The Pharma Innovation Journal 2023; 12(8): 2525-2529

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(8): 2525-2529

www.thepharmajournal.com
Received: 23-06-2023
Accepted: 29-07-2023

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Screening and clone evaluation in different species for biomass productivity for clean dendro-energy generation

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DOI: https://doi.org/10.22271/tpi.2023.v12.i8ad.22487

Abstract
This study examines the growth patterns of various tree species over a 12-month period, focusing on diameter, height, and volume growth. Multiple clones of different species were monitored at intervals of 4, 8, and 12 months, providing insights into their growth trajectories and variability. Substantial diversity in growth among the species, notable differences in diameter, height, and volume were observed. The clone "MD KP 01" (*Melia dubia*) displayed best steady diameter growth, reaching 4.84 cm after 12 months. "LL 15" (*Leucaena leucocephala*) exhibited remarkable height (391.12 cm) and volume (7,807.54 cm^3) growth, respectively. These findings underscore the role of species-specific attributes and environmental factors in shaping growth performance. Statistical analyses confirmed significant differences between initial and subsequent growth stages for most species. The study highlights the importance of selecting suitable tree species for specific applications, considering their growth rates and potential yields. This research offers valuable insights into the growth dynamics of diverse tree species and their implications for biomass production, afforestation, and agroforestry systems. Particularly these screened clones could be used for biomass dendro-energy generation. It will reduce the demand of raw materials in power generation. Underscoring the need for strategic species selection to optimize growth outcomes and meet diverse forestry and environmental goals.

Keywords: Clone evaluation, biomass, dendro-energy generation

Introduction
The demand for energy in India is increasing rapidly. Despite a prolonged supply-demand gap, severe energy and peak shortages predominated in the years prior to the recent increase in electricity availability in India. Additionally, there are other issues to be concerned about apart from a lack of electricity or energy, such as the rising demand. Energy security is crucial for development and economic growth, and it is one of the most fundamental inputs (Katuwal and Bohara, 2009; Mulder and Tembe, 2008; Mahapatra and Dasappa, 2012) [14, 24, 21]. India is dedicated to reducing its carbon footprint, by boosting the production of renewable electricity, and reaching net-zero carbon emissions in order to pave the road for sustainable development and battle the dangers posed by climate change through widespread use of renewable energy sources. India now has a total installed capacity of roughly 395,075 MW, of which the government, state, and private sectors are each providing about 98,327 MW (24.9%), 105,314 MW (26.7%), and 191,434 MW (48.5%), respectively (Ministry of Power, 2022). There were 92,970.48 MW of grid-connected renewable energy programs as of February 2021, with contributions from waste to power (0.18%), biomass (11%), hydro (5%), solar (42%), and wind (41.7%). According to MNRE data, the additional biomass from forestry and agricultural waste is probably 120–150 million metric tonnes per year, or about 18 GW of capacity. According to predictions made, India would have approximately 400 GW of installed energy capacity by 2030.

The idea of a "Silvicultural Energy Farm" was first presented in 1960 to meet the needs of the paper industries (Larson and Gardon 1967) [19]. This idea has recently been applied principally to the widespread planting of trees cultivated solely for firewood or tree biomass to produce alternative energy (Henry 1979) [11]. Silvicultural Energy Farming, often known as agroforestry, blends agriculture and forestry practises through brief rotations (Qureshi 1968;

Franser 1979) [32, 9]. The agroforestry system used in India is extremely important to the country's efforts to conserve energy and provide food security (Panwar et al., 2022) [28]. The traditional use of wood as fuel is still the most important basic fuel for rural communities in developing countries, and demand for wood will rise as the cost of subsurface resources rises. Wood is a renewable energy source that can be produced continuously, making it the most accessible and affordable source of energy for the majority of rural populations (Saravannan *et al.*, 2013) [33]. In the nation, 58.75 million tonnes of the 216.42 million tonnes of fuel wood used each year come from forests. According to Kumar *et al.* (2011) [17], 23% of the population uses wood as fuel, with most of it coming from forests. Biomass is a rich renewable energy source that is widely available and has advantages over other resources since it can be pyrolyzed to produce biofuels in solid, liquid, and gaseous phases (Ahmed *et al.*, 2021) [1]. Crop wastes, animal dung, wood from energy plantations on farmlands, biogas, and other rural home energy alternatives do not affect the forest. These alternative fuel wood sources can relieve pressure on natural forests by introducing fast-growing, short-rotation indigenous species. Many fast-growing tree species are widely known to be excellent for energy plantations (Luna 2006) [20]. Despite the fact that many multipurpose tree species (MPTs) are being explored around the world, it is vital to identify and analyse the species capable of generating high-quality fuel on underutilised land in short rotations while also improving the soil. Wood quality is an important issue when selecting a species to produce fuelwood from and organising harvest rotation cycles (Goel and Beh, 1996) [10]. As a result, the country's increasing demand for energy demanded the discovery of energy-rich species appropriate for short rotation forestry, culminating in a detailed investigation that identified 10 improved multipurpose tree species as an energy resource crop. As a result, the goal of this research is to analyse several species for productivity and renewable energy generation.

Materials and Methods

This study was conducted in Forest College and Research Institute, Mettupalayam, Tamil Nadu (11.3237° N, 76.9362° E). High-Density Energy Plantation Model was developed deploying ten different (Table 1) with an objective to evaluate and identify the best clones for biomass productivity.

Table 1: Tree species and screened clones

Sl.no.	Species	Screened Clone
1.	*Acacia hybrids*	MTP- 1 AM2
2.	*Casuarina junghuhniana*	CJ- 01
3.	*Eucalyptus urograndis*	EU 09
4.	*Dalbergia sissoo*	DS 18
5.	*Khaya senegalensis*	KS 01
6.	*Leucaena leucocephala*	LL 15
7.	*Melia dubia*	MD KP 01
8.	*Mitragyna parvifolia*	MP 01
9.	*Populus deltoides*	G- 48
10.	*Terminalia bellirica*	FCRITB 13

The tree species were planted with an espacement of 1m×1m with 5 replications for each. The clones included for the study were collected from established plus trees from the college campus. The plantation was subjected with regular management treatments including weeding, pruning, cleaning alongside with fertilization and irrigation applied at alternate intervals days to help increase their vigour. Data for basal diameter and height was collected every 4 months to track the biomass yield. Furthermore, the parameters included for the biomass growth yield assessment were height and diameter, which would give finally give the volume index of the standing trees, Manavalan (1990) [22].

Table 2: Volume index formula

Sl.no.	Parameters	Volume index
1.	Height (cm)	$d^2 \times h$
2.	Basal diameter (cm)	

Data Analysis

The data was analysed by ANOVA (analysis of variance) on one factor for determining the significance. OPSTAT and IBM SPSS software system were used for statistical analysis of the collected data.

Results and Discussion

Table 3: 12 months diameter (cm) observation data

Sl.no.	Species	Initial	4MAP	8MAP	12MAP
1.	MTP- 1 AM2	0.70^{d}	1.50^{c}	2.14^{f}	3.56^{d}
2.	CJ- 01	0.43^{f}	0.82^{f}	2.21^{f}	2.32^{f}
3.	DS 18	0.72^{d}	1.81^{b}	2.68^{c}	3.80^{cd}
4.	EU 09	0.88^{b}	1.49^{cd}	2.61^{cd}	3.94^{c}
5.	KS 01	0.79^{c}	1.36^{de}	2.49^{de}	4.45^{b}
6.	LL 15	0.90^{b}	1.72^{b}	2.92^{b}	4.49^{ab}
7.	MD KP 01	0.50^{e}	1.85^{b}	3.14^{a}	4.84^{a}
8.	MP 01	1.26^{a}	2.09^{a}	3.13^{a}	4.58^{ab}
9.	G- 48	0.80^{c}	1.51^{c}	2.40^{e}	3.87^{cd}
10.	FCRITB 13	0.86^{b}	1.31^{e}	1.85^{g}	3.02^{e}
	CD	0.07	0.14	0.193^{g}	0.35
	SE(d) P= 0.05	0.03	0.07	0.091	0.16

In the initial month, MP 01 was observed to have the largest diameter followed by LL 15, EU 09 and FCRITB 13 all measuring at 1.26cm, 0.88cm and 0.86cm whereas, the least diameter was observed in CJ 01 (0.43cm). 4MAP and 6MAP showed the similar results for highest diameter in MP 01. Zhang *et al.* (2020) [36] studied the effects of nutrient fertility in *Mitragyna speciosa* and found that there was a significant increase in the plant diameter with increasing the fertilizer doses. In 12MAP the diameter growth of MD KP 01 was recorded to be the highest followed by LL 15 and MP 01 at 4.84 cm, 4.58 cm and 4.49 cm. Nayana *et al.* (2021) [25] found similar results for nine-months old Melia clones' diameter, height and volume productivity. Least diameter growth was noted in CJ 01 with only 2.32 cm, respectively. In a study conducted by Nicodemus *et al.* (2014) [26] showed dbh growth of only 6.5cm in a four-years old plantation for clones of *Casuarina junghuhniana*.

Table 4: 12 months height (cm) growth

Sl.no.	Species	Initial	4MAP	8MAP	12MAP
1.	MTP- 1 AM2	85.39^{d}	103.60^{d}	158.86^{e}	307.88^{c}
2.	CJ- 01	34.02^{g}	62.22^{f}	130.44^{g}	169.73^{e}
3.	DS 18	93.21^{bc}	183.02^{a}	246.87^{a}	337.11^{b}
4.	EU 09	89.61^{c}	126.96^{c}	211.85^{c}	237.75^{d}
5.	KS 01	23.11^{h}	44.76^{g}	102.23^{h}	166.82^{e}
6.	LL 15	101.14^{a}	143.88^{b}	232.19^{b}	391.12^{a}
7.	MD KP 01	51.55^{e}	84.51^{e}	169.78^{d}	330.35^{b}
8.	MP 01	43.40^{f}	85.14^{e}	144.31^{f}	158.12^{e}
9.	G- 48	96.16^{b}	127.93^{c}	248.57^{a}	382.37^{a}

10.	FCRITB 13	35.91[g]	57.33[f]	79.72[i]	133.90[f]
	CD	4.15	6.77	9.42	20.66
	SE(d) P= 0.05	1.96	3.20	4.87	9.76

LL 15 and G 48 recorded the maximum height in both the initial month and 12MAP. The initial readings were 101.14cm and 96.16cm whilst the final readings were recorded at 391.12cm and 330 cm for both LL 15 and G 48 clones, respectively. The results are on par with the findings done by Dhillon *et al*. (2020) [6] and Tomar *et al.* (2020) [34] for growth performance of Populus clones. The number of trees per area (stand density or spacing) has a significant impact on the yield of tree plantations (Evans, 2009) [8]. For numerous other reasons, higher densities often have higher output. CJ 01 had the least initial height growth standing at 34.02cm and FCRITB 13 at 133.90 cm in the final 12MAP reading. Inconsistent stem forms were found in clonal trials of Casuarina hybrid clones, according to Kageyama and Kikuti (1988) [13], who also found that genetic and environmental factors had an impact on stem forms. Prasad *et al*. (2010) [31] conducted spacing tests on *Leucaena leucocephala* and found tree height was unaffected, increased spacing and decreased tree density both increased breast-height diameter.

Table 5: 12 months volume (cm^3) growth

Sl.no.	Species	Initial	4MAP	8MAP	12MAP
1.	MTP- 1 AM2	40.35[e]	238.13[e]	728.99[e]	3,930.49[d]
2.	CJ- 01	6.25[h]	41.90[g]	628.62[f]	901.61[f]
3.	DS 18	48.45[d]	588.83[a]	1,759.64[b]	4,774.45[c]
4.	EU 09	69.60[b]	281.80[d]	1,432.88[c]	3,684.99[de]
5.	KS 01	14.56[g]	82.95[f]	633.57[ef]	3,255.18[e]
6.	LL 15	83.23[a]	429.64[b]	1,970.90[a]	7,807.54[a]
7.	MD KP 01	12.95[g]	284.80[d]	1,672.59[b]	7,650.33[a]
8.	MP 01	69.78[b]	340.38[c]	1,374.02[c]	3,261.27[e]
9.	G- 48	61.67[c]	292.15[d]	1,227.09[d]	5,701.43[b]
10.	FCRITB 13	26.62[f]	99.80[f]	271.39[g]	1,216.27[f]
	CD	5.26	21.26	96.88	350.6
	S.E(d) P= 0.05	2.49	10.04	45.8	165.58

The volume index of the plantation was found to be significant during the four intervals of recordings (Table.5; Figure.1). In the initial month of data interpretation, the maximum volume index was recorded in the clones of LL 15 (83.23 cm^3), followed by MP 01 (69.78 cm^3). In four months after planting records, it was observed that the clones of DS 18 and LL 15 had the maximum volume growth with 588.82 cm^3 and 429.64 cm^3 respectively. For the records of 8MAP, the clones and LL 15, followed by DS 18 recorded the maximum volume growth with 1970.90 cm^3 and 1759.64 cm^3. Deve & Parthiban (2014) [5] recorded highest volume index of 652.41 cm^3 in Dalbergia sissoo clone of six-month-old. The final readings at 12 months showed the maximum volume index for LL 15 (7807.54 cm^3), MD KP 01 (7650.33 cm^3) and G 48(5,701.43 cm^3). The results are similar to a study conducted by Sangram & Keerthika (2013) [4] in 15 months old Leucaena clones and Kumar *et al*. (2020) in 12MAP populus clones. In all the four intervals of data collection and interpretation the lowest volume index was recorded in the CJ 01, measuring at initial (6.25 cm^3), 4MAP (41.90 cm^3) and 12MAP (901.61 cm^3). Because trees have a long gestation time, it is essential to analyse growth characteristics in young trees to compare how well different clones perform (Chaturvedi and Pandey, 2005) [3]. According to a study by Dhiman and Chander, G-48 and Udai were the most prominent clones in agroforestry. Through nursery performance, Kumar *et al.* (2017) [18] similarly reported the same results in various clones. Age, spacing, and site quality are all factors which influence a tree's growth (Nissen *et al.*, 2001) [27].

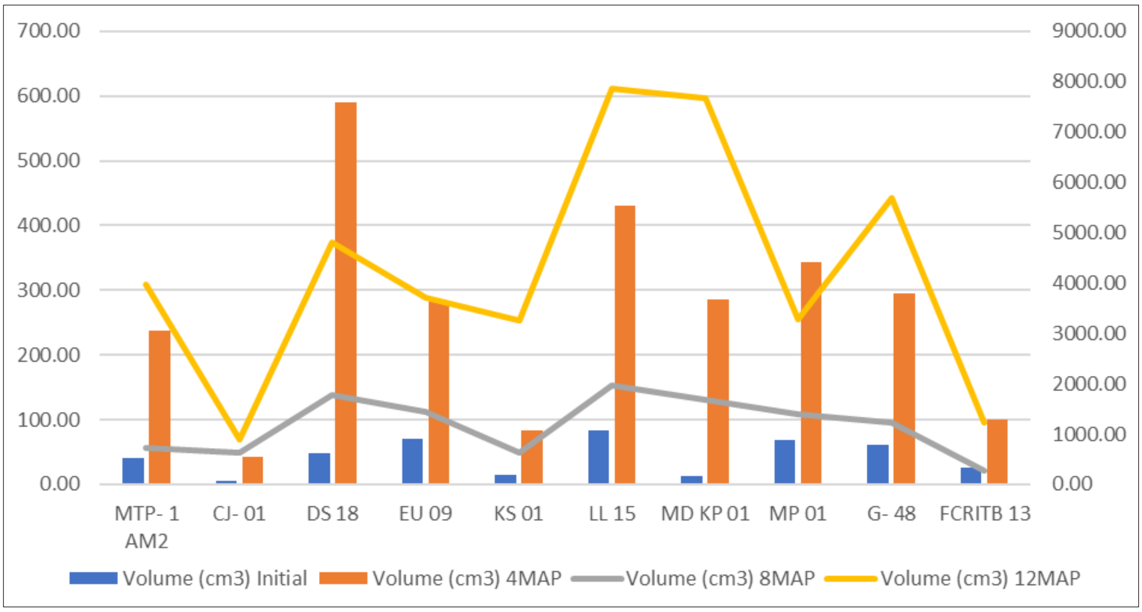

Fig 1: 12 months old volume index of ten clones

Conclusion

It can be concluded that different species has different growth pace and this may be affected by the genotype of the tree itself or the environmental factors they are exposed to. The clones LL 15 along with G 48 and MD KP 01 can be seen to be thriving best in a period of twelve months with greatest volume index. Underscoring their potential for rapid development and substantial biomass accumulation. These species could serve as valuable candidates for afforestation and biomass production initiatives. Identification of high performing clones will help in promotion of dendro-biomass plantations establishment in the future. Higher diameter yield can be expected from wider spacing and regular fertilizer interventions. Overall, this study's findings highlight the importance of tailored species selection based on growth rates, intended applications, and environmental conditions.

Acknowledgement
I' am expressing my sincere gratitude to the USAID- TOFI (Trees Outside Forests in India) project and all the members of the scheme for supporting my research.

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