RESEARCH ARTICLE

Comparative Growth Performance and Eco-Physiological Response of Tree Species Grown Under Intensive Silvicultural Management Practices

Hari Prasath C N*, Balasubramanian A, Radhakrishnan S, Sivaprakash M and Swathiga G

Department of Silviculture, Forest College and Research Institute, Tamil Nadu Agricultural, University, Mettupalayam – 641 301, Tamil Nadu, India

ABSTRACT

The present study aimed to investigate the comparative growth performance and the eco-physiological response of tree species grown under intensive silvicultural management practices (Water management, drip fertigation, pruning, and thinning operations). The tree plantation was established in October, 2017 and maintained at Forest College and Research Institute, Mettupalayam, Coimbatore, India (11° 19’ N and 77°56’ E), with an altitude of 300 m above MSL and mean annual rainfall of 920.5 mm. The study was carried out with 3m x 2m in 7 different tree species namely *Neolamarckia cadamba, Acrocarpus fraxinifolius, Grewia tiliaefolia, Melia dubia, Tectona grandis, Swietenia macrophylla,* and *Dalbergia sissoo*. The biometric (Height and Diameter at Breast Height), biochemical (Chlorophyll) and physiological parameters (Photosynthesis rate and Transpiration rate) were measured at different ages under field conditions. The tree species namely *Neolamarckia cadamba, Melia dubia,* and *Tectona grandis* recorded the highest biometric observations, chlorophyll, photosynthesis rate, and transpiration rate. It is interesting to note that, even though *Tectona grandis* is a long rotation tree crop, the tree perform superior growth performance in early stages. *Swietenia macrophylla* showed poor performance in both the biometric and physiological parameters. The present study recommended that planting fast-growing tree species with short rotation can yield maximum biomasscompared to the long rotation trees if the tree plantation is appropriately managed with intensive silvicultural operations.

Keywords: *Biometric attributes; Eco-physiology; Chlorophyll; Precision Silviculture; Tree Species; Teak*

INTRODUCTION

The increasing human population and rapid economic growth have put immense pressure on forests and other natural resources. In India, the forest situation is the net result of different happenings i.e., degradation, deforestation, afforestation, conservation, etc. to varying scales during different temporal phases (Singh *et al*., 2014). 93 percent of the forests are naturally regenerated, about 41 % of the forest cover in the country has already been degraded and dense forests are losing their crown density and productivity continuously (Only 2.61 % are rated as very dense forests with canopy density more than 70 % equivalent to 85904 km^2). India has about 2.5 % of the world’s geographical and 1.8 % of the forest area. The country supports 16 % of the world’s human population and 18 % of the domestic cattle population, amounting to about 500 million.

India is facing a severe scarcity of wood and a major portion is supplied by the plantations. Jurgensen *et al*. (2014) assesses the production of industrial roundwood from planted forests and revealed that planted forests have become a substantial component of the productive and protective forest resources and play an ever more important part in securing both industrial roundwood and wood fuel. India shares 43.1 million m^3 from the plantation forests and globally plantations contribute 83 percent of the global industrial roundwood. However, in India, this change was realized only after the third national forest policy, and the trend would increase in the future for the shortfall in supply against increasing demand (Approximately 34% demand gap) and cost escalation in imported wood due to principles of certification in forest-based products.

The establishment of fast-growing plantations is considered the main tool to produce more wood on reduced land areas by preserving the remainder of native forests while ensuring long-term timber supplies (Heilman, 1999; Anderson and Luckert, 2007). To maintain high growth rates and/or increase product value, fast-growing plantations require silvicultural interventions right from stand establishment to the final cut. The timing and intensity of silvicultural operations can significantly affect profitability, and also the physiology and growth of trees. Trees develop physiological responses to compensate for silvicultural operations (Bud pruning, Pruning, Thinning or Defoliation), such as compensatory photosynthesis, which is defined as an increase in the photosynthetic rates of foliage of partially defoliated plants relative to foliage of the same age (Nowak and Caldwell, 1984; Hart *et al*., 2000). This mechanism also triggers an increase in the rate of leaf development and the longevity of existing leaves (Pinkard and Beadle, 1998). Increased utilization of carbohydrate reserves is also a compensatory mechanism to support the production of new foliage (Tschaplinski and Blake, 1994), which eventually helps in increasing the growth rate of the trees by increasing the chlorophyll content as well as photosynthesis activity. To achieve these wood demand of the country, the silvicultural interventions, namely water management (Drip irrigation based on the soil surface), drip fertigation (Fertilizer was applied through drip), pruning (Side branches was removed periodically) and thinning operations for improving the diameter of trees is

MATERIALS AND METHODS

The tree plantation was established in October, 2017 and maintained at Forest College and Research Institute, Mettupalayam, Coimbatore, India (11° 19' N and 77°56' E) with an altitude of 300 m above MSL and mean annual rainfall of 920.5 mm. The soil was Illupanatham soil series, slightly alkaline (pH-7.87) in nature; the soil was loamy sand, well drained, and non saline (EC-0.20 dSm^{-1}). The study was carried out in 7 different tree species: *Neolamarckia cadamba, Acrocarpus fraxinifolius, Grewia tiliaefolia, Melia dubia, Tectona grandis, Swietenia macrophylla* and *Dalbergia sissoo.*

The plantation was established with 3m x 2m spacing and regularly managed with water management (Drip irrigation based on the soil surface), drip fertigation (Fertilizer was applied through drip), pruning (Side branches were removed periodically), and thinning operations for improving the diameter of trees. The tree plantation was initiated with drip irrigation and an irrigation schedule of once every three days during summer/non rainy days for the first six months and in later stages, it was irrigated twice/week with a discharge rate of 4.0 liters/hour for one hour/day.

Biometric calculation

The biometric characteristics viz., height, and Diameter at Breast Height (DBH) were measured during 12 months after planting (MAP), 24 MAP, and 36 MAP. The height of the trees was measured from the ground level to the leading terminal tip using the standard scale. Diameter at Breast Height (DBH) is measured with the help of a digital vernier caliper at 1.37 m from the ground level.

Measurements of leaf photosynthesis and transpiration rate

Using a Portable Photosynthesis System (PPS, model LCpro + Photosynthesis System CO_2 gas analyzer, UK), the net rate of photosynthesis rate and transpiration rate were estimated for three-year-old tree plantation between 09.00 am to 11.00 am for three consecutive sunny days for effective results. The observed CO_2 concentration during the field experiment varied between 350 ppm to 360 ppm with the leaf temperature of 32.5 °C on fully matured leaves (5-6 leaves from the bud).

Chlorophyll content

The chlorophyll 'a', chlorophyll 'b', total chlorophyll, and chlorophyll a/b ratio were estimated by Yoshida *et al*. (1976) and expressed as mg g^{-1} f.wt. Fully matured young fresh leaf samples (250 mg) were collected, washed in distilled water, and then ground in 80 % acetone using a pestle and mortar. The homogenate solution was centrifuged at 500 rpm for 10 min. The supernatant was collected and the volume was made up to 25 mL with 80% acetone. The optical density of the content was measured at 663 and 645 nm using a double beam UV Spectrophotometer. The chlorophyll 'a', chlorophyll 'b' and total chlorophyll content were calculated.

STATISTICAL ANALYSIS

Data were subjected to statistical analysis to evaluate the possible relationship between different parameters and to employ analysis of variance (Gomez and Gomez, 1984). The comparison between growth and physiological performance in different tree species was assessed using ANOVA and the physiological analysis was carried out through SPSS.

RESULT AND DISCUSSION

The silvicultural management practices (Pruning, water management, fertilizer management, thinning) in farm plantation is nowadays mandatory for improving the growth of the tree species (Hari Prasath *et al*., 2017) in farmlands. It is also important to note that, the drip irrigation system used in the arid region helps directly in irrigating trees in rhizosphere soil and it also helps in reducing the cultivation cost to farmers.

Among the seven tree species in the present study, *Neolamarckia cadamba* was exhibited maximum height of 11.55 m and diameter of 0.813 m during 36 MAP followed by Melia dubia (Height of 11.36 m and diameter of 0.0.640 m), *Grewia tiliaefolia* and minimum in *Swietenia macrophylla* (Height of 7.21 m and diameter of 0.412 m). Wood *et al*. (1975) and Bheemaiah *et al*. (1997) reported that maximum height increment in Casuarina may be attributed to micro irrigation with regular intervals. In supporting the present result, Balasubramanian *et al.* (2017); Hari Prasath *et al*. (2016a), and Kandell *et al*. (1980) reported that tree growth, especially the height was increased by carrying the silvicultural operation namely irrigation, weeding, and pruning at the earlier stages. Similarly, thinning practices in the tree plantation increase the tree spacing, which exposes the tree to maximum sunlight and reduces the competition for nutrients and water. Therefore, these thinning operations in tree plantations helps increase the diameter of the trees.

Plant growth may be affected directly by the response of biochemical, namely chlorophyll (Smith and Dukes, 2013) and physiological processes, viz., photosynthesis and stomatal conductance (Zheng *et al*., 2013), or indirectly by changes in nutrient and water availability (Jonsdottir *et al*., 2005). Changes in stomatal apertures and density are often associated with changes in water-use efficiency (Franks *et al*., 2015) which can affect plant growth and water stress (Han *et al*., 2013). In present study, physiological performance, *Neolamarckia cadamba* exhibited a maximum photosynthesis rate of 19.16 μ mol. m^{-2} s^{-1} followed by Dalbergia sissoo and a minimum of 17.33 μ mol. m^{-2} s^{-1} was recorded in *Swietenia macrophylla*. A similar observation was observed in transpiration rate also with the maximum in *Neolamarckia cadamba* and minimum in *Swietenia macrophylla.* In supporting the present result, Hari Prasath *et al.* (2014) and Balasubramanian *et al*., (2017) reported that maximum photosynthesis and transpiration rate was observed in *Dalbergia sissoo* even under wasteland condition at Sivagangai, Tamil Nadu. The availability of water to plants and the ability of the plant to regulate water potential under climate change conditions will help to adapt species (Rouhi *et al*., 2007 and Souza *et al*., 2004). The plant's physiological character, such as transpiration and its control, is also an important factor in changing environmental conditions (Campose *et al*., 2011 and Hari Prasath *et al*., 2016b).

The performance of every plant (Living organism) was primarily dependent on the chlorophyll status of the plant, where the maximum chlorophyll on the leaf leads the plant to uptake, translocation of various mineral nutrients, and photosynthesis efficiency were reported by different authors (Ananthapadmanabha *et al.* 1984, Rangaswamy *et al*. 1986, Brand 2002, Lu *et al*., 2014, Rocha *et al*., 2014, Balasubramanian *et al*., 2018). In the present comparative study on chlorophyll content of 7 different tree species, the maximum chlorophyll content was recorded in *Neolamarckia cadamba* with the value of 0.747 mg g^{-1} (Chlorophyll a), 0.454 mg g^{-1} (Chlorophyll b) and 1.201 mg g^{-1} (Total chlorophyll) followed by *Melia dubia* with total chlorophyll of 1.161 mg g^{-1} and *Tectona grandis* with the value of 1.111 mg g^{-1} (Table 3). The tree species with a maximum production of functional chloroplast perform photosynthesis action for food production, an important role in water development and physiological action (Pate, 2001; Bell and Adams, 2011; Cameron and Seel, 2007 and Balasubramanian *et al*., 2021).

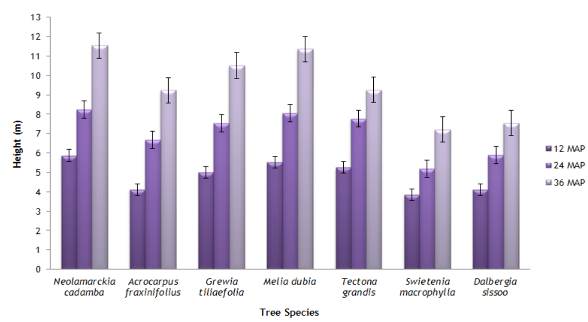

Figure 1. Effect of intensive silvicultural practices on height in three-year old tree species

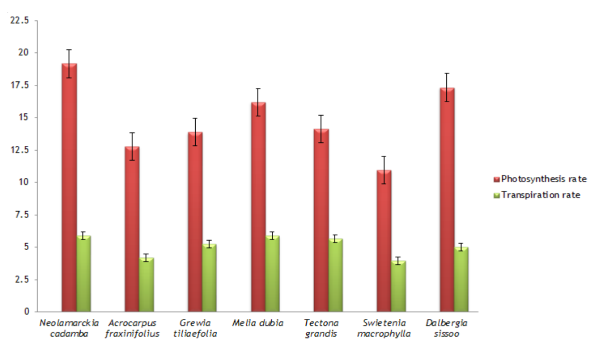

Figure 2. Effect of intensive silvicultural practices on photosynthesis rate (μ mol. m^{-2} s^{-1}) and transpiration rate (m mol. m^{-2} s^{-1}) of three-year old tree species

Table 1. Effect of intensive silvicultural practices on biometric attributes of three-year old tree species

Tree species	12 MAP		24 MAP		36 MAP	
	Height (m)	DBH (m)	Height (m)	DBH (m)	Height (m)	DBH (m)
Neolamarckia cadamba	5.87	0.214	8.25	0.547	11.55	0.813
Acrocarpus fraxinifolius	4.11	0.098	6.66	0.241	9.24	0.457
Grewia tiliaefolia	5.01	0.155	7.54	0.351	10.51	0.574
Melia dubia	5.51	0.215	8.04	0.403	11.36	0.640
Tectona grandis	5.25	0.073	7.77	0.311	9.25	0.590
Swietenia macrophylla	3.85	0.054	5.17	0.217	7.21	0.412
Dalbergia sissoo	4.11	0.074	5.88	0.398	7.54	0.601
S.Ed	0.161	0.006	0.341	0.020	0.314	0.022
CD (0.05)	0.352	0.014	0.744	0.044	0.684	0.048

Table 2. Effect of intensive silvicultural practices on photosynthesis rate (μ mol. m^{-2} s^{-1}) and transpiration rate (m mol. m^{-2} s^{-1}) of three-year old tree species

Treatments	Photosynthesis rate (μ mol. m^{-2} s^{-1})	Transpiration rate (m mol. m^{-2} s^{-1})
Neolamarckia cadamba	19.16	5.88
Acrocarpus fraxinifolius	12.78	4.20
Grewia tiliaefolia	13.88	5.23
Melia dubia	16.21	5.87
Tectona grandis	14.15	5.66
Swietenia macrophylla	10.94	3.96
Dalbergia sissoo	17.33	4.99
S.Ed	0.586	0.232
CD (0.05)	1.233	0.487

Table 3. Effect of intensive silvicultural practices on chlorophyll content (mg g^{-1}) of three-year old tree species

Treatments	Chlorophyll ‘a’	Chlorophyll ‘b’	Total chlorophyll	Chlorophyll a/b ratio
Neolamarckia cadamba	0.747	0.454	1.201	1.645
Acrocarpus fraxinifolius	0.606	0.291	0.897	2.082
Grewia tiliaefolia	0.698	0.383	1.081	1.822
Melia dubia	0.728	0.433	1.161	1.681
Tectona grandis	0.703	0.408	1.111	1.772
Swietenia macrophylla	0.601	0.300	0.901	2.003
Dalbergia sissoo	0.671	0.367	1.038	1.828
S.Ed	0.026	0.013	0.047	0.099
CD (0.05)	0.056	0.027	0.099	0.209

CONCLUSION

Neolamarckia cadamba, Melia dubia and *Tectona grandis* recorded the highest biometric observations, chlorophyll, photosynthesis rate and transpiration rate. Interestingly, regular silvicultural practices (Pruning, water management, fertilizer management, thinning) in farm plantation improves the tree's growth compared to the unmanaged tree plantation. The present study also revealed that planting fast growing tree species with short rotation can yiyield maximum biomass. Even though *Tectona grandis* is a long rotation tree crop, the tree performs superior growth in the early stages, and in later stages, the growth pattern will decrease.

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Ethical Approval

Not applicable

Statements and Declarations

All authors are ready to afford all financial or non-financial interests that are directly or indirectly related to the work submitted for publication.

Originality and plagiarism

Authors should ensure that they have written and submit only entirely original works, and if they have used the work and/or words of others, that this has been appropriately cited. Plagiarism in all its forms constitutes unethical publishing behavior and is unacceptable

Consent for publication

The authors give consent for the publication of identifiable details, text, tables, and figures to be published in the above journal.

Competing Interests

The authors declare that they have no competing interests" in this article.

Data availability

All data generated or analyzed during this study are included in this manuscript article and some of the datasets generated during and/or analyzed during the current study are not publicly available.

Authors Contributions

Hari Prasath C. N. contributed to the conceptualization, investigation and writing original draft and all other authors contribute to review, editing and preparation of the final draft.

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