and total biomass produced per hectare in different spacing treatments vary significantly. The closer spacing was significantly superior over the other treatments (94.9 Mg ha^{-1}). The values for the total biomass ranged from 89.6 Mg ha^{-1} to 119.6 Mg ha^{-1}.

Table 4: Effect of spacing on biomass production

Treatments	Individual tree					Stand	
	Bark Dry weight (kg)	Branch wood dry weight (kg)	Leaf dry weight (kg)	Pulpwood dry weight (kg)	Total dry weight (kg)	Above ground Biomass (Mg ha^{-1})	Total Biomass (Mg ha^{-1})
T_1	6.94 ^{ab}	2.87 ^{a}	1.00 ^{a}	44.40 ^{a}	54.30 ^{a}	94.90 ^{c}	119.60 ^{b}
T_2	6.82 ^{a}	2.78 ^{a}	1.09 ^{a}	44.50 ^{a}	54.10 ^{a}	79.40 ^{b}	100.00 ^{a}
T_3	8.16 ^{bc}	5.59 ^{c}	1.03 ^{a}	46.10 ^{a}	59.90 ^{a}	76.40 ^{a}	96.30 ^{a}
T_4	6.99 ^{ab}	3.61 ^{ab}	1.30 ^{ab}	48.80 ^{a}	59.40 ^{a}	71.10 ^{a}	89.60 ^{a}
T_5	8.82 ^{c}	4.86 ^{bc}	1.59 ^{b}	59.20 ^{b}	72.80 ^{b}	80.90 ^{b}	102.00 ^{a}
S. Em (±)	0.44	0.49	0.11	3.14	3.61	4.80	8.56
CD.(0.05)	1.33	1.46	0.33	9.41	10.82	6.79	18.25

Figures with similar letters as superscripts do not differ significantly
CD-Critical Difference

The aforementioned results revealed that the biomass of an individual tree increased with increased spacing regimes. This could be closely related to the crown width as the crown of an individual tree increased with an increase in spacing. In wider spacing, trees produce larger crowns with more foliage for photosynthesis resulting in more biomass production. The effect of spacing on relative resource capture is amplified as competition for resources could be less in wide spacing due to a smaller number of trees per unit area, which would have resulted in higher biomass production per tree. Comprehending the influence of spacing and the species' response in growth and biomass accumulation in various plant parts over time is essential. In the current study, above-ground biomass and the biomass of each tree component (bark, branch wood, foliage, and pulpwood) varied significantly with spacing. Generally, wider spacing produced more bark, branch wood, leaf, and pulpwood in individual trees. Hegazy *et al.* (2008) [13] reported that in *Conocarpus erectus*, the biomass of an individual tree increased with increased spacing regimes. Akin, Benomar *et al*. (2012) [3], stated that increased spacing between trees significantly increased above-ground biomass at the individual tree level after the first six growing seasons in two hybrid poplar clones. Biomass allocation of individual trees in different spacing regimes revealed that more than 80 per cent of the above-ground biomass is allocated towards pulpwood production and less than 10 per cent for bark production (Fig. 1). Allocation of more biomass for bark, foliage, and branch wood production would affect the quantity of marketable pulpwood.

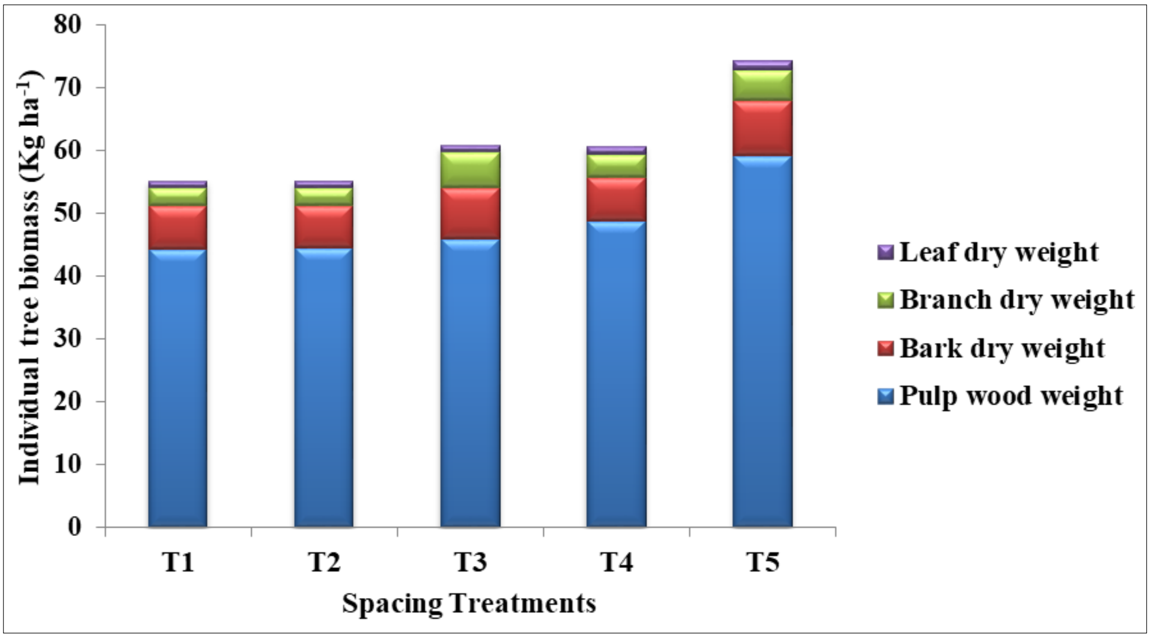

Fig 1: Biomass allocation pattern under different spacing treatments

The total biomass of the stand (which includes both above-ground and below-ground biomass) also varied with different spacing treatments. Allocation of photosynthate to various components of the plant systems is an essential physiological process; biomass allocation strategies of plants need to be understood for an effective captive plantation programme. Clear bole wood volume, low branching, and narrow crown are attributes used for selecting plus trees. Spacing is also as important as the genetic potential of the genotype to obtain the maximum allocation of biomass for bole wood production. Considerable variation among the different spacing treatments was observed in the above-ground biomass of the stand. Above-ground biomass in the stand was found to be high for 2.00 m × 3.00 m spacing producing 94.90 Mg ha^{-1}, whereas it was lowest for the spacing 2.75 m × 3.00 m (71.1 Mg ha^{-1}). The total biomass production also showed the same trend (high in 2.00 m × 3.00 m spacing and the least for 2.75 m × 3.00 m). Closer spacing led to greater biomass production due to more trees per unit area. The results are in accord with Nagar *et al*. (2015) [21] for *Eucalyptus Camaldulensis* and Chotchutima *et al.* (2013) [7] for *Leucaena leucocephala* signifying that the maximum total wood biomass was observed in closer spacing due to the greater number of trees present compared to wider spaced regimes.

Allometric regression equation

Determination of yield in a stand is of paramount importance for a forest manager to decide on harvesting and marketing of the products. The development of an easy and quick approach is desirable in forest yield prediction. Estimating yield through an allometric regression equation is common in forest management. In the present study, such an allometric equation to calculate the biomass of trees was developed to predict total biomass, based on easily measurable growth parameters (Table 5). These equations aid in assessing the biomass, based on given parameters such as DBH and height. The standing biomass of the tree can be estimated with the help of equation 1 when only DBH is taken. Similarly, equation 2 can be used by using the tree's height. Determination of total biomass of standing can be made with the help of equation 3 by considering DBH and the height of the tree. To estimate the pulpwood weight based on DBH and height allometric equations were also developed and are presented in Table 6. These equations assist in computing the pulpwood based on given parameters such as DBH and height. The quantity of pulpwood in a standing tree can be determined with the help of regression equation 1 using DBH and equation 2 using height. Pulpwood present in a standing tree can be quantified with the help of equation 3 by considering both DBH and height. The use of diameter as an independent variable in estimating both total biomass and pulpwood was ideal and statistically sound in the present study. All the allometric equations developed in the present study, that is DBH-based, Height-based, and Height- and -DBH-based, provided highly accurate estimation for biomass and pulpwood weight of trees with R^2 values of 0.99. Similarly, allometric equations for estimating the above-ground volume were developed by Yoon *et al.* (2013) [25] for five important urban street tree species *viz.*, *Ginkgo biloba*, *Zelkova serrata*, *Platanus orientali*, *Prunus yedoensis*, and *Acer buergerianum* by considering DBH-based and DBH-and-height based wherein the observed R^2 values were over 0.92 implicating the accuracy of the equations.

Table 5: Allometric equation to estimate biomass of trees

Sl. No.	Variable/s	Equation	n-1	R^2	p
1	DBH	1. W= 7.18 D – 59.0	24	0.99	<.001
2	Height	2. W= 7.89 H – 75.7	24	0.99	<.001
3	Height & DBH	3. W= 15.37D +13.74H–(0.680×D×H)–257.00	24	0.99	<.001

W –Total weight in kg; D - DBH in cm; H – Height in m

Table 6: Allometric equation to estimate pulpwood weight of trees

Sl. No.	Variable/s	Equation	n-1	R^2	p
1	DBH	1. W= 5.980 D - 50.6	24	0.99	<.001
2	Height	2. W= 6.17 H - 57.6	24	0.99	<.001
3	Height & DBH	3. W= 16.22D + 13.54H – (0.680×D×H)– 259.00	24	0.99	<.001

W –Total weight in kg; D - DBH in cm; H – Height in m

Conclusion

The area under plantation forestry has increased substantially in the last decade to meet the growing demand from industry. Eucalypts are quite attractive as they can be managed in short rotations. *Eucalyptus urophylla* is one of the most commercially important forest species as an exotic for the pulpwood industry in the world. High-yielding clones are now widely deployed, but the most appropriate silvicultural practices need to be provided to get optimum returns. Thus, the present study focuses on the optimum spacing requirement for pulpwood production. It is prudent that pulpwood yield can be increased by 25 per cent higher in *E. urophylla* at the test site by following a close spacing of 2.00 m × 3.00 m compared to a wider spacing, even if the survival rate is slightly lower. Henceforth, to obtain the maximum output from fast-growing species, they can be managed under closer spacing.

Acknowledgment

This research paper was achieved through the help and support from numerous people. Authors would place sincere and profound gratitude and reverence on record to Dr. N. A. Prakash, Rtd. Dean, College of Forestry, Ponnampet, and field staff of Forestry wing at Mysore Paper Mill, Bhadravathi, for their help during field data collection.

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