

Growth and Biomass Production of *Ailanthus Triphysa* in Nilambur, Kerala, India

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ABSTRACT

Ailanthus triphysa (Dennst.) Alston is a multipurpose tree with strong potential for restoring or rehabilitating degraded forests and for improving farm forestry and agroforestry systems. However, information on its girth, height, and aboveground growth increments has been limited. In this study, we periodically recorded GBH (girth at 1.37 m above ground) and height of 18- to 38-year-old trees in a species trial plot. Mean GBH increased from 63.1 cm at 18 years to 121.3 cm at 38 years, while mean height increased from 24.3 to 33.3 m over the same period. Tree GBH showed significantly greater structural diversity than tree height. Total aboveground biomass increased linearly with age, from 167.6 kg tree⁻¹ at 18 years to 892.4 kg tree⁻¹ at 38 years. We developed an allometric equation to predict tree age using GBH as the independent variable: Tree age (years) = 0.3403 × GBH (cm) – 3.4804 (R² = 0.9915). This equation provides a reliable tool for estimating the age of *A. triphysa* trees.

Key words: Halmaddi, Species trial plot, Mean annual increment in Gbh, Tree age-tree Gbh allometry, Aboveground biomass

INTRODUCTION

Ailanthus triphysa (Dennst.) Alston (Family: Simaroubaceae) is a lofty deciduous tree that attains heights of up to 40 m. Its native range includes India, Myanmar, and Nepal. In India, the species occurs predominantly in the wet evergreen climax forests of the Western Ghats, extending from the Konkan region in the north to Travancore in the south. The tree is traded under the name “Halmaddi (Halumaddi).” Various parts of the plant - including the wood, leaves, roots, gum, and bark - possess medicinal properties, and the aromatic resin extracted from the bark is widely used as incense (Anonymous 2025). The timber is traditionally used for packing cases, match splints and boxes, Class III veneers, fishing floats, boats, toys, and other light-wood purposes (Nazma et al. 1981).

Among tropical land-use systems, farm forestry and agroforestry have been recognized as promising approaches for reducing pressure on natural forests and for rehabilitating degraded landscapes, while simultaneously delivering diverse ecosystem services (Anonymous 2016). Within these systems, *A. triphysa* has been recommended for planting (Kumar 2000, Chandrashekhara 2007), both as a shade tree and as a source of green manure (Chandrashekhara

2007), as well as for use as live stakes to support black pepper (*Piper nigrum*) vines (Orwa et al. 2009). The species is also considered suitable for forest restoration and rehabilitation programmes and for establishing small- or large-scale plantations (Kumar and Shibu 2018).

Regardless of whether the objective is forest restoration, rehabilitation of degraded areas, or improvement of farm forestry and agroforestry systems, appropriate species selection based on growth performance is critical for success (Anonymous 2016). However, quantitative information on growth patterns and biomass accumulation in *A. triphysa* remains limited. In this study, we assessed girth, height, and above-ground biomass increment in *A. triphysa* planted in a species trial plot established in 1980 at the Kerala Forest Research Institute (KFRI) Sub Centre, Nilambur. The aim is to provide farmers, natural forest managers, and plantation practitioners with reliable age-growth and allometric information to support species selection and management planning for *A. triphysa*.

MATERIALS AND METHODS

Study area and climate

The study was conducted on the KFRI Sub Centre

campus (76°152'283" E longitude, 11°182'143" N latitude) at an elevation of approximately 65 m above mean sea level. The area receives an average annual rainfall of about 2360 mm, with the highest precipitation occurring in July (approximately 422 mm). In contrast, rainfall is minimal during January, February, and March, with monthly totals of 30.4 mm, 8.26 mm, and 26.4 mm, respectively. The mean maximum temperature is about 37°C, while the mean minimum temperature is around 17°C. The surface soil is red (oxisol), fine-loamy in texture, underlain by gravelly and red sandy subsoil. During the dry season, humidity drops considerably, and herbs and shrubs often desiccate due to insufficient subsoil moisture.

Methods

The *A. triphysa* species trial plot was established on 21 June 1980. A total of 238 seedlings (17 × 14) were planted at a spacing of 3 × 3 m. In 1998, all trees in the plot were numbered and a detailed plot map was prepared. This exercise enabled accurate tracking of individual trees and ensured the collection of error-free data during the subsequent 20-year monitoring period (1998–2018).

Over the course of monitoring, some trees died or were damaged due to events such as crown breakage, trunk splitting, and partial uprooting. For the present study, only trees that remained healthy throughout the entire monitoring period were included in the analysis of girth, height, and aboveground biomass increment patterns.

Tree girth was measured at 1.37 m above ground level (GBH), and tree height was measured using a clinometer. Monitoring of GBH and height was carried out at irregular intervals up to 2018. Data for the years 1998, 2001, 2003, 2005, 2008, 2010, 2013, 2015, 2016, and 2018 were compiled in spreadsheets for analysis.

Repeated-measures ANOVA was used to assess changes in GBH and height over time for the trees that remained healthy. Mauchly's test was performed to evaluate the assumption of sphericity. When this assumption was violated, multivariate tests were applied to determine whether time (tree age) had a statistically significant effect on GBH and height.

To assess size and height hierarchies and the presence of asymmetric competition among trees in

the species trial plot, the Gini index (Damgaard and Weiner 2000) was calculated for individual tree GBH and height at each monitoring interval. The Gini index was computed using the equation:

$$\text{Gini} = 2[\sum(g_i/nG) - (n+1)/n]$$

where g_i is the Gbh of tree i (trees are sorted in ascending order), G the total Gbh of all trees or total and n the number of trees.

The index ranges from 0 (perfect equality) to 1 (maximum theoretical inequality). The same equation was applied to compute the Gini index for tree height. The mean annual increment (MAI) in GBH was calculated by dividing the measured GBH in each monitoring year by tree age in that year; MAI for height was calculated similarly. Periodic annual increment (PAI) for GBH and height was derived by dividing the change in GBH or height between two measurement years by the number of years between measurements.

Aboveground biomass of individual trees was estimated by first calculating tree volume using the formula:

$$V = (Gbh^2/4\pi) * h * F$$

where h = tree height (m), Gbh = Girth at breast height (m), and F = Form factor. A form factor value of 0.6 was used for this study (Kumar 2000). Tree volume was then multiplied by wood density and a biomass expansion factor to estimate aboveground biomass. A wood density of 400 g cm⁻³ and a biomass expansion factor of 1.5 were applied (Nazma et al. 1981, Brown and Lugo 1992). Trends in mean aboveground biomass over time were modelled using simple linear regression with tree age as the predictor variable.

RESULTS AND DISCUSSION

Quantitative information on age-specific girth, height, and annual increment of *A. triphysa* is limited. Previous studies reported mean GBH values of 17.7 cm, 21.0 cm, and 26.4 cm, and mean heights of 4.18 m, 5.11 m, and 5.00 m for 5-, 7-, and 8.8-year-old trees, respectively, in silvopastoral and woodlot experimental plots in Kerala (Kumar et al. 1998). Similarly, a mean height of 15.5 m was recorded for 13-year-old trees at the Nam Suoung Silviculture Research Station in Laos (Hgelm 1995). In the

Table 1. Periodic growth in Gbh (cm; mean \pm SD) and height (m; mean \pm SD), along with periodic changes in the Gini Index s for Gbh and height, in the *Ailanthus triphysa* species trail plot at the KFRI Sub Centre, Nilambur, Kerala

Tree age (year)	Tree Gbh (cm)	Tree height (m)	Gini Index values for	
			Tree Gbh	Tree height
18	63.1 \pm 6.7	24.3 \pm 0.6	0.11	0.021
21	72.8 \pm 11.2	25.2 \pm 0.6	0.13	0.020
23	78.8 \pm 13.1	26.3 \pm 0.5	0.14	0.018
25	79.9 \pm 13.7	27.4 \pm 0.5	0.14	0.018
28	95.4 \pm 16.2	28.7 \pm 0.6	0.16	0.018
30	98.5 \pm 18.2	29.8 \pm 0.6	0.17	0.018
33	108.4 \pm 18.8	31.0 \pm 0.6	0.19	0.016
35	111.0 \pm 17.5	32.2 \pm 0.7	0.19	0.017
36	116.4 \pm 17.3	32.4 \pm 1.3	0.19	0.016
38	121.3 \pm 15.3	33.3 \pm 1.3	0.20	0.016

present study, mean GBH values of 63.1 and 121.3 cm and mean heights of 24.3 and 33.3 m were observed in 18- and 38-year-old trees, respectively (Table 1). The corresponding mean annual increments were 2.91 cm year⁻¹ for GBH and 0.45 m year⁻¹ for height. These findings indicate that *A. triphysa* maintains relatively steady growth over several decades, supporting its suitability for long-term forestry, agroforestry, and restoration applications.

The effects of age on GBH and height were assessed separately using repeated-measures ANOVA. Mauchly's test indicated that the assumption of sphericity was violated for both GBH (χ^2 (44) = 1758.241, $p < 0.001$) and height (χ^2 (44) = 913.3, $p < 0.001$). Consequently, multivariate tests were employed. These tests revealed a statistically significant effect of time (tree age) on both GBH ($V = 0.753$, $F(10, 52) = 15.836$, $p < 0.001$) and height ($V = 0.758$, $F(10, 52) = 16.235$, $p < 0.001$).

The Gini index values for GBH ranged from 0.11 to 0.20, whereas values for height ranged from 0.016 to 0.02 (Table 1). This indicates that the stand exhibits considerably greater structural heterogeneity in GBH than in height. Furthermore, GBH inequality increased significantly with stand age (correlation coefficient = 0.998, $p < 0.01$), while height inequality decreased significantly (correlation coefficient = -0.943, $p < 0.01$). These contrasting patterns suggest increasing asymmetry in diameter growth over time,

despite a gradual convergence in tree height.

In species trial plots and plantation forests, stand age is usually known with precision. However, in mixed-species natural stands, farmland, and public lands, tree age is often unknown due to the absence of planting records. Estimating age under such conditions can be laborious and costly, typically requiring increment coring, which may also negatively affect tree health (Koivuniemi and Korhonen 2006). To overcome these limitations, several indirect approaches and models have been developed that estimate tree age using easily measurable tree attributes such as GBH, DBH, or height. In the present study, the relationship between tree age and mean GBH of *A. triphysa* was examined using simple linear regression, with GBH as the predictor. The resulting model, (Tree age (year) = 0.3403x - 3.4804; where x is Gbh in cm), explained 99.15% of the variation in age ($R^2 = 0.9915$), indicating a strong linear relationship between GBH and tree age. A similar regression using tree height as the predictor yielded the equation, (Tree age (year) = 2.1418x - 33.54; where x is tree height in meter), with an even higher coefficient of determination ($R^2 = 0.9976$). These results demonstrate that both GBH and height are reliable predictors of tree age in *A. triphysa*. Accordingly, the two fitted equations provide practical tools for estimating the age of trees in unrecorded stands using straightforward field measurements.

Commercial volume prediction equations for *A. triphysa* (= *A. malabarica*) have been developed previously in Laos (Hgelm 1995) and Kerala (Krishnankutty 2013) using regression analyses, with either DBH alone or DBH combined with commercial height as independent variables and stem volume as the dependent variable. In the present study, changes in total tree volume in the age-sequence of the species trial plot were estimated using tree GBH, height, and a form factor. Individual tree volume increased from 0.47 to 2.5 m³ over twenty years, following a sigmoid growth pattern characterized by relatively slow initial growth, followed by a period of rapid development (Table 2).

In plantation production systems, rotation age is typically determined based on the relationship between mean annual increment (MAI) and periodic annual increment (PAI) of tree volume (Husch et al. 2003). The tree is considered to have reached its maximum production potential when MAI equals PAI. In the present study, MAI in volume increased from 0.026 to 0.066 m³ yr⁻¹, while PAI increased from 0.066 to 0.125 m³ yr⁻¹ over twenty years (Fig. 1). These results indicate that the trees are still in the active growth phase, and have not reached rotation

age. Most previous studies on biomass estimation in *A. triphysa* have focused on relatively young trees, ranging from 8.8 to 15 years of age (Kumar 2000, Gopikumar 2009). The present study provides detailed information on aboveground biomass for *A.*

Table 2. Total volume (m³ tree⁻¹; mean ± SD) and aboveground biomass (Kg tree⁻¹, dry weight: mean ± SD) of 18- to 38-year-old *Ailanthus triphysa* trees in the species trail plot at the KFRI Sub Centre, Nilambur, Kerala

Tree age (year)	Tree volume (m ³ tree ⁻¹)	Tree aboveground biomass (kg tree ⁻¹ , dry weight)
18	0.47±0.08	167.6±28.7
21	0.65±0.11	233.4±39.3
23	0.80±0.12	286.7±43.2
25	0.86±0.14	307.8±50.0
28	1.31±0.26	468.0±92.6
30	1.45±0.21	519.6±74.0
33	1.87±0.28	667.2±100.4
35	2.03±0.35	725.4±125.6
36	2.25±0.32	803.1±114.0
38	2.50±0.32	892.4±114.3



Figure 1. Mean annual increment (MAI) and periodic annual increment (PAI) in total volume (m³ yr⁻¹) of 18- to 38-year-old *Ailanthus triphysa* trees in the species trail plot at the KFRI Sub Centre, Nilambur, Kerala

triphyssa in a species trial plot across an age sequence of 18- to 38-year-old trees in Kerala, India. Total aboveground biomass increased with stand age from 167.6 kg tree⁻¹ in the 18-year-old plot to 892.4 kg tree⁻¹ in the 38-year-old plot, following a linear trend (Table 2). An allometric equation relating tree age to aboveground biomass was developed as:

$$\text{Aboveground Biomass (dry: kg tree}^{-1}\text{)} = 37.099x - 557.62$$

where x is the tree age (year); R²=0.9808. This equation provides a reliable tool for predicting the aboveground biomass of *A. triphysa* based on tree age, facilitating yield prediction, forest management and restoration planning.

CONCLUSION

Ailanthus triphysa is a promising multipurpose tree suitable for forest restoration, rehabilitation, and the establishment of plantations at various scales. Given the declining supply of its raw material for herbal industries in India, its cultivation has been actively promoted under the National Mission on Medicinal Plants (NMMP) by the National Medicinal Plants Board (NMPB), with support in quality planting material and technical guidance. The growth data presented in this study—including girth, height, volume, and aboveground biomass—along with the developed allometric equations and regression models, provide practical tools to estimate tree age, growth, and biomass. These resources will support medicinal plant growers, plantation managers, and forest restoration practitioners in planning and managing sustainable *A. triphysa* plantations. These findings offer valuable guidance for medicinal plant growers, plantation managers, and forest restoration practitioners, facilitating informed decisions for cultivation, resource planning, and sustainable management of *A. triphysa*. Overall, the species' predictable growth and biomass accumulation make it a reliable option for long-term cultivation, agroforestry systems, and enhancement of the medicinal plant resource base in India.

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