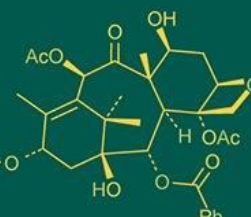
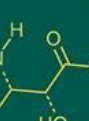
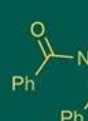


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(3): 39-42
www.biochemjournal.com
Received: 13-01-2025
Accepted: 16-02-2026

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Assessment of growth and productivity of *Aquilaria malaccensis* Lam. (Agarwood) growing under different agroclimatic zones 8, 9 and 10 of Karnataka

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i3Sa.7812>

Abstract

A study was carried out in the year 2022-2023 in agroclimatic zones 8 (Northern Transition Zone), 9 (Hilly Zone) and 10 (Coastal Zone) of Karnataka for assessment of growth and productivity of *Aquilaria malaccensis* Lam. (Agarwood) growing in arecanut plantations. Growth parameters such as tree height, tree girth at breast height, crown diameter were measured and calculated the basal area, tree volume of agarwood. The research found that various growth parameters, including girth at breast height (GBH), crown diameter, basal area, and tree volume exhibited significant differences between agroclimatic zones, while tree height did not vary significantly. In terms of tree height, it ranged from 10.1 to 10.5 meters, with the highest recorded in Zone A followed by Zone C and Zone B. Whereas GBH ranged from 0.535 to 0.673 meters, crown diameter varied from 1.7 to 2.8 meters, basal area ranged from 0.025 to 0.039 m² and tree volume varied from 103.12 to 230.83 m³ ha⁻¹. The growth and productivity of agarwood showed highest in in Zone B, followed by Zone A and Zone C. Interestingly, the study did not find a significant influence of altitude on agarwood growth and productivity, suggesting that rainfall was the primary factor affecting these parameters. Agarwood demonstrated better growth and productivity in regions with higher rainfall and acidic soils, regardless of altitude.

Keywords: *Aquilaria malaccensis*, Agarwood, agroclimatic zones, arecanut plantation

Introduction

Aquilaria malaccensis Lam. syn. *Aquilaria agallocha* which is commercially well known for its resinous heartwood, commonly known as agarwood belongs to family Thymelaeaceae. It is locally known as 'Agaru', also refers to as the "Wood of the Gods" because of its frequent use in religious, fragrant, and medicinal contexts and is endemic to Indo-malayasian region. It is widely distributed in South and South-East Asian regions. *A. malaccensis* is found in ten countries viz. Bangladesh, Bhutan, India, Indonesia, Iran, Malaysia, Myanmar, Philippines, Singapore and Thailand (Barden *et al.*, 2000) [3]. In India, it occurs in the natural woods of evergreen and semi evergreen regions of North East India (Hajra, 2000) [6]. Agar is an evergreen tree, grows upto a height of 18 to 40 m with a diameter of 0.6 to 0.8 m and grows well at an altitude of 500 m above sea level but can grow upto 1000 m. The wood of tree is soft, light, elastic and the colour is white to yellowish-white (Chakrabarty *et al.*, 1994) [4].

Due to its high demand both government and private agencies are promoting agarwood cultivation. In recent years, Karnataka witnessed a surge in agarwood cultivation as farmers tap into burgeoning market for its resinous heartwood. Several farmers have planted agarwood in different parts of the Karnataka especially in agroclimatic zone 8, 9 and 10. Vanadurgi Agarwood India Limited, headquartered at Sringeri, Karnataka started its operations in 2007, is closely associated with the farmers and grower associations of the Karnataka. It aimed at promoting the agarwood cultivation in different parts especially in hilly and coastal districts by providing seedlings, agrotechniques and also sharing information on inoculation technologies for agarwood. As per the company, currently 10,176 farmers from Karnataka are growing in 9,670 acres of land (Anon, 2007) [2]. As the tree growth rates are influenced by external environmental factors like rainfall and site conditions like altitude and other extrinsic factors. The present study aimed to assess the growth and productivity of agarwood grown under different agroclimatic zones.

Materials and Methods

Study site: The field experiments were carried out in Uttara Kannada and Haveri districts of Karnataka. This region exhibits a wide range of climate and topographic situations. The experimental sites are situated in Coastal Zone-10 (Zone A), Hilly Zone-9 (Zone B) and North Transition Zone-8 (Zone C). The rainfall in these site ranges between 1000-3700 mm per year and the elevation ranges between 20-622 MSL. The details of the study area are depicted in Table 1.

Over the few years farmers have been growing Agarwood (*Aquilaria malaccensis*) as an intercrop in arecanut plantations. Trees having age gradations of 12 to 14 years were selected. The selected plantations have spacing of 2.75 × 5.5 m. In this selected plantations, 20 trees per plantations were selected for recording growth parameters. Growth parameters such as total tree height (m), girth at breast height (GBH), canopy diameter (m) were recorded in the field and calculated the basal area (m²) and tree volume (m³/ha).

The experiment was laid out in two Factorial Randomized block design with 6 main factors (Agro climatic zones), 2 sub factors (Sampling sites) and 4 replications.

The growth parameters such as tree height, Girth at breast height (GBH) and Girth at Base (GAB) was measured using the measuring tape.

The crown diameter of a tree refers to the horizontal distance from one side of the tree's canopy to the other side, measured at the widest point of the tree's foliage. Crown diameter was calculated using the formula (Chaturvedi and Khanna, 1984) [5].

$$\text{Crown diameter} = \frac{D_1 + D_2}{2}$$

Where, D₁ is diameter of crown at major axis and D₂ is diameter of crown at minor axis.

Basal area is measured as the cross-sectional area of tree stems at breast height (usually at a height of 4.5 feet or 1.37 meters above the ground) per unit area of land. Basal area was calculated using the formula (Chaturvedi and Khanna, 1984) [5].

$$\text{Basal area} = \frac{G^2}{4} \Pi$$

Where, G is girth at breast height and expressed in meter (m)

Π is constant equal to 3.14

The Form factor is a numerical value that represents the shape or form of a tree's stem or trunk. Form factor was calculated by using the formula (Chaturvedi and Khanna, 1984) [5].

$$\text{Form factor} = \frac{(\text{Girth at breast height})^2}{(\text{Girth at base})^2}$$

The volume of a standing tree was determined by using the various growth parameters, including tree height, diameter at breast height (DBH), form factor and basal area. Total tree volume was calculated by using the formulae (Chaturvedi and Khanna, 1984) [5].

$$\text{Total volume} = \text{Total height (m)} \times \text{Basal area (m}^2\text{)} \times \text{Form Factor (m)}$$

Results and Discussion

The influence of agroclimatic zones and sites on *Aquilaria malaccensis* growth parameters and productivity are depicted in Table 2 and Figure 1(a-e). Different growth parameters like mean total tree height (m), mean girth at breast height (GBH, m), mean crown diameter (m) and form factor (m), mean basal area (m²) and mean volume (m³ha⁻¹) are presented below.

Among the growth parameters of *A. malaccensis*, all parameters such as GBH, crown diameter, basal area and volume showed statistically significant difference between agro climatic zones except for tree height but none of the parameters showed statistical difference between sites and interaction.

Among the agroclimatic zones, mean tree height was varying from 10.1 to 10.5 m. Highest tree height was recorded in Zone A (10.5 m) followed by Zone C (10.3 m) and least in Zone A (10.1 m). Mean GBH was varying from 0.535 to 0.673 m and highest was recorded in Zone B (0.673 m) followed by Zone A (0.624 m) and least in Zone C (0.535 m). Mean tree crown diameter was varying from 1.7 to 2.8 m with Zone B recorded highest with 2.8 m followed by Zone A (2.1 m) and least was in Zone C (1.7 m). Mean tree basal area was in the range of 0.025 to 0.039 m² with Zone B having highest with 0.039 m² followed by Zone A (0.032 m²) and least was in Zone C (0.025 m²). Mean tree volume was varying from 103.12 to 230.83 m³ per ha. Highest mean tree volume was recorded in Zone B (230.83 m³ ha⁻¹) followed by Zone A (138.33 m³ ha⁻¹) and least in Zone C (103.12 m³ ha⁻¹).

In the present study, in a 13 to 14 years old agarwood plantation under mean annual rainfall range of 1000-3500 mm it was observed that mean tree height ranged from 10.1 to 10.5 m, mean girth at breast varied from 0.535 to 0.673 m, crown diameter ranged from 1.7 to 2.8 m, basal area ranged from 0.025 to 0.032 m² and volume ranged from 103.12 (m³ha⁻¹) to 230.83 (m³ha⁻¹). The observed variations in growth and productivity of agarwood was also reported by Hossen and Hossain (2016), who studied growth and productivity of 12-16 year old agarwood plantation in Bangladesh. They reported that, tree height range from 9.90 to 14.67 m, the girth size range was 0.41 to 0.465 m, basal area varies from of 0.014 to 0.019 m² and volume range from 72.59 to 307.08 (m³ha⁻¹) under the mean annual rainfall range of 2735 to 3634 mm. In the present study the observed tree height was not influenced by site conditions, however, they reported that height was found to be significantly varying. Other growth parameters like girth at breast, crown diameter, basal area and tree volume were found to be higher than observed in Bangladesh.

The current results showed the higher growth and productivity in Zone B with high altitude and high rainfall whereas, Zone A showed moderate growth and productivity having low altitude and high rainfall and least growth and productivity was observed in Zone C having high altitude and low rainfall (Fig. 1). In all the study sites, the soils were found to be of acidic nature and it seems that rainfall having the significant influence on growth and productivity but not the altitude of the region. Positive influence of acidic soils on growth and productivity of agarwood are reported by various workers. Akter and Neelim (2008) [11] also reported

higher growth and productivity of agarwood in soils having pH range of 5.5 to 6.5.

In the present investigation, it was observed that, influence of altitude on growth and productivity of agarwood was found to be insignificant. Several workers have reported that, agarwood grows very well in different altitudinal zones like Mat *et al.* (2012) [8] who reported agarwood species grows extremely well at the altitudinal range of 300 to 850 m. Similarly Rabgay *et al.* (2020) [9] reported that agarwood tree grows best in altitudinal limits of 143 to 1037 m. Hence, the growth was found to be good in different altitudes. However, present study indicated that, rainfall was found to have significant influence on growth and productivity of agarwood. Agarwood grown in high rainfall region (1800 to 3500 mm) reported with higher growth and productivity with Zone A having 3000 to 3700 mm and Zone B in the range of 2500 to 3600 mm when compare to Zone C with low rainfall (1100 to 1500 mm). Suharti *et al.*

(2011) [10] reported that 1,800 to 3,500 mm of precipitation is best suited for agarwood growth. It seems that, for good growth and productivity of agarwood, it requires high rainfall coupled with acidic site conditions.

In the present study, the temperature range of 20 to 24 °C was found to be more suitable for growth and productivity of agarwood. Similar positive influence of temperature on agarwood growth was reported by Mat *et al.* (2012) [8], higher growth was observed at daily temperature range of 20 to 22 °C. Similar findings by Rabgay *et al.* (2020) [9] who reported that agarwood tree grows best in mean temperature range of 19.68 to 24.31 °C. Mean annual range of precipitation, 2,127 to 5,441 mm and they concluded that agarwood grows well in areas with slightly acidic soil having good rainfall. Hence, agarwood growth is significantly influenced by rainfall but not by altitude as it has reported good growth both at low and high altitudes. However, poor growth was observed in low rainfall area.

Table 1: Details of the area selected for the current study

Agroclimatic Zone	Sampling sites		Latitude	Longitude	Altitude (m)	Rainfall (mm)
Zone A (ACZ-10) Coastal	S ₁	Athravalli	14° 27' 38"	74° 27' 36"	86	3611
	S ₂	Santhaguli	14° 25' 16"	74° 34' 52"	20	3700
Zone B (ACZ-09) Hilly	S ₁	Heggumbli	14° 36' 18"	74° 27' 36"	510	3550
	S ₂	Nelallimatta	14° 44' 17"	74° 44' 36"	522	3600
Zone C (ACZ-08) Northern Transition	S ₁	Muttur	14° 37' 37"	75° 22' 34"	622	1100
	S ₂	Ajjehali	14° 55' 36"	75° 03' 10"	549	1500

*Rainfall data by KSNDMC report 2022

Table 2: Influence of agroclimatic zones on growth and productivity of *A. malaccensis*

Agroclimatic Zones	Sampling Site	Tree height (m)	Girth at breast height (m)	Crown diameter (m)	Basal area (m ²)	Tree volume (m ³ /ha)
A	S ₁	9.5	0.582	1.9	0.028	103.67
	S ₂	11.5	0.665	2.2	0.036	172.99
	Mean of Zone A	10.5	0.624	2.1	0.032	138.33
B	S ₁	9.2	0.678	2.8	0.042	260.23
	S ₂	11.1	0.667	2.7	0.036	201.43
	Mean of Zone B	10.1	0.673	2.8	0.039	230.83
C	S ₁	10.6	0.630	1.8	0.033	140.29
	S ₂	10.0	0.436	1.6	0.018	65.95
	Mean of Zone C	10.3	0.535	1.7	0.025	103.12
SEm ±	Zone	0.795	0.031	0.158	0.004	27.16
	Site	0.649	0.025	0.129	0.003	22.177
	Interaction	1.125	0.044	0.224	0.005	38.41
CD @ 5%	Zone	NS	0.094	0.481	0.011	82.62
	Site	NS	NS	NS	NS	NS
	Interaction	NS	NS	NS	NS	NS

*Figures in column are NS = non-significant, CD = Critical difference, SEm-Standard error of mean

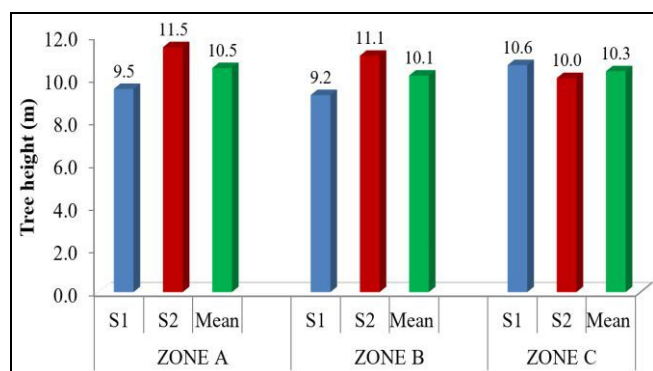


Fig 1a: Tree height of *Aquilaria malaccensis*

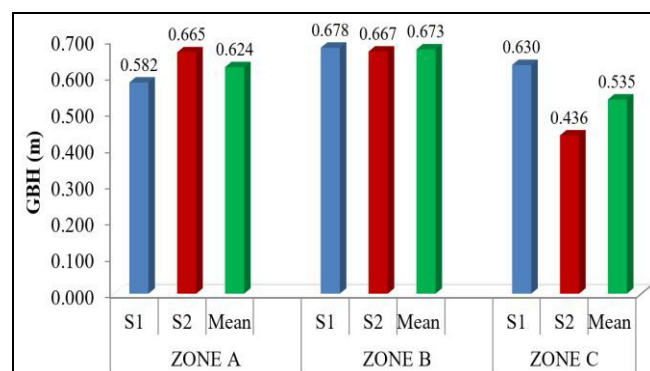


Fig 1b: Girth at breast height of *Aquilaria malaccensis*

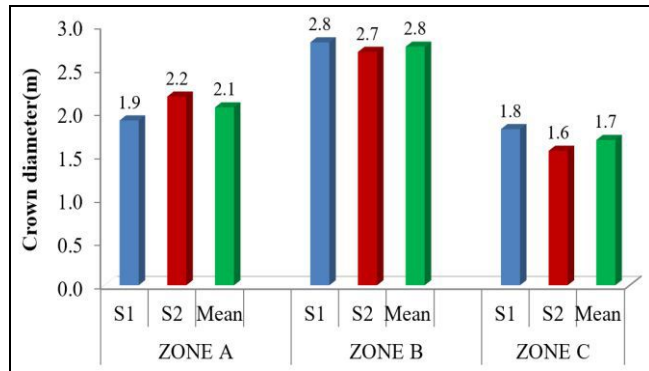


Fig 1c: Crown diameter of *Aquilaria malaccensis*

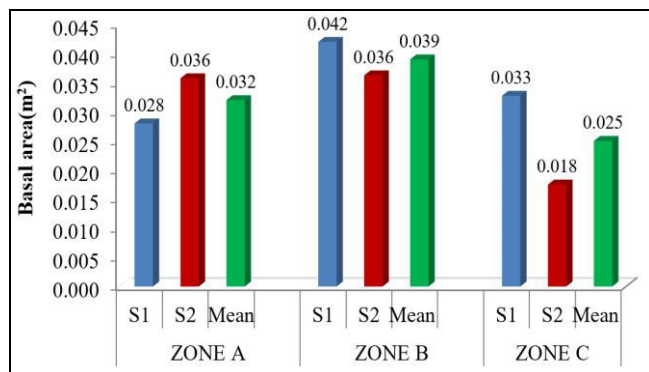


Fig 1d: Basal area of *Aquilaria malaccensis*

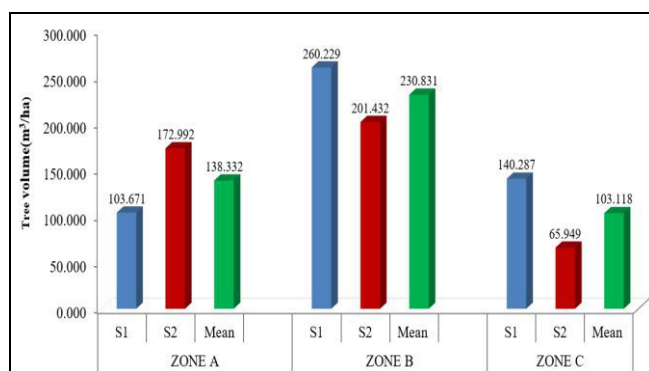


Fig 1e: Tree Volume of *Aquilaria malaccensis*

Fig 1: Growth and productivity of *Aquilaria malaccensis* under different agroclimatic zones

Conclusion

In this present investigation, Zone B showed the highest values for growth parameters such as mean GBH (0.673 m), tree crown diameter (2.8 m), tree basal area (0.039 m²), and tree volume (230.83 m³ ha⁻¹). Zone A showed highest average tree height of 10.5 m and Zone C with 10.3 m. The results showed the higher growth and productivity in Zone B (Hilly zone) with high altitude and high rainfall whereas, Zone A (Coastal zone) showed moderate growth and productivity having low altitude and high rainfall and least growth and productivity was observed in Zone C (North transition zone) having high altitude and low rainfall. These measurements provide insights into the characteristics of tree growth and productivity of agarwood grown in arecanut gardens across different agroclimatic zones of Uttara Kannada and Haveri districts. Agarwood demonstrated better growth and productivity in regions with higher rainfall and acidic soils, regardless of altitude.

References

1. Akter N, Neelim AZ. Agarwood plantation at BRAC tea estate: Introduction, environmental factors and financial analysis. *Econ Stud.* 2008;26:1-23.
2. Anonymous. Vanadurghi Agarwood India Limited. 2007. Available from: <http://indianagarwood.com>
3. Barden A, Anak NA, Mulliken T, Song M. Heart of the matter: agarwood use and trade and CITES implementation for *Aquilaria malaccensis*. Cambridge (UK): Traffic International; 2000. p. 17-18.
4. Chakrabarty K, Kumar A, Menon V. Trade in agarwood. New Delhi: TRAFFIC India and WWF-India; 1994. p. 1-51.
5. Chaturvedi, Khanna LS. Forest mensuration. Dehradun: International Book Distributors; 1984.
6. Hajra PK. A review of the genus *Aquilaria* Lam. in India. In: Ahmed M, Gogoi P, Ahmed GU, editors. Scope and dimension of agar (*Aquilaria* spp.) plantation in north east region. Nagaon (Assam): All Assam Traders and Agar Oil Manufacturers Association; 2000. p. 1-5.
7. Hossen S, Hossain MK. Initial growth performance of agar (*Aquilaria malaccensis*) plantations at public and private sectors in Bangladesh. *J Biosci Agric Res.* 2016;10(2):871-876.
8. Mat N, Rahman SA, Ngah N, Mahmud K, Rosni NA, Rahim KA. Growth and mineral nutrition of *Aquilaria malaccensis* (Karas) in two habitats as affected by different cultural practices. *J Nucl Relat Technol.* 2012;9(1):6-16.
9. Rabgay T, Gurung DB, Wangchuk K, Thinley P, Tshering B, Tshering K, Sitaula BK, Raut N. Environmental factors affecting agarwood (*Aquilaria malaccensis*) in forests of Bhutan. *Bhutan J Nat Resour Dev.* 2020;7(1):12-25.
10. Suharti S, Pratiwi P, Santosa E, Turjaman M. Feasibility study of business in agarwood inoculation at different stem diameters and inoculation periods. *Indones J For Res.* 2011;8(2):114-129.