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Research Article

GROWERS PERCEPTIONS IN ASSESSING THE PROSPECTS, CHALLENGES AND COST-BENEFIT ANALYSIS OF AGARWOOD (*Aquilaria malaccensis roxb.*) PRODUCTION: A CASE STUDY IN MOULVIBAZAR DISTRICT OF BANGLADESH

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Abstract

Among the most important non-wood forest products worldwide, Agarwood, derived from *Aquilaria malaccensis* Roxb., has growing economic and livelihood importance along with Bangladesh. Despite its significant export potential, empirical data regarding farm-level production practices, profitability and limitations are still scarce. This present study assessed the opportunities, obstacles and cost-benefit aids of agar tree cultivation based on the perspectives of growers in Barlekha upazila, Moulvibazar district of northeastern Bangladesh. A survey was administered to 120 households between November 2019 to May 2020. Primary data were obtained using structured questionnaire surveys, focus group discussions (FGDs) and field observations. Descriptive statistics, a Constraints Facing Index (CFI) and financial evaluation instruments, such as net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR) were utilized for the study. The findings indicated that agar farming is primarily showed by middle aged farmers (51.67%) posing primary to secondary education, small land holdings and moderate to high production experience. Agarwood was mostly grown in mixed cropping systems within homesteads and fallow lands often in association with jackfruit, mango and acacia species reflecting significant on-farm biodiversity. The majority of famers are depended on seedlings, cultivate in nurseries and followed a traditional management technique utilizing minimal irrigation and agrochemicals. The economic analysis revealed remarkable profitability with a net return of BDT 3,300.28 per tree and a benefit cost ratio of 5.92 over a 12 years production cycle. At the hectare level the NPV was BDT 3.36 million the discounted BCR was 3.54 and the IRR was 27.45% indicating strong financial viability. However, significant barriers included inadequate finance, poor technical assistance, unavailability of enhanced varieties and restricted access to contemporary production technology. Farmers indicated that enhanced agar production needed stronger marketing channels, training, technical support, favorable government policies and access to finance facilities. The study indicates that agar tree farming is a lucrative and viable agroforestry practice in Bangladesh and certain policy and institutional interventions might significantly improve its sustainability and impact on rural life.

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Introduction

Agar is a significant and costly non-wood forest product globally (Naziz et al., 2019). It refers to the resinous, aromatic and highly priced heartwood primarily derived from agar trees of the 'Thymelaeaceae' family (Barden et al., 2000; Das and Alam, 2001). While forest silviculturists focus on healthy and thriving trees, growers prioritize fungal-infected agar trees. Typically, agarwood forms as a result of the plant's defense mechanisms against wounding, through fungal infection, insect infestation, animal grazing or through natural or artificial inoculation. Agar is typically utilized in the production of fragrances, perfumes, incense, decorative displays, aromatherapy and pharmaceuticals (CITES, 2004; Pojanagaroon and Kaewrak, 2005; Liu et al., 2013; Abdin, 2014; Lee and Mohamed, 2016). Historically, it served as incense in religious services among Buddhists, Hindus, Christians and Muslims (Liu et al., 2013). Additionally, incense is employed in the manufacturing of soaps and shampoos (Schippmann, 2001).

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The family Thymelaeaceae is widely distributed across Asia, Africa and Australia and comprises about 50 genera with nearly 500 species. Agarwood is produced by several genera, including *Aquilaria*, *Aetoxylon*, *Gyrinops*, *Gonystylus*, and *Wikstroemia*; however, commercial agarwood production mainly relies on *Aquilaria* species (Lok, 2016; Lee and Mohamed, 2016; Rasool and Mohamed, 2016). Out of the 21 identified *Aquilaria* species, 13 are known to produce agarwood (Lee and Mohamed, 2016). *Aquilaria* is a fast-growing evergreen tree native to the Indo-Malayan region, reaching 18–40 m in height and about 40 cm in diameter (Elias et al., 2017). It grows best in well-drained acidic soils under warm, humid conditions with annual temperatures of 18–22°C and rainfall of 1500–6500 mm (Akter and Neelim, 2008).

Agarwood has a long history in Bangladesh and has traditionally grown naturally. Agar trees were once commonly found in Sylhet, Chittagong, Cox's Bazar and the Chittagong Hill Tracts, though they are now scarce and occur only sporadically (Hossain et al., 2021 and Hossen and Hossain, 2016). Commercial-scale cultivation remains limited; currently, about 30–35 families in Patharia, Dakshinbhadra and Sujanagar of Barlekha upazila, Moulvibazar district cultivate and process agar on a small scale within mixed plantations. Agar is a highly promising non-timber forest product (NTFP) in Bangladesh, contributing significantly to export earnings through agar oil (Hayder et al. 2005).

Agar is a highly promising non-wood forest product in Bangladesh, generating annual revenues ranging from US\$0.05 million to US\$1.19 million (Ador et al., 2021; Chowdhury et al., 2018). Historically, two species of agarwood (*A. agallocha* and *A. malaccensis*) were cultivated in the northeastern part of Bangladesh. Initially, wild resources constituted the primary source of agar raw material. However, due to the depletion of natural agar sources and heightened demand, numerous agar plantations have lately been constructed in Chittagong, the Chittagong Hill Tracts (CHT) and the Sylhet division of Bangladesh (Rahman et al., 2015). Currently, about 3009 hectares are dedicated to the production of agar trees across various regions of the country (Talucder et al., 2016). Additionally, a total of 121 private agar gardens has been built in the Sylhet division, with 111 of these gardens situated in the Barlekha Upazila of Moulvibazar district.

The agar farm is a viable company, yielding a net return of around US \$0.054 million per hectare over a 12-year rotation period. Consequently, the quantity of agar-based firms rose to 300 by 2015 (Rahman et al., 2015). The growing prevalence of agar firms and plantations is generating jobs and significantly contributing to the livelihood advancement of rural populations. Notwithstanding the significant economic contribution of agar products, limited research has been conducted on agar plantations and small-scale enterprises based on agar in Bangladesh (Hossen and Hossain, 2016; Chowdhury et al., 2018; Das et al., 2018; Islam et al., 2014; Akter et al., 2013) Furthermore, scant information exists concerning the socio-economic conditions, manufacture and marketing of agar products.

However, very limited information's are available on cultivation practices, processing and its problem and profitability (Ali et al. 2021). There is a necessity to examine the process due to significant potential for increasing its production, especially in the southeastern hilly regions of the country. Therefore, this study was conducted to analyze the socio-economic conditions and to summarize the agarwood production methods used at the farm level. This study also examined farmers' views on the potential benefits and limitations, as well as the financial aspects of Agar tree cultivation in the northeastern part of Bangladesh.

Methodology

Study area

The study was carried out Barlekha upazila (sub-district) of Moulvibazar district in Bangladesh. Barlekha Upazila is situated between latitudes 24°33" and 24°50" north and longitudes 92°02" and 92°18" east (Figure 1). The Moulvibazar district of Bangladesh is home to about 300 agar-based businesses (Hossain et al., 2021, Chowdhury et al., 2018 and Rahman et al., 2015).

The Barlekha upazila, one of the seven upazilas of the Moulvibazar district, is home to the majority of the agar plants and agar oil companies. Barlekha upazila was therefore specifically selected as the research region. The upazilas of Beanibazar in the north, Kulaura in the south, Golabganj and Fenchuganj in the west and India in the east encircle the research area. Grey Piedmont soils and non-calcareous grey floodplain soils are the two main soil types in the region (Rahman et al., 2015 and BARC, 2005). These soils have a slightly acidic to severely acidic reactivity and range in texture from loam to clay. According to BARC (2005) and Rahman et al. (2015), the fertility rate is low to medium.

Approach to gathering and analyzing data

In the Barlekha upazila of Moulvibazar district, Bangladesh, six villages in the unions of Sujanagar and Dakshinbhag were surveyed. The agar tree abundance was used to classify the villages as A, B, or C. For the survey, two communities were chosen from each category. From each of the six communities, a random selection of twenty agar farmers was made.

From November 2019 to May 2020, the survey utilized a face-to-face interview style. We wanted to know how the respondents were doing financially, what they knew about growing agar wood and what obstacles they faced when growing agar trees. The specific objectives of the study were to describe the socio-economic characteristics of the agar farmers, to assessing the prospects and challenges as well as the financial aspects of agar tree (*Aquilaria malaccensis* roxb.) production through growers' perceptions.

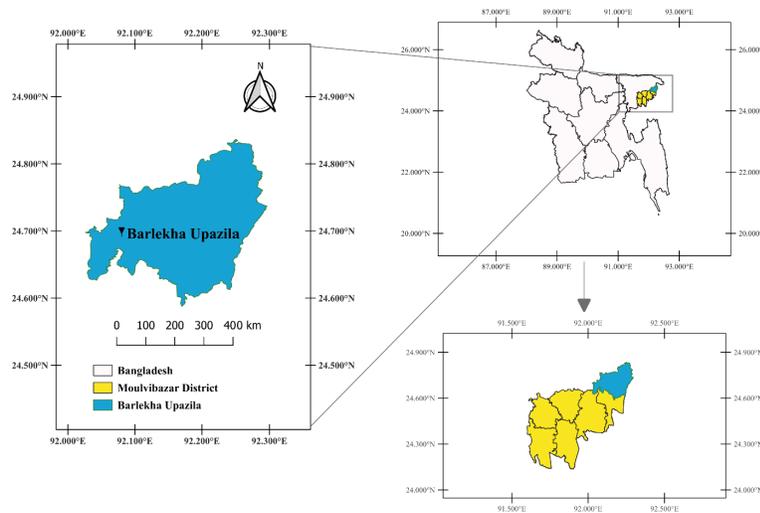


Figure 1. Map of Bangladesh and the Moulvibazar district delineating the study region.

Measurement of variables

The study variables comprised respondents' socio-economic characteristics and agar tree-based agroforestry practices. Age was measured in complete years and categorized as young (≤ 35 years), middle-aged (36–50 years), and old (> 50 years). Family size was determined by the number of household members living and eating together and classified as small (≤ 4), medium (6–8), and large (> 8). Occupation was identified based on respondents' primary and secondary livelihood activities. Education was measured by years of schooling and grouped into illiterate, primary (1–5 years), secondary (6–10 years), higher secondary (11–12 years), graduate (13–16 years), and above 16 years (MS/PhD/Postdoctoral). Farm size was measured in hectares and categorized as landless (0–0.20 ha), marginal (0.21–0.60 ha), small (0.61–1.0 ha), medium (1.01–3.0 ha), and large (> 3.0 ha).

Agar tree cultivation practices were assessed based on planting materials (seed, seedling, cutting, graft), sources of planting materials (own garden, nursery, neighbor, others), planting time, fertilizer use (cow dung, urea, both, or none), maturity symptoms, and harvesting time. Land use patterns were classified as homestead, crop field, roadside, fallow land, and others, while land resource utilization for cropping was recorded according to actual land use. Annual household income was estimated by summing agricultural and non-agricultural income sources during the study period. Training on agroforestry or crop production and adoption of agroforestry practices were recorded as yes/no variables. Indigenous agroforestry knowledge was assessed through cropping systems practiced in agar-based gardens (sole cropping or intercropping).

The Shannon-Wiener Index (SWI) was also used to evaluate the species richness and abundance of trees in all the locations in the study area (Margurran, 1988). The proportion of species; relative to the total number of species (p_i) was calculated and then multiplied by the natural logarithm of the same proportion ($\ln p_i$). The resulting products is summed across species and multiplied by -1.

$$SWI = -\sum p_i [\ln p_i]$$

Experience in agar tree cultivation was categorized as <10 years, 11–21 years, and >21 years. Motivation for adopting agar cultivation was classified into high profit, low cultivation cost, low labor cost, easy marketing, and others.

Economic analysis of agar tree production

Profitability of agar tree production was estimated by deducting total production costs from the gross value of outputs (wood chips only). Costs were calculated using prevailing market prices and farmers' recall for the previous 12 years. The major cost components included human labor (measured in man-days for land preparation, transplanting, fertilizer application, irrigation, pruning, harvesting, and marketing), seedlings, bamboo sticks (where used), manure (cow dung), chemical fertilizers (urea, TSP, MP, oil cake), and irrigation. All inputs were valued at actual prices paid by farmers in the study area.

Cost of interest on operating capital

Interest on operating capital was calculated for both material and non-material inputs using the formula:

$$\text{Interest on operating capital} = \frac{\text{Operating cost} \times \text{Rate of interest} \times \text{Time period (1 year)}}{2}$$

Land use cost was estimated based on the average annual cash rental value of land per hectare as reported by farmers. Benefits from associated trees were not included, as they were considered minor and economically insignificant.

Gross margin was calculated as the difference between gross return and variable cost, while net return was estimated by subtracting total cost from gross return. Benefit–Cost Ratio (BCR) was computed as the ratio of gross return to gross cost.

Financial viability analysis

Financial viability of 1ha agar plantations was assessed over a 12-year period using Net Present Value (NPV), Discounted Benefit Cost Ratio (BCR), and Internal Rate of Return (IRR). A discount rate of 10% was applied based on the lending rate of Bangladesh Krishi Bank. The investment was considered viable when $NPV > 0$, $BCR > 1$, and IRR exceeded the opportunity cost of capital. NPV and BCR were calculated using discounted annual benefits and costs, while IRR was estimated as the discount rate at which NPV equals zero (Rahman et al., 2015).

Net present value was calculated as: $NPV = \sum_{t=1}^n \frac{Bt-Ct}{(1+i)^t}$

Where,

Bt = Incremental benefit in the tth year

Ct = Incremental cost in the tth year

n = Project expected life period

i = Discount rate

Discounted benefit cost ratio is the ratio of present value of gross benefit to present value of gross cost. It was calculated using following formula:

$$BCR = \frac{\sum_{t=1}^n \frac{Bt}{(1+i)^t}}{\sum_{t=1}^n \frac{Ct}{(1+i)^t}}$$

Where,

Bt = Incremental benefit in the tth year

Ct = Incremental cost in the tth year

n = Project expected life period

i = Discount rate

IRR may be defined as that which equates initial investment with the future value of resulting cash flows (Torries, 1998). It was calculated using following formula:

$$IRR = LDR + (HDR - LDR) \times \frac{NPV \text{ at } LDR}{\text{Difference between } NPV \text{ at } LDR \text{ \& } HDR}$$

Where,

LDR = Lower discount rate

HDR = Higher discount rates

NPV = Net present value

Constraints and opportunities

Constraints to agar cultivation were assessed using a four-point rating scale (high = 3, medium = 2, low = 1, not at all = 0). Twelve constraints were identified through FGDs and literature review, with total scores ranging from 0 to 36 and classified as low, moderate, or severe. Opportunities and improvement measures were identified based on farmers' suggestions, which were recorded and ranked accordingly.

Data analysis

Collected data were checked, cleaned, coded and analyzed using SPSS (version 20), while Microsoft Excel 2013 was used for tabulation, charts and graphs. Functional analysis was applied to examine quantitative relationships among variables.

Results and Discussion

Socio-economic characteristics of agar farmers

Table 1 presents the socio-economic characteristics of the respondents. In the 120 agar farmers surveyed, 51.67% were middle-aged, equivalent to 62 respondents, followed by 31.66% elderly, with an average age of 48.48 years.

The sample farmers in the study area were classified into five categories based on their educational level: illiterate, primary (grades 1 to 5), secondary (grades 6 to 10), upper secondary (grades 11 to 12), and graduate (beyond grade 12, encompassing honors, degrees, and postgraduate qualifications). The respondents' educational status ranged from 0 to 16, with a mean of 8.01. A majority of the responders (35.00%) had primary education. The results revealed that the majority of farmers in Barlekha upazila had attained schooling only up to the primary and secondary levels. This outcome agreed with the facts referenced in BBS (2019). Education influences farmers' perspectives, attitudes, and inclinations towards the modernization of traditional agriculture (Alam, 2004; Hossain et al., 2021) and significantly aids in enhancing their comprehension of technical aspects and problem-solving (Olaoye et al., 2013). Ogunmefun and Achike (2017) have shown that a farmer's educational attainment influences the management and adoption of appropriate management and production technology. The mean number of family members among the respondents was 6.40, with 71.70% belonging to medium-sized households, equating to 86 respondents. In the Sylhet division, living with parents, siblings, and occasionally relatives are prevalent (Das et al., 2019). The respondents were classified into five distinct groups, as seen in Table 1, based on the size of the homestead. The marginal group (40.80%) and the landless group (30.00%) were the most prevalent, in contrast to the small group (19.20%), the medium group (5.80%), and the large group (4.20%).

Ten percent had medium farm holdings (1.01-3.0 ha) under agarwood production, whereas the majority of respondents, 103 (85.80%), had small farm holdings. Large farm holders (>3.0 ha) made up just 4.20%. There was considerable variation in the number of agar trees per farmer; 69 (57.50%) of the respondents were in the small group, followed by the medium group (46; 38.30%) and the large group (4.20%), with a standard deviation of 3383.64. The respondents were found to be most prevalent in the low-income group (56; 46.70%), followed by the medium group (43; 35.80%) based on their annual family income. Of the enormous group, only 17.50% had an annual monthly income of more than 300,000 BDT. The respondents' average annual income was Tk. 227.09 thousand, with a range of Tk. 65 to 1800 thousand. The results suggested that farmers in the study area had poor

Das et al., 2019). According to Table 1, roughly 10.80% of farmers had 0–10 years of experience, 59.20% had 11–21 years, and 30% had more than 22 years of agar farming experience.

Fourteen respondents had limited experience in agar cultivation under trees, classified as low (up to 10 years), with a mean of 18.72 (± 0.70). It was disclosed that elderly and middle-aged individuals with less education and extensive experience participated in agar production operations (Das et al., 2018). Experienced farmers can forecast agricultural output and market conditions (Olaoye et al., 2013). The majority of respondents, 83 (69.20%), possessed medium experience (11–20 years) growing agarwood under trees, followed by 23 (19.20%) with high experience. In an assessment comprising 10 questions to evaluate respondents' knowledge of agar tree cultivation, it was determined that the majority, 59 (49.20%), exhibited moderate knowledge, while 48 (40.00%) demonstrated high knowledge (Table 1). A Bangladeshi study by Hasan et al. (2021), Hossain et al. (2021), and Ghosh et al. (2020) asserted that knowledge is a pivotal factor affecting an individual's attentiveness and mental awareness.

Table 1: Socio-economic characteristics of the respondents (n=120)

Category	Frequency	Respondents (percent)	Mean ± SE	SD*
Age (years)				
Young (<35)	20	16.67		
Middle (35-50)	62	51.67	48.48 (±1.14)	12.50
Old (>50)	38	31.66		
Education (years of schooling)				
Illiterate (No schooling)	11	9.20		
Primary (1-5)	42	35.00		
Secondary (6-10)	37	30.80	8.01 (±0.36)	4.02
Higher secondary (11-12)	19	15.80		
Graduate (above 12)	11	9.20		
Household size (number)				
Small (≤4)	19	15.80		
Medium (5-8)	86	71.70	6.40 (±0.17)	1.92
Large (>8)	15	12.50		
Homestead size (ha)				
Landless (up to 0.05)	36	30.00		
Marginal (0.05-0.10)	49	40.80		
Small (0.11-0.20)	23	19.20	0.099 (±0.007)	0.078
Medium (0.21-0.3)	7	5.80		
Large (>03)	5	4.20		
Farm size (ha)				
Small (0.2-1)	103	85.80		
Medium (1.01-3)	12	10.00	0.63 (±0.07)	0.80
Large (above 3)	5	4.20		
Total number of agar tree per farmer				
Small (up to 1000)	69	57.50		
Medium (1001 to 10000)	46	38.30	2081.58 (±308.88)	3383.64
Large (above 10000)	5	4.20		
Annual family income ('000' BDT)				
Low (up to 150)	56	46.70		
Medium (151-300)	43	35.80	227.09 (±19.46)	213.16
High (above 300)	21	17.50		
Experience in agar cultivation (years)				
Low (up to 10)	13	10.80		
Medium (11-21)	71	59.20	22.00 (±1.04)	11.43
High (above 22)	36	30.00		
Agar wood cultivation under trees (years)				
Low (up to 10)	14	11.70		
Medium (11-20)	83	69.20	18.72 (±0.70)	7.69
High (above 20)	23	19.20		
Knowledge of Agar cultivation (Possible score: 0-30)				
Low (up to 10)	13	10.80		
Moderate (11-12)	59	49.20	19.41 (±0.62)	6.76
High (21-30)	48	40.00		

SD* = standard deviation; SE = std. error; BDT = Bangladeshi Taka, where 1 BDT = 0.012\$, Survey 2019-2020

Agar tree cultivation cropping system: Results shown in figure 2 indicates the cropping system for agar tree cultivation in the study area. It was noted that respondents used their land resources throughout the year with some remarkable variations among the seasons. In the study area, mixed cropping was the most important cropping system (85%) followed by significantly differed from sole cropping (15%). It is found that irrigation water was a big problem, particularly during the dry season.

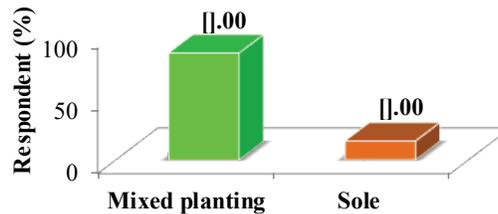


Figure 2. Distribution of the respondent according to the cropping system in the study area.

Planting site (Homestead and other places): The study shows that most of the respondent farmers planted their agar saplings at different microsities of homestead and adjacent fallow land (Figure 3). Among different microsities, most of the respondents (50.83%) planted agar saplings along with the backyard, which was followed by 22.50% and 18.33% in the boundary and home yard, respectively. Few farmers (8.33%) also planted at backyard + high land. On the other hand, considering the places, 65.83% respondent farmers planted agar trees in fallow land, while 26.67% and 7.50% respondents planted it in roadside and forestland, respectively (Figure 4). Alam (2004) observed similar results were found in his study.

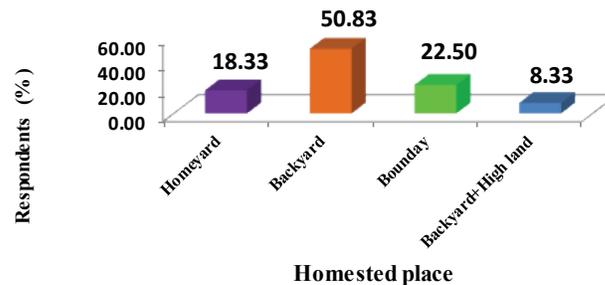


Figure 3. Distribution of the respondent according to planting site based on homestead of agar seedling.

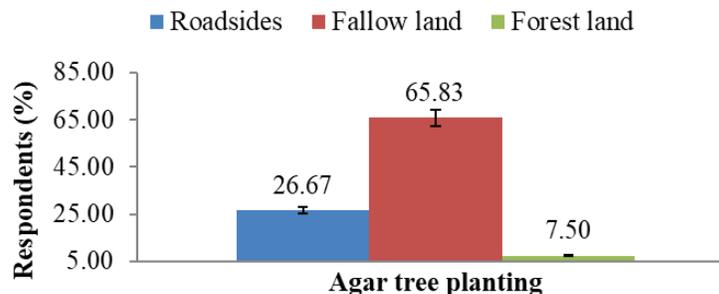


Figure 4. Distribution of the respondent according to planting site of agar seedling.

Associated trees and relative prevalence: The investigation shows that most of the respondents planted agar trees in association with jackfruit (*Artocarpus heterophyllus*) (83.30%) which were followed by mango (68.30%), akashmoni (65%), mangium (51.70%), orange, teak, guava etc. (Table 2). Relative prevalence (RP) of different timber and fruit tree species is shown in the Table 2. A total of 23 tree species was identified as associated trees/intercrops with agar trees in the surveyed agar farmers' field.

Table 2. Associated trees/crops with Agar cultivation in farmers field

Sl. No.	Name of associated tree	Number of respondents	Percent	Relative prevalence
1.	Jackfruit (<i>Artocarpus heterophyllus</i>)	100	83.30	0.224
2.	Mango (<i>Mangifera indica</i>)	82	68.30	0.166
3.	Akashmoni (<i>Acacia auriculiformis</i>)	78	65.00	0.313
4.	Mangium (<i>Acacia mangium</i>)	62	51.7	0.334
5.	Orange (<i>Citrus sinensis</i>)	24	20.00	0.086
6.	Teak (<i>Tectona grandis</i>)	20	16.70	0.061
7.	Guava (<i>Psidium guajava</i>)	20	16.70	0.061
8.	Mahogoni (<i>Swietonia macrophylla</i>)	18	15.00	0.056
9.	Bel (<i>Aegle mermelos</i>)	15	12.50	0.049
11.	Banana (<i>Musa spp.</i>)	14	11.70	0.068
12.	Litchi (<i>Litchi chinensis</i>)	13	10.80	0.031
13.	Papaya (<i>Carica papaya</i>)	13	10.80	0.083
14.	Pineapple (<i>Ananas comosus</i>)	12	10.00	0.188
15.	Tamarind (<i>Tamarindus indica</i>)	11	9.20	0.065
16.	Sissoo (<i>Dalbergia sissoo</i>)	10	8.30	0.113
17.	Pummelo (<i>Citrus maxima</i>)	10	8.30	0.053
18.	Koroi (<i>Albizia procera</i>)	9	7.50	0.148
19.	Ginger (<i>Zingiber officinale</i>)	8	6.70	0.058
20.	Betel nut (<i>Areca catechu</i>)	6	5.00	0.105
21.	Shimul (<i>Bombax ceiba</i>)	6	5.00	0.046
22.	Betel leaf (<i>Pimenta acris</i>)	4	3.30	0.124
23.	Lemon (<i>Citrus limon</i>)	4	3.30	0.145

Note: Total number of respondents 120.

The most relative prevalent and top ranked of Mangium (*Acacia mangium*) followed by Akashmoni (*Acacia auriculiformis*), Jackfruit (*Artocarpus heterophyllus*), Mango (*Mangifera indica*) etc. The variation in number of different species at the agar farms was wide, which indicated high plant biodiversity. Many species were very poor in number that indicated diminishing trend of agar plant diversity.

Planting materials: The findings of the study indicates that most of the respondent farmers (76.67%) used seedlings collected from a nursery for agar cultivation, whereas only 23.33% of the respondent farmers used seed (Figure 5). From this table, it is clear that most respondent farmers depend on seeding from a nursery for better agar cultivation. Sarker (2016) opined that relatively most of the respondents were used seedlings as planting material (95.00%) in the study area. Das et al. (2019) observed that majority of the respondents used seedlings as planting materials (80.00%) followed by 20.00% used seed for agar cultivation.

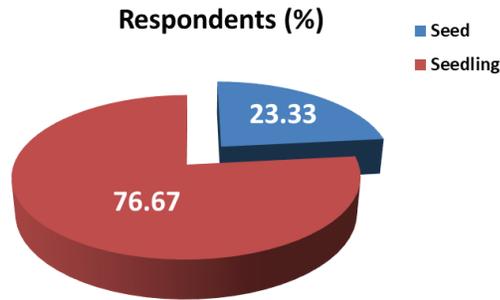


Figure 5. Distribution of the respondent as to the use of planting material for Agar cultivation.

Source of planting materials: The finding indicates that (Figure 6) generally the agar tree is wild in nature and propagates by natural regeneration, and farmers usually collect seedlings from nursery sources. Most of the respondents (69.17%) used seedlings as planting materials which were collected from the nursery, while 20.00% of respondents collected from natural regeneration and only 10.83% were own sources.

Sarker (2016) observed planting materials mostly used in the study area were seedlings, which were collected mostly from a nursery. Das et al. (2019); it was also observed that nearly 80.00% of planting materials used in the Barlekha upazila were seedlings, which were also collected from the nursery.

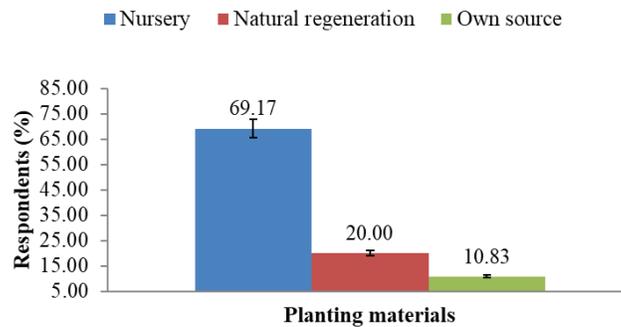


Figure 6. Distribution of the respondent in percentage regarding the source of planting materials for Agar cultivation.

Days to seed germination: Seed viability is approximately one week and germination takes place between 16 and 63 days (Ng et al., 1997). In this study, germination was observed mostly between 6 and 30 days. The respondents opined that most of them (46.67%) seed germination occurred between 15 to 20 days (Figure 7). Das et al. (2019) observed that nearly 44.00 percent of seeds germination occurred between 11 to 20 days.

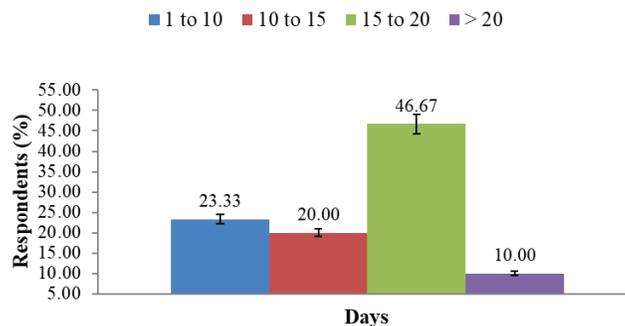


Figure 7. Distribution of the respondent (%) regarding days to agar seed germination

Age of seedlings: In Barlekha upazila, most of the farmers (51.67%) opined that less than 1 year-aged seedlings were used for planting. In contrast, 40percent of respondents opined that they used more than 1 to 1.50 year and up to 2 years aged seedlings for planting (Figure 8). Das et al. (2019) observed that, in Barlekha upazila, at most all the farmers (96.00%) used one year or less aged seedlings for planting. In contrast, only 4.00 percent of farmers used 1- to 2-year-old seedlings for planting.

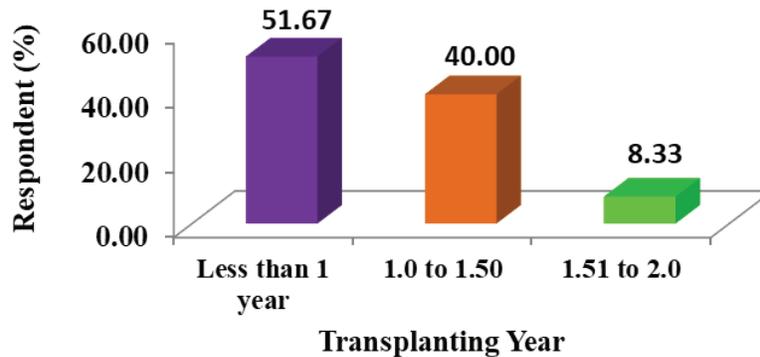


Figure 8. Distribution of the respondent (%) according to seedling age of agar tree for transplanting.

Different management practices of agar trees

The investigation shows that most of the respondent farmers (88.30%) used fertilizer and manure for agar tree production but only 11.30% of them did not use any fertilizer and manure (Table 3). More than two-fifth 43.40% of respondent farmers used fertilizer and manure during May to June, while 41.50% and 15.10% respondent applied during April-May and March-April, respectively. Rahman et al. (2015) opined that they mainly used cowdung but sometimes used chemical fertilizers like urea, TSP and MP. During the seedling and sapling stages both organic and inorganic fertilizers were applied to promote growth. The organic fertilizers included fresh cowdung, plant debris and compost made from cowdung. The common inorganic fertilizers used in agar plantations included urea, triple superphosphate (TSP) and muriate of potash (MP). Alam (2004) found similar results in their study area and Sarker (2016) also observed relevant results.

Most of the respondents farmers (59.20%) did not apply any irrigation because farmers frequently applied mulch at the base of agar trees to reduce water loss through evaporation (Table 3). Commonly used mulching materials included weeds removed during weeding operations, water hyacinth available from small and large water bodies, and sometimes straw or crop residue. However, mulching is not sufficient to prevent water loss during the dry season. Watering is carried out in the first year after out planting. Only 40.80% respondent farmers applied irrigation. More than half of the (57.10%) respondent farmers applied irrigation during January-February, whereas 38.80% and 4.10% farmers applied irrigation during March-April and April-May (Table 3). Sixty five percent farmers performed weeding but 35% farmers didn't weeding. More than three-fifth (64.10%) farmers performed weeding during August-September whereas 20.50% and 15.40% farmers did the same during June-July and July-August, respectively (Table 3). Weeding to reduce the competition between the agar trees and other undesired plant species was the most frequently applied operation in agar plantations. Intensive weeding was carried out during the first 3 years.

Table 3. Distribution of the respondent with regard to different management practices of Agar trees

Category	Number	Percent
Fertilizer and manuring application		
Yes	106	88.30
No	14	11.70
If yes, when		
April-May	44	41.50
May-June	46	43.40
March-April	16	15.10
Total	106	100
Irrigation		
Yes	49	40.80
No	71	59.20
If yes, when		
January- February	28	57.10
March-April	19	38.80
April-May	2	4.10
Total	49	100
Weeding		
Yes	78	65.00
No	42	35.00
If yes, when		
June -July	16	20.50
July-August	12	15.40
Aug-Sept	50	64.10
Total	78	100
Pruning		
Yes	102	85.00
No	18	15.00
If yes, when		
June -July	8	7.80
July-August	18	17.60
Oct.-Nov.	76	74.50
Total	102	100
Insecticide application		
Yes	42	35.00
No	78	65.00
If yes, when		
July-August	4	9.50
Oct.-Nov.	38	90.50
Total	42	100

Rahman et al. (2015) opined that weeding intensity varies with plantation age. Intensive weeding is required at the seedling stage. Most of the respondent farmers (85.00%) pruned agar trees, while 15% respondents did not pruned agar trees. About 74.50% respondent famers pruned agar tree during October-November. Whereas 17.60% and 7.80% respondent farmers pruned agar trees during July-August and June-July respectively (Table 3).

Pruning was done only once a year, from the third to fifth or sixth year after planting. According to the farmers, the best time for the pruning is the end of November. Information contained (Table 3) indicate that most of the respondents (65%) did not use any insecticide/pesticide/fungicide while only 35% respondent farmers used insecticide/pesticide/fungicide. Majority of the (90.50%) respondent farmers applied insecticide during October-November and only 9.50% respondent farmers applied insecticide during July-August. Rahman et al. (2015) opined that the traditional management practices are adapted based mostly on indigenous knowledge and technology to manage agar cultivation in the Barlekha upazila of Maulvibazar district. According to the EIRI Board (2009), in agar plantation no such serious pests and diseases have been observed. However, *Heortia vitessoides* a leaf-eating caterpillar is considered to be the most destructive pest causing damage by complete defoliation of agar plantations and has become a real menace to the plantations in this region. In this study, 45.00% respondent farmers responded about positive insect-pest infestation. According to respondent farmers' base line survey the insect was ant, caterpillars but they didn't use any type of insecticide/ fungicide because they thought insect attack was not so harmful for the trees.

Flowering time

In Barlekha upazila, most of the respondent farmers (53.33%) opined that the agar plant took 6-9 years for flowering after planting and 35.00 percent opined that it took 10-12 years and 11.67% pronounced that it took <6 years (Figure 9). Ahmed (2010) reported that in agar plant, flowering occurs 6-10 years after planting which is similar to this observation. Das et al. (2019) also opined that the (61.54%) agar plant took 6-10 years for flowering after planting.

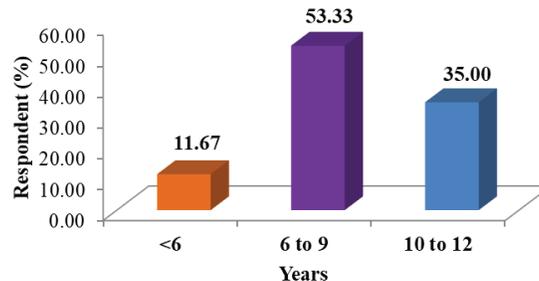


Figure 9. Distribution of the respondent according to their response on time of first flowering (years) of after planting of agar trees.

Height of agar tree

Height of agar tree ranged from less than 6 to 15m. In this range, 11.67% respondent farmers opined that the length of agar tree was <6.0m, 48.33% of them opined that the length was 6.0-9.0 m. Around one third (35.00%) respondent farmers opined that the height ranged from 9.0-12.0 m and rest 5.00% respondent farmers reported that the length varied from 12.0-15.0 m (Figure 10).

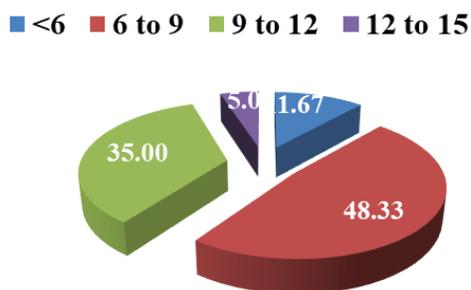


Figure 10. Distribution of the respondent according to their response on plant height at maturity stage (m) of Agar tree.

Economics performance of agar wood production

Cost of agar-wood production

Total cost of production involves all cost items incurred by the farmers in cultivating of agar plant during a period of 12 years. The total cost was derived by adding variable cost and fixed cost, and total variable cost comprises material cost labour cost for agar production. The variable cost per agar tree was BDT 588.57, which was 88.66 percent of the total cost. Total fixed cost was BDT 82.82 per agar tree, which was 12.34 percent of the total cost. Under variable cost, material cost was calculated as BDT 325.34 per agar tree which was 48.46 percent of the total cost and labour cost was BDT 195.52 per agar tree, which was 29.12 percent of the total cost. Among different cost items, purchasing of nail and setup nail for nailing on mature agar plant (at 6-7 years) occupied highest share (63.31%) of total cost (Appendix table 1).

Table 4. Gross cost, gross margin, net return and benefit cost ratio of Agar tree cultivation

Sl no.	Profitability indicator	Return (BDT Tk.)
1.	Total cultivation cost/tree	520.86
2.	Overhead cost/tree	150.53
3.	Gross cost/tree	671.39
4.	Gross margin/tree*	3771.67
5.	Gross return/tree*	3971.67
6.	Net return/tree*	3,300.28
7.	Benefit cost ratio*	5.92

*Economic cycle of agar tree is 12 years; (Source: Estimation based on field survey (2019-2020))

Gross return, net return and benefit cost ratio

It was estimated that 3702 agar trees can be obtained from 1 hectare of land due to damage of some seedlings at initial stage of production (assumed 80.00% survival rate). The farmers sell their agar plant to the processors and the price is fixed through the bargaining. The average price of agar plant was BDT 3,771.67 per tree. The gross return of agar farmers was BDT 3971.67 per tree (Table 4). The net return was estimated at BDT 3300.28 per agar tree. Benefit cost ratio (after 12 years) of agar farmers was estimated be 5.92, that means the farmers are getting BDT 592 by investing BDT 100 (Table 4). This indicates that, agar-wood production is a profitable business.

Financial viability of agar-wood production

Financial viability for agar-wood production was determined for a farm of 1 hectare of land for a period of twelve years. Cash inflow, cash outflow and incremental net benefit (INB) with their present values for a duration of 12 years are shown in (Table 5). Most of the cost items of agar production was incurred in the first year of operation. Because of nailing cost and gross cost was highest in seventh year. The net present value calculated at 10% discount rate was BDT 33,62,881.83 (Table 6). Similarly, discounted benefit cost ratio was 3.54 which means that BDT 100 of initial investment yields a net benefit of BDT 354. The internal rate of return (IRR) was 27.45% which was very high as compared to required rate of return i.e., 10%. Since, IRR was greater than the required rate of return representing the opportunity cost of capital, investment in agar production was financially viable.

Table 5. Cash flow in agar-wood production for one hectare of land

Year	Gross cost (GC)	Gross benefit (GB)	Incremental net benefit (INB)	Dis. Factor @10%	Present value of GC	Present value GB	Present value of INB
0	564921.85	0	-564921.85	1	564921.85	0.00	-564921.85
1	35426.69	0	-35426.69	0.91	32206.08	0.00	-32206.08
2	24712.62	0	-24712.62	0.83	20423.65	0.00	-20423.65
3	24712.62	0	-24712.62	0.75	18566.96	0.00	-18566.96
4	28648.53	10000	-18648.53	0.68	19567.33	6830.13	-12737.19
5	14649.98	193506.6	178856.69	0.62	9096.48	120152.42	111055.93
6	13935.90	243506.6	229570.76	0.56	7866.45	137453.17	129586.71
7	1577951.1	293506.6	-1284444.48	0.51	809738.44	150615.33	-659123.11
8	10000	0	-10000	0.47	4665.07	0.00	-4665.07
9	10000	0	-10000	0.42	4240.98	0.00	-4240.98
10	10000	0	-10000	0.39	3855.43	0.00	-3855.43
11	10000	0	-10000	0.35	3504.94	0.00	-3504.94
12	10000	13964973	13954973	0.32	3186.31	4449670.77	4446484.46

Source: Estimation based on field survey (2019-2020)

Table 6. Financial viability of agar-wood production for 1 hectare of land in the study area

Sl. No.	Particulars	Value
1.	Net present value (NPV)	3362881.83
2.	Discounted Benefit cost ratio	3.54
3.	Internal rate of return (IRR)	27.45

Source: Estimation based on field survey (2019-2020)

Problem and prospect of agar tree

Constraints in Agar tree cultivation

A Constraints Facing Index (CFI) was computed and represented in rank order (Table 7). The findings showed that lack of capital to invest in agar tree cultivation, with a CFI score of 2.81, was the most critical constraint to the agar farmers.

According to Das et al. (2018) and Uddin et al. (2008); agar-wood production cost is very high and all the farmers in the study area were not economically solvent for which they the interviewed farmers in the study area mainly belonged to the low-income group who need money for running their farming operations, but credit was available only at a very high interest rate (Table 7). Rahman et al. (2015) also reported that lack of credit facilities was the major problem in agar production and processing. Moreover, lack of credit support could be another reason for low investment constraint (Table 7). Lack of technical guidance (CFI = 2.77) was the second most critical constraint in agar tree cultivation. A majority of the farmers in the study area were semi-intensive agar tree growers.

Table 7. Constraints in Agar tree cultivation faced by the farmer (n = 120)

Constraints	Extent				CFI	Rank order
	High	Medium	Low	Not at all		
Lack of capital to invest	100	17	3	0	2.81	1
Lack of technical guidance	92	28	0	0	2.77	2
Lack of improved Variety	82	30	10	0	2.63	3
Lack of improved technology	71	35	14	0	2.48	4
Introspection by forestry	63	40	17	0	2.38	5
Lack of credit	46	47	27	0	2.16	6
Disease and pest infestation	42	50	28	0	2.12	7
Growing type	55	35	21	9	2.13	8
Lack of land	24	40	48	8	1.67	9
Seedling mortality rate	4	72	40	4	1.63	10
Lack of seedling	31	26	46	17	1.59	11
Lack of workers	18	24	70	8	1.43	12

Note: High = 3, medium = 2, low = 1 and not at all = 0; CFI = constraints facing index. Survey 2019-2020

Unavailability of improved variety (CFI = 2.63) was the third critical constraint to the farmers. The growth and quality of agar plant in respect of oil extraction largely depends on improved variety. Low quality variety can easily be affected by different insects and diseases (Das et al., 2018). Lack of improved technology (CFI = 2.48) was the fourth critical constraint to the agar tree farmers. However, lack of workers (CFI = 1.43) was the least critical constraint. Without efficient labour, work is not possible in any sector. Das et al. (2018) and Chowdhury et al. (2018a) opined that in the rainy season shortage of human labour was exhibited in the study area and cost of labour was very high.

Farmer’s suggestions for increased agar production

Respondents provided some suggestions to increase the productivity of agar trees, which are presented in Table 8. In the study area, most of the respondents (86.70%) suggested that improved proper marketing channel with various relevant aspects would be very helpful to increase agarwood cultivation followed by the use of improved training facilities (73.30%), technical support (71.70%), required government policy (70.00%) and improved production technology (63.30%). Proper monitoring should be done by the forest department (60.00%), developing of high yielding variety (58.30%) and take the easy way for a public bank loan (38.30%) and lease of khasland (20.00%) were also suggested by the good number of respondents in the study area.

Table 8. Respondents opinion regarding measures to be taken for solving the problems in study area (n=120)

Suggestion	Respondents (%)	Rank
Proper marketing channel	86.70	1
Training facilities	73.30	2
Technical support	71.70	3
Required govt. policy	70.00	4
Improved production technology	63.30	5
Proper monitoring should be done by the forest department	60.00	6
Developing of high yielding variety	58.30	7
Take easy way for public bank loan	38.30	8
Lease of khasland	20.00	9

Conclusion

The study reveals that the cultivation of *Aquilaria malaccensis* in the Moulvibazar district represents a very lucrative and economically feasible agroforestry systems with significant potential to improve rural lifestyles in Bangladesh. Smallholders mostly conduct agar farming using mixed cropping systems and traditional management techniques which enhances on-farm biodiversity and land-use efficiency. Economic analysis substantiates substantial profitability, evidenced by a high benefit cost ratio (BCR), a positive net present value (NPV) and an internal rate of return (IRR) significantly exceeding the current discount rate. Agar production, despite its economic potential, is hampered by restricted access to capital, insufficient technical assistance, the absence of enhanced planting materials and inadequate institutional and marketing support. Mitigating these limits through specialized training programs the creation and distribution of improved varieties and technologies access to inexpensive loans and supporting governmental policies might substantially boost productivity and sustainability. Agar cultivation constitutes and essential non-timber forest product industry that can enhance export revenues, create employment opportunities and promote sustainable agroforestry development in Bangladesh.

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Competing interests

Authors have declared that no competing interests exist.

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Appendix table 1. Cultivation production Cost of per agar tree

A. Input cost

i. Material cost

Sl no.	Inputs	Amount of inputs (Tk/tree)	Unit Price (Tk)	Total cost (Tk)	% of total cost
1.	Seed/Seedling	1	9.47	9.47	1.41
2.	Fertilizer (kg)				0.00
	Urea	0.36	20.00	7.15	1.07
	TSP	0.26	35.00	9.05	1.35
	MP	0.10	25.00	2.52	0.37
	Cow dung	3.31	1.90	6.27	0.93
	Compost	1.51	3.43	5.17	0.77
3.	Irrigation			15.78	2.35
4.	Bamboo stick	0.09	144.00	12.30	1.83
5.	Nailing materials kg (25.56% of total trees)	10.98	91.80	257.64	38.37
	Total			325.34	48.46

ii. Non material cost

Sl no.	Operation	Man power @ 422 Tk/day	Total cost (Tk)	% of total cost
1.	Pit making	0.020	8.40	1.25
2.	Seedling transplanting	0.010	4.13	0.62
3.	Fertilizer application	0.008	3.50	0.52
4.	Bamboo stick	0.011	4.64	0.69
5.	Irrigation	0.007	3.12	0.47
6.	Nailing labor	0.256	167.48	24.94
7.	Pruning and others application	0.010	4.25	0.63
	Total	0.322	195.52	29.12

Total input cost = 325.34+195.52=520.86

B. Overhead cost

Sl	Profitability indicator	Return (Tk.)	% of total cost
1.	Interest (8%) of total input cost	41.67	6.21
2.	Rental value of land up to 15 years	82.82	12.34
3.	Miscellaneous (5%) of total input cost	26.04	3.88
4.	Total	150.53	22.42