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Population structure and regeneration status of *Aquilaria malaccensis* Lam. in homegardens of Upper Assam, northeast India

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Abstract: *Aquilaria malaccensis,* a critically endangered tree species of India, is cultivated in homegardens of Assam. We studied the population structure and regeneration status of this species in homegardens of Upper Assam, northeast India. Population structure of the species was studied in 135 homegardens and regeneration status was studied in eight selected homegardens of Jorhat and Golaghat districts of Upper Assam. In the studied homegardens, population density (individuals ha^{-1}) of *A. malaccensis* was 1,443, 4,060 and 33,917 for trees (> 3.18 cm diameter at breast height = DBH), saplings and seedlings, respectively. This pattern of density distribution (seedlings > saplings > trees) indicates good regeneration status of the species in homegardens. On the other hand, out of the eight selected homegardens, seven showed good regeneration status, whereas, one showed fair regeneration status for the species. Seasonal survival rate of *A. malaccensis* saplings was significantly different among the eight selected homegardens during all the four seasons (each season of three months) of the year but that of seedlings and trees did not differ significantly. Average seasonal growth rate of *A. malaccensis* (in terms of collar diameter for seedlings and saplings, and DBH for trees) varied significantly among the eight selected homegardens as well as between the four seasons. The findings of the present study suggest that homegardens can save the species from the risk of extinction.

Resumen: *Aquilaria malaccensis,* especie arbórea de la India en peligro crítico de extinción, se cultiva en huertos familiares de Assam. Se estudió la estructura de la población y el estado de la regeneración de esta especie en huertos familiares del Alto Assam, noreste de la India. La estructura de la población de la especie fue estudiada en 135 huertos familiares y el estado de la regeneración se estudió en ocho huertos selectos de los distritos Jorhat y Golaghat, Alto Assam. En los huertos familiares estudiados, la densidad poblacional (individuos ha^{-1}) de *A. malaccensis* fue 1,443, 4,060 y 33,917 para árboles (> 3.18 cm de diámetro a la altura del pecho = DAP), brinzales y plántulas, respectivamente. Este patrón de distribución de la densidad (plántulas > brinzales > árboles) indica un buen estado de regeneración de las especies en los huertos familiares. Por otro lado, de los ocho huertos seleccionados, siete mostraron un buenestado de regeneración para la especie, mientras queel otro mostró un estado de regeneración regular. La tasa de supervivencia estacional de los brinzales de *A. malaccensis* difirió significativamente entre los ocho huertos seleccionados en las cuatro estaciones (temporadas de tres meses) del año, pero las tasas de los brinzales y los árboles no difirieron significativamente. La tasa de crecimiento estacional promedio de *A. malaccensis* (en términos de diámetro del cuello de plántulas y brinzales, y de DAP de los árboles) varió significativamente entre los ocho huertos seleccionados y entre las cuatro estaciones. Los resultados del presente estudio sugieren que los huertos familiares pueden salvar a la especie del riesgo de extinción.

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Resumo: *Aquilaria malaccensis,* uma espécie arbórea criticamente ameaçada na Índia, é cultivada nas hortas de casa em Assam. Este estudo aborda, assim, a estrutura populacional e o estado da regeneração desta espécie nas hortas do Alto Assam, nordeste da Índia. A estrutura populacional da espécie foi estudada em 135 hortas sendo o estado da regeneração estudado em oito hortas selecionadas em Jorhat e nos distritos de Golaghat nas zonas altas de Assam. Nas hortas estudadas, a densidade populacional (indivíduos ha^{-1}) de *A. malaccensis* foi de 1.443, 4.060 e 33.917 para as árvores (com diâmetro à altura do peito = DAP > 3,18 cm), novedio e nascedio, respectivamente. Este padrão de distribuição da densidade (nascedio > novedio > árvores) indica o bom estado de regeneração da espécie nas hortas de casa. Por outro lado, das oito hortas selecionados, sete apresentaram um bom status de regeneração, enquanto que uma revelou um estado de regeneração razoável. A taxa de sobrevivência sazonal do novedio de *A. malaccensis* apresentou-se significativamente diferente entre as oito hortas de casa selecionadas durante todas as quatro estações do ano (cada estação de três meses), excepto para o novedio e árvores onde as diferenças não eram significativas. A taxa média de crescimento sazonal da *A. malaccensis* (em termos do diâmetro do colo do nascedio e novedio, e DAP para as árvores) variou significativamente entre as oito hortas selecionadas, bem como entre as quatro estações do ano. As conclusões do estudo sugerem que hortas de casa podem salvar a espécie do risco de extinção.

Key words: Agarwood, basal cover, coppice regeneration, density, growth, survival.

Introduction

Natural regeneration is a key process for the continued existence of a species in a community. Ability of species to initiate new seedlings, their survival and growth are the three major components of successful regeneration (Good & Good 1972). The success of regeneration can be predicted on the basis of current population structure, growth and fecundity (Guedje *et al.* 2003). Successful regeneration is perhaps the single most important step towards achieving long term sustainability of managed forests. Presence of sufficient number of seedlings, saplings and young trees in a given population indicates successful regeneration (Saxena & Singh 1984), which is frequently influenced by the biotic interactions and physical factors in the community. Studies on tree population structure and regeneration behavior in the natural tropical forest ecosystems of northeast India have been carried out by several workers (Bhuyan *et al.* 2003; Duchok *et al.* 2005; Khan *et al.* 1987; Khumbongmoyum *et al.* 2005; Uma Shankar 2001; Upadhaya *et al.* 2009). Similar studies are lacking on tree species commonly grown in the home gardens of the region (Saikia *et al.* 2012).

Population of *A. malaccensis* has markedly decreased in natural forests of northeast India due to unsustainable harvesting of mature trees for agarwood trade, forcing the government to take action to bring the international trade within sustainable limits. Hence, the species is included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 1994). The species is also listed as 'Vulnerable' globally, 'Critically Endangered' in India (IUCN 2009) and almost 'Extinct in Wild' in Assam (Anonymous 2003). Therefore, there is an urgent need to develop suitable regeneration strategies to augment its natural regeneration and conservation. The species is commonly cultivated in the homegardens of Upper Assam in association with other useful plants for its high commercial value. We studied the population structure and regeneration status of *A. malaccensis* in the home gardens of Upper Assam in northeast India and results are discussed in the present paper.

Materials and methods

Study site

The study was conducted in the homegardens of Golaghat and Jorhat districts of Upper Assam,

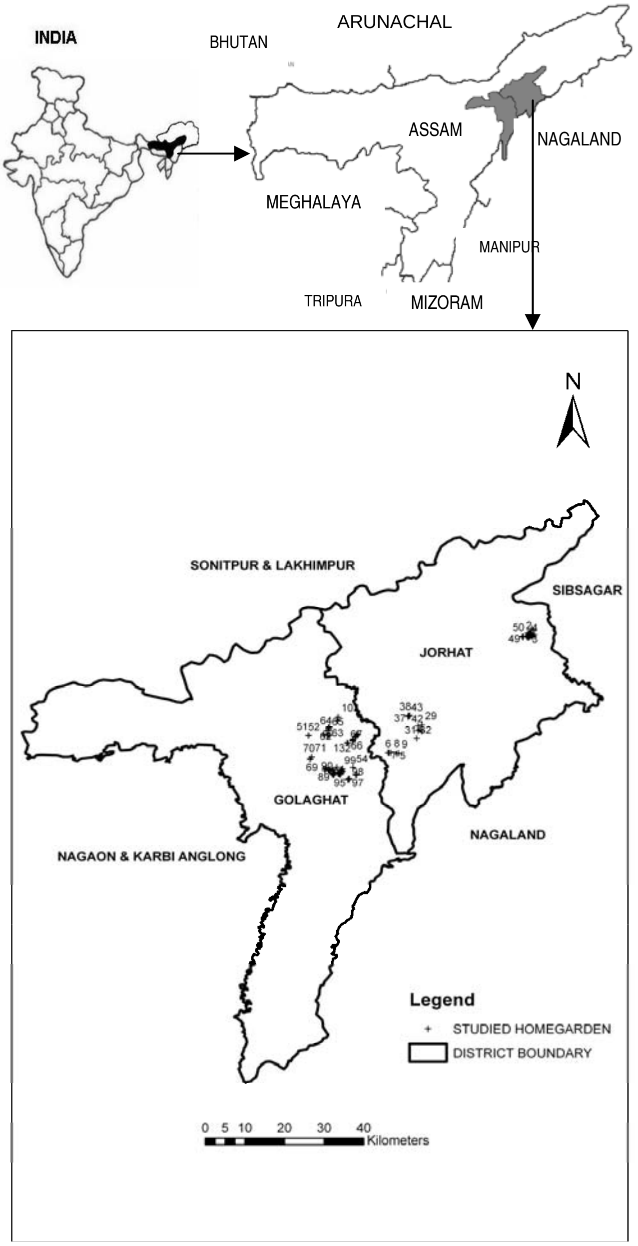

Fig. 1. Map of the study area (Golaghat and Jorhat districts of Upper Assam) showing the locations of studied homegardens.

northeast India (25˚ 48' to 27˚ 10' N lat and 93˚ 17' to 94° 36' E long) covering *ca.* 6400 square kilometer area (Fig. 1). The area is surrounded by Sibsagar and Dibrugarh districts in the east, Karbi Anglong and Nagaon districts in the west, Lakhimpur and Sonitpur districts in the north and bordering the state of Nagaland in the south. The climate is distinctly seasonal with a hot and humid summer (39 °C during June - July) and cooler winters (9 °C during December - January).

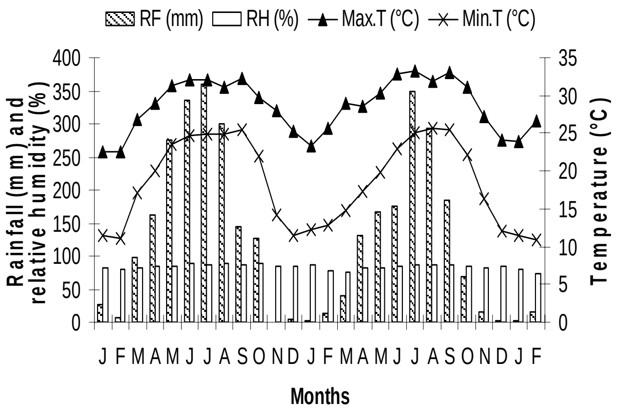

Fig. 2. Total monthly rainfall, average relative humidity and average maximum and minimum temperatures of the study sites (Jorhat and Golaghat districts of Upper Assam) during January 2008 to February 2010.

Average annual rainfall at Golaghat and Jorhat district is 1300 mm and 2244 mm, respectively, with maximum precipitation occurring during June - July. Different environmental parameters of the study site during different months of the years are shown in Fig. 2. The human population density of Golaghat and Jorhat districts is 236 and 354 per km^2, respectively (Census of India 2001). The economy of the two districts is mainly based on agriculture comprising rice, tea and sugarcane as the major crops. Agarwood also contributes significantly to the economy of the region.

Vegetation analysis

Field survey was undertaken in homegardens of Upper Assam, northeast India during 2007 - 2010. Twenty seven (16 in Golaghat and 11 in Jorhat districts) villages were selected randomly from the pool of agarwood cultivating areas of Golaghat and Jorhat districts. This roughly represented about 30 % of all the agarwood cultivating area in the districts. Trees were sampled using 10 x 10 m quadrats covering at least 30 % area in each homegarden. Within each randomly laid quadrat for trees, one 5 x 5 m quadrat for saplings and two 1 x 1 m quadrats for seedlings were studied. Diameter at breast height (1.37 m above ground) and height of all the individuals were recorded in each quadrat. They were grouped into seedlings (≤ 20 cm height), saplings (≤ 3.18 cm DBH and > 20 cm height) and trees (> 3.18 cm DBH) of different diameter classes for analyses of population structure. The data were used to compute density (individuals ha^{-1}) of seedlings, saplings and trees and basal area (cm^2 ha^{-1}) of trees in each homegarden. *Aquilaria malaccensis* regenerates mainly through seeds. But regeneration through sprouting from cut stumps of harvested trees is also common in this species. Number and collar diameter of such stumps and the number of sprouts per stump were recorded to study the coppice regeneration.

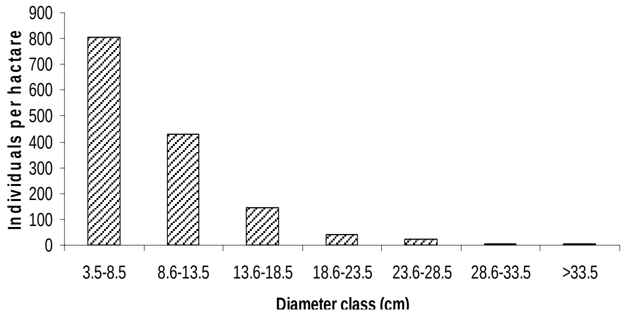

Fig. 3. Density (ha^{-1}) of *A. malaccensis* in different diameter classes in 135 studied homegardens of Upper Assam, NE India.

Out of the total 135 surveyed homegardens, eight homegardens (four from each district) were selected to enumerate the regeneration status based on homegarden size, location, vegetation and regeneration potential of *A. malaccensis*. Regeneration was studied in permanent quadrats in these eight selected homegardens from March 2008 to March 2010 by enumerating the population size of seedlings, saplings and trees at three-month interval following Khumbongmayum (2004). Like population structure study, permanent quadrats were also laid covering a minimum of 30 % area in each homegarden. Regeneration was considered as (i) good, if seedlings > saplings > adult (ii) fair, if seedling > sapling ≤ adult (iii) poor, if species survived in only sapling stage or sapling population was less than that of adult, and (iv) no regeneration, if only adult individuals were present in the population (Uma Shankar 2001). Survival and growth of all seedlings, saplings and trees were studied at three-month interval over a period of two years (from March 2008 to March 2010). For the present study, the year was divided into four seasons, with three months per season. Sufficient number of individuals (n = 50 - 160) per homegarden were tagged with aluminium labels. Growth of the tagged seedlings and saplings was measured in terms of collar diameter, height and leaf number and for trees in terms of diameter at breast height (DBH). Growth rate was calculated by using the formula:

Growth rate (%) per three months (season) = B – A/A × 100

where, A is initial growth and B is the growth after three months.

Different environmental parameters (average monthly rainfall, maximum - minimum temperature and relative humidity) of both the Golaghat and Jorhat districts during different months, from January 2008 to February 2010, were collected from the Sugarcane Research Institute and Agrometeorological Department of Assam Agricultural University of Golaghat and Jorhat district, respectively.

Standard error was calculated using MS Excel and ANOVA (*F*-test) was performed using software package SYSTAT.

Results

Population structure

Tree density of *A. malaccensis* varied between different homegardens, and ranged from 260 to 7,913 individuals ha^{-1}, the average value being 1,466 individuals ha^{-1}. DBH of the tree ranged from 3.5 to 56 cm (mean 9.13 cm; SE ± 0.05). Stand density decreased with the increasing diameter class size (Fig. 3). Highest tree density (almost 56 % of the total tree density) was in 3.5 to 8.5 cm diameter class. Plant height ranged from 1 to 28 m (mean 7.79 m; SE ± 0.04). Percentage of individuals decreased with the increasing height class and was the highest (40 % of the total individuals) in the height class 1 to 5 m (Fig. 4). Our study showed that about 52 % homegardens have good regeneration, 8 % fair and 40 % poor

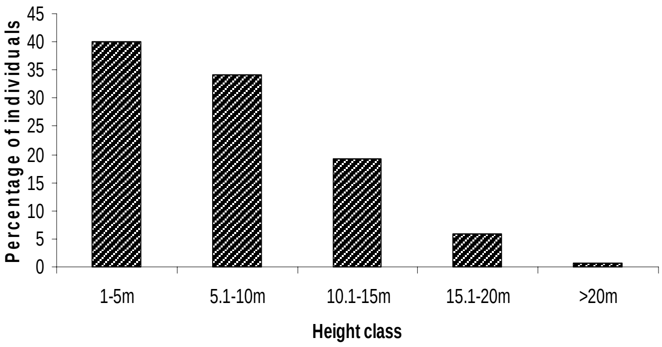

Fig. 4. Percentage of individuals of *A. malaccensis* in different height classes in 135 studied homegardens of Upper Assam, NE India.

Table 1. Location, area (ha), density (individuals ha^{-1}), basal area (cm^2 ha^{-1}) and regeneration status of *A. malaccensis* in eight selected homegardens (HGs) of Upper Assam.

S. No.	HG No.	District	Village	Area (ha)	Basal area of trees (cm^2 ha^{-1})	Density ha^{-1}				Regeneration status
						Seedlings	Saplings	Trees	Associated tree species	
1	HG1	Jorhat	Gayan Gaon	0.13	52.60	155000	4880	2840	1560	Good
2	HG44	Jorhat	Doloigaon	0.13	73.24	60000	4200	2050	1275	Good
3	HG4	Jorhat	Kakati Gaon	0.20	79.20	89167	2400	1317	1200	Good
4	HG5	Jorhat	Kakati Gaon	0.20	70.75	101667	5933	700	1617	Good
5	HG28	Golaghat	Sialekhati	0.13	47.49	33125	900	1488	2138	Fair
6	HG77	Golaghat	Namsonia Gaon	0.27	99.92	403889	7244	2356	1478	Good
7	HG26	Golaghat	Kabarugaon	0.13	30.27	22000	2400	780	900	Good
8	HG52	Golaghat	Kabarugaon	0.16	145.11	413000	3200	1520	1500	Good

regeneration of *A. malaccensis,* leaving only 1 % of homegardens with no regeneration (Appendix Table 1). The average seedling and sapling densities (37,052 and 4,406 individuals ha^{-1}, respectively) were higher in the homegardens of Jorhat compared to Golaghat district (32,198 and 3,870 individuals ha^{-1}, respectively) but, tree density (1,483 individuals ha^{-1}) was higher in the homegardens of Golaghat than those of Jorhat (1,369 ha^{-1}) district. *A. malaccensis* showed good regeneration status in homegardens of both the Jorhat and Golaghat districts with density of seedlings > saplings > trees.

Regeneration status

Population structure of *A. malaccensis* in terms of proportions of seedlings, saplings and adults among the eight homegardens selected for detailed study, varied greatly (Table 1). Stand density ha^{-1} for trees (> 3.18 cm DBH) was highest in homegarden 1 (2,840 individuals ha^{-1}) and lowest in homegarden 5 (700 individuals ha^{-1}) of Jorhat district. Similarly, seedling and sapling densities were highest in homegarden 52 and 77, and lowest in homegarden 26 and 28, respectively (Table 1). On the other hand, basal area of trees was highest in homegarden 52 (145.11 cm^2 ha^{-1}) followed by homegarden 77 (99.92 cm^2 ha^{-1}) and lowest in the homegarden 26 (30.27 cm^2 ha^{-1}). Out of the eight selected homegardens, seven showed good regeneration status of *A. malaccensis* with seedling > sapling > tree, whereas, homegarden 28 showed fair regeneration with seedling > sapling < tree.

Seasonal survival rate of *A. malaccensis* saplings was significantly different among the eight selected homegardens ($F_{7,24}$ = 2.78, P < 0.05) but that of seedlings and trees was not significantly different. Average seasonal survival rate was highest in homegarden 26 of Golaghat district for seedlings, in homegarden 4 and 44 of Jorhat district for saplings and in homegarden 28 of Golaghat district for trees. The survival was lowest in homegarden 77 of Golaghat district for seedlings and saplings and in homegarden 44 of Jorhat district for trees (Fig. 5). Among seasons, across homegardens, the survival rate was highest for seedlings, saplings and trees during February to April and lowest during November to January. Across all homegardens and seasons, the survival was highest for saplings (85 % ± 4.85) followed by trees (71 % ± 5.27) and seedlings (63 % ± 5.91).

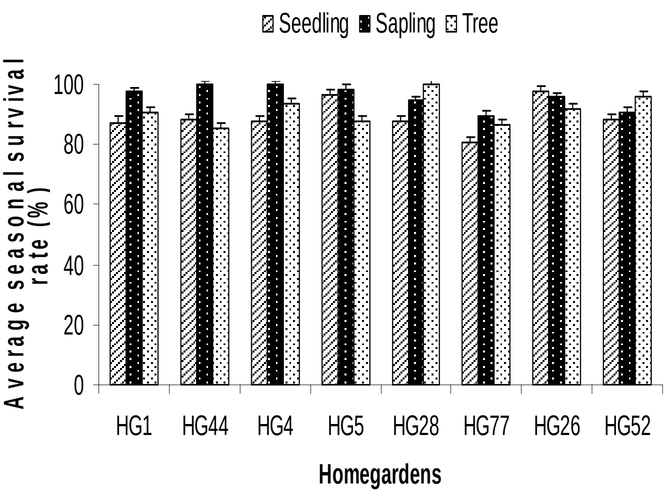

Fig. 5. Average seasonal survival rate (%) of *A. malaccensis* (seedling, sapling and tree) in eight selected homegardens of Upper Assam.

Average seasonal growth rate of *A. malaccensis* (in terms of collar diameter for seedlings and saplings, and DBH for trees) varied significantly among the eight selected home-gardens (trees: $F_{7,160}$ = 7.23, P < 0.01; saplings: $F_{7,712}$ = 2.87, P < 0.01 and seedlings: $F_{7,532}$ = 15.35, P < 0.001) as well as between the four seasons (trees: $F_{3,160}$ = 6.13, P < 0.001; saplings: $F_{3,712}$ = 27.11, P < 0.001 and seedlings: $F_{3,532}$ = 19.51, P < 0.001). Seasonal growth rate differed significantly among the tree individuals growing in homegarden 5 (HG5: $F_{3,15}$ = 4.23, P < 0.05) but not in other homegardens. For saplings, seasonal growth rate varied significantly among the individuals growing in seven homegardens (HG1: $F_{3,36}$ = 8.22, P < 0.001; HG4: $F_{3,68}$ = 5.31, P < 0.01; HG5: $F_{3,116}$ = 21.29, P < 0.001; HG26: $F_{3,96}$ = 3.75, P < 0.05; HG28: $F_{3,136}$ = 6.73, P < 0.001; HG52: $F_{3,88}$ = 4.69, P < 0.01; HG77: $F_{3,112}$ = 4.44, P < 0.01) but not among the individuals growing in homegarden 44. For seedlings, the growth rate varied significantly in homegardens 1, 28, 52 and 77 (HG1: $F_{3,60}$ = 6.48, P < 0.01; HG28: $F_{3,52}$ = 3.59, P < 0.05; HG52: $F_{3,100}$ = 8.09, P < 0.001; HG77: $F_{3,156}$ = 9.08, P < 0.001) but not in the remaining four homegardens (home-garden 4, 5, 26 and 44). Average seasonal growth rate was highest in homegarden 26 of Golaghat district for seedlings and in homegarden 5 of Jorhat district for both saplings and trees, and lowest in homegarden 44 of Jorhat district for both the seedlings and saplings and in homegarden 52 of Golaghat district for trees (Fig. 6). The growth rate, among the seasons, was highest during rainy season (May to July) and lowest during dry winter (November to January). Similarly, growth in terms of height and leaf number of seedlings and saplings also increased during rainy season and decreased considerably after the rainy season, and the growth was lowest during the dry winter season.

Regeneration through coppice

Although regeneration through coppice in *A. malaccensis* is common, cut stumps were not of common occurrence as people are used to harvest the underground part also with the hope of getting more resin and benefits. Cut stumps were observed only in 7 % of the studied homegardens of upper Assam. A total of 40 cut stumps with the average density of 5 stumps ha^{-1} were recorded in these homegardens. The diameter of the cut stumps ranged from 8.27 to 33.41 cm (mean 20.27 cm; SE ± 1.02) and greatest number of cut stumps was found in the medium diameter class (17.83 - 27.86 cm) (Fig. 7). The larger stumps exhibited better sprouting than the smaller ones (Fig. 8). In majority of cases (90 %), sprout density per stump varied between 3 and 20 (mean 6.33; SE ± 0.69).

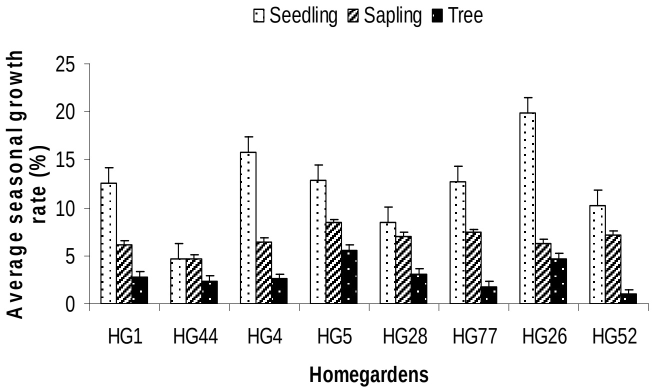

Fig. 6. Average seasonal growth rate (%) of *A. malaccensis* (seedling, sapling and tree) in terms of girth increment in eight selected homegardens of Upper Assam.

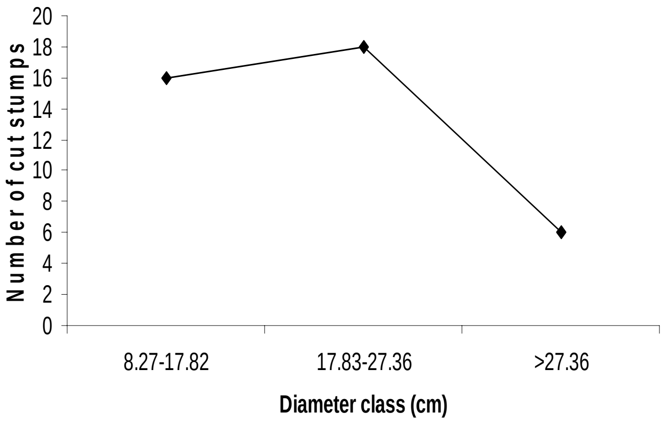

Fig. 7. Number of cut stumps of *A. malaccensis* in different diameter classes in 135 studied home-gardens of Upper Assam, NE India.

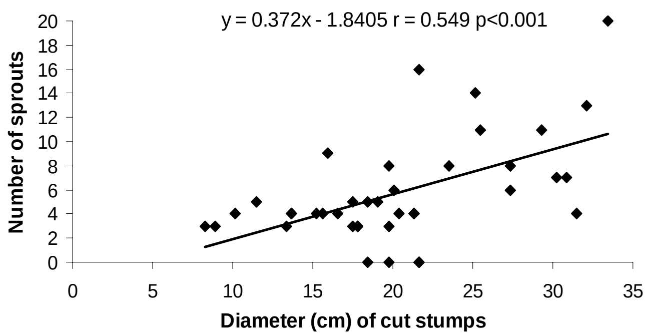

Fig. 8. Number of sprouts per cut stump of different size (diameter) in 135 studied homegardens of Upper Assam, NE India.

Discussion

The overall population structure of *A. malaccensis* in the studied homegardens showed that contribution of seedlings to the total population was highest followed by that of saplings and trees. This indicates a good regeneration status (expanding population) of *A. malaccensis* in the homegardens, and signifies the sustainability of the species for the future. The differences in relative proportions of seedlings, saplings and trees among different homegardens may be due to the differences in the level of anthropogenic disturbances among the homegardens. There was a gradual decrease in density with increase in girth class size, which is in conformity with the study in the Western Ghats, India, by Parthasarathy & Karthikeyan (1997). In general, regeneration of a species is affected by anthropogenic factors (Barik *et al.* 1996; Tripathi & Khan 2007) as well as natural phenomena (Welden *et al.* 1991). Variation in population structure of *A. malaccensis* in different homegardens may be partly attributed to the differences in the prevailing micro-environmental factors. Poor regeneration status in 40 % of the studied homegardens may be due to different extrinsic factors such as insect damage, mainly herbivory by caterpillar and grasshopper, uprooting of seedlings by humans or due to harsh environmental conditions such as drought. Further, homegarden is a managed agroforestry system and seedlings grow along with other herbaceous species and weeds. Associated vegetation may also exert competitive effect on seedling survival and growth. Damage to seedlings during maintenance of homegarden may also be a reason of poor survival.

The population structure of *A. malaccensis* in the eight selected homegardens reveals that seedlings dominate the total population indicating good regeneration of the species in seven out of eight homegardens. The fluctuation of population density in different homegardens during various seasons is related to the prevailing environmental conditions. During different seasons, rainfall, temperature, humidity, moisture content and nutrient status of the soil, etc. also fluctuate considerably. Seedling survival and growth of *A. malaccensis* was highest in homegarden 26 because of the low density of both *A. malaccensis* and other associated vegetation and, thus, low competition for available resources like nutrients, water and sunlight.

Natural regeneration through seeds is often impaired by unfavourable environmental conditions during germination period and seedling establishment phase. Germination of freshly dispersed seeds was high during July and August. Therefore, recruitment increased during the rainy season attaining a peak during August. In general, seedling population decreased substantially after the rainy season with mortality being highest during the dry winter. Thus the reduced seedling numbers in the eight selected homegardens during dry winter season may be due to drought stress associated with limited rainfall and low temperatures. Similar results have also been reported by several workers (Kumar *et al.* 1994; Schulte & Marshall 1983). Khan *et al.* (1986) reported lowest survival of tree seedlings during the dry winter season in tropical deciduous and sub-tropical forests of Meghalaya, northeast India. Germination and subsequent seedling emergence in homegardens of the studied area were good, thus, resulting in dense seedling population. However, majority of the seedlings fail to reach sapling stage which may be due to competition for resources, allelopathic affects as well as external disturbances (Khumbongmayum 2004; Rao *et al.* 1990).

Aquilaria malaccensis also regenerates very well by coppice, which is an important means of propagation and regeneration mechanism to maintain a viable population in many tree species (Castillo & Hall 2000; Luoga *et al.* 2004). Khan & Tripathi (1986) found that stump diameter and height have an interactive influence on the behavior and survival of sprouts. In the present study, rate of sprouting was also positively correlated with stump diameter. In general, vegetative reproduction predominates in the juvenile phase and sexual reproduction in the adult phase (Hartmann & Kester 1975). This argument had been used by many workers (Clark & Liming 1953; Solomon & Blum 1967) to explain the effect of stump thickness on sprouting. *Aquilaria malaccensis* is harvested based on its infection rate and agarwood formation irrespective of its size. In general, *A. malaccensis* grows up to 60 cm in diameter. However, the present study showed a maximum cut stump diameter of 33.41 cm which, therefore, may represent middle aged plants. This may be the reason why maximum number of sprouts occurred in higher girth classes. Unlike the present report, MacDonald & Powell (1983) observed that the percentage of sprouted stumps and the average number of sprouts per stump in *Acer saccharum* was greater for small diameter than for large diameter stumps. Similarly, Khan &

Tripathi (1986) also reported a decrease in the number of sprouts with the increase in stump diameter.

Conclusions

Our study showed that stand density decreases gradually with the increase in girth class size in almost all the studied homegardens and 52 % homegardens showed good regeneration status of *A. malaccensis*. Also, seven out of the eight selected homegardens revealed good regeneration status of the species. Survival rate of *A. malaccensis* per year in all the eight selected homegardens varied greatly (49 - 87 %) with an average of 74 % ± 4.44 in their prevailing microclimatic conditions. On the other hand, 90 % stumps showed sprouting with an average of 6.33 sprouts per stump, indicating that the species is a good coppicer. Natural regeneration is essential for conservation and maintenance of biodiversity and *A. malaccensis* showed good regeneration and population status in homegardens. Based on the present study, it may be concluded that homegardens can save the species from the risk of extinction and thus, homegardens can be considered as a tool for on-farm conservation of *A. malaccensis*.

Acknowledgements

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Appendix Table 1. Density (individuals ha^{-1}) of *A. malaccensis* and associated tree species and regeneration status of *A. malaccensis* in homegardens of Upper Assam.

S. No.	Home garden (No.)	Density (individuals ha^{-1})				Regeneration status
		Seedlings	Saplings	Trees (>3.18 cm DBH)	Associated tree species (>3.18 cm DBH)	
				Jorhat		
1	HG1	155000	4880	2840	1560	Good
2	HG2	115000	5800	800	1100	Good
3	HG3	73750	1000	675	3125	Good
4	HG4	89167	2400	1317	1200	Good
5	HG5	101667	5933	700	1617	Good
6	HG6	119167	4200	767	1317	Good
7	HG7	-	1680	850	470	Poor
8	HG8	186000	7240	1310	800	Good
9	HG9	71250	5100	350	1700	Good
10	HG10	-	3133	750	2133	Poor
11	HG11	36500	3640	1260	1530	Good
12	HG12	-	5400	550	650	Poor
13	HG13	108571	2171	800	714	Good
14	HG14	320000	2400	1575	1125	Good
15	HG37	1667	5600	1300	10467	Fair
16	HG38	38333	3400	783	1317	Good
17	HG39	35000	2800	2125	1475	Good
18	HG40	-	1400	1125	6375	Poor
19	HG41	26250	1400	1250	5825	Good
20	HG42	-	5067	1833	1250	Poor
21	HG43	10000	2400	1200	1540	Good
22	HG44	60000	4200	2050	1275	Good
23	HG45	6250	1400	700	4400	Good
24	HG46	18750	3700	1150	1950	Good
25	HG47	71667	8133	933	4467	Good
26	HG48	107500	6600	1600	2600	Good
27	HG49	-	3400	2125	3475	Poor
28	HG50	-	400	1050	2850	Poor
29	HG51	31667	1200	1367	7133	Fair
30	HG72	46250	5500	2000	1775	Good
31	HG73	-	4640	1640	3520	Poor
32	HG74	18750	14500	1050	3400	Good
33	HG75	-	-	850	1200	Nil
34	HG76	28333	9600	1967	9433	Good
35	HG99	-	1000	1183	1183	Poor

Contd...

Appendix Table 1. Continued.

S. No.	Home garden (No.)	Density (individuals ha^{-1})				Regeneration status
		Seedlings	Saplings	Trees (>3.18 cm DBH)	Associated tree species (>3.18 cm DBH)	
36	HG100	-	6067	2183	1350	Poor
37	HG101	-	6400	2588	3188	Poor
38	HG102	-	5467	1233	933	Poor
39	HG103	-	2080	1620	1970	Poor
40	HG114	-	2500	1225	6450	Poor
41	HG115	-	5750	3088	6900	Poor
42	HG116	-	7900	2200	7225	Poor
43	HG117	-	6700	1213	4425	Poor
44	HG118	-	4533	1067	9567	Poor
45	HG119	-	4500	1300	2225	Poor
46	HG127	5000	5371	1343	2243	Fair
47	HG128	-	6533	1150	3083	Poor
48	HG129	-	5500	1088	4388	Poor
49	HG130	-	3067	1167	967	Poor
50	HG131	-	6667	1200	1600	Poor
				Golaghat		
51	HG15	119000	1600	470	1800	Good
52	HG16	-	3350	725	1638	Poor
53	HG17	13750	4150	1350	963	Good
54	HG18	44375	2250	900	2475	Good
55	HG19	218333	3000	1100	783	Good
56	HG20	-	2720	260	2780	Poor
57	HG21	14000	1680	700	1080	Good
58	HG22	13750	1700	600	1600	Good
59	HG23	13750	350	413	5763	Fair
60	HG24	-	2800	720	1360	Poor
61	HG25	33125	2850	825	1475	Good
62	HG26	20000	2400	780	900	Good
63	HG27	-	2500	825	675	Poor
64	HG28	33125	900	1488	2138	Fair
65	HG29	6667	5400	917	767	Good
66	HG30	21667	667	633	650	Good
67	HG31	8333	333	400	1400	Fair
68	HG32	-	320	1480	2440	Poor
69	HG33	16875	-	475	1063	Fair
70	HG34	9000	400	640	1300	Fair

Contd...

Appendix Table 1. Continued.

S. No.	Home garden (No.)	Density (individuals ha^{-1})				Regeneration status
		Seedlings	Saplings	Trees (>3.18 cm DBH)	Associated tree species (>3.18 cm DBH)	
71	HG35	12500	1600	950	1217	Good
72	HG36	7857	857	929	1829	Fair
73	HG52	413000	3200	1520	1500	Good
74	HG53	-	6733	1433	883	Poor
75	HG54	32500	2700	2000	1925	Good
76	HG55	6250	2900	1475	6550	Good
77	HG56	31875	3550	2800	4538	Good
78	HG57	14000	5200	1620	5960	Good
79	HG58	10714	2286	1086	1314	Good
80	HG59	107222	6178	1778	989	Good
81	HG60	27500	2700	2800	500	Good
82	HG61	18333	6067	1100	1567	Good
83	HG62	30000	3000	1100	1550	Good
84	HG63	58125	6300	1650	1850	Good
85	HG64	8333	2800	2367	3733	Good
86	HG65	26667	5067	2083	1117	Good
87	HG66	26250	4600	1575	2225	Good
88	HG67	10000	7840	1400	2140	Good
89	HG68	20000	13120	2300	1700	Good
90	HG69	46000	3440	1680	8580	Good
91	HG70	26250	11050	7913	7275	Good
92	HG71	-	5067	1767	6933	Poor
93	HG77	403889	7244	2356	1478	Good
94	HG78	-	5900	3075	4325	Poor
95	HG79	27500	12533	1250	10833	Good
96	HG80	-	9333	6600	933	Poor
97	HG81	-	5100	2025	6150	Poor
98	HG82	30833	2200	633	1333	Good
99	HG83	24500	3040	770	1760	Good
100	HG84	15000	4000	1050	4450	Good
101	HG85	27500	600	1400	1350	Fair
102	HG86	-	2000	950	3950	Poor
103	HG87	15000	4100	1000	4450	Good
104	HG88	20000	2560	1100	4220	Good
105	HG89	17500	3800	2075	975	Good
106	HG90	2500	3500	1913	3075	Good

Contd...

Appendix Table 1. Continued.

S. No.	Home garden (No.)	Density (individuals ha^{-1})				Regeneration status
		Seedlings	Saplings	Trees (>3.18 cm DBH)	Associated tree species (>3.18 cm DBH	
107	HG91	-	7633	2342	4008	Poor
108	HG92	-	3200	1108	1208	Poor
109	HG93	-	3000	2450	5600	Poor
110	HG94	-	2200	517	1300	Poor
111	HG95	-	2333	1267	5567	Poor
112	HG96	-	4667	1383	6117	Poor
113	HG97	-	4733	1333	3583	Poor
114	HG98	-	3200	1133	4300	Poor
115	HG104	35000	2000	1167	1750	Good
116	HG105	16667	3133	483	2683	Good
117	HG106	30000	2300	1250	1350	Good
118	HG107	59000	2080	1040	2000	Good
119	HG108	-	2960	560	1800	Poor
120	HG109	-	3600	429	2157	Poor
121	HG110	37000	2720	1080	2980	Good
122	HG111	15000	2560	1120	1500	Good
123	HG112	29000	2320	1820	1080	Good
124	HG113	46250	4300	1650	1100	Good
125	HG120	-	8000	4875	2075	Poor
126	HG121	30000	5867	2500	1400	Good
127	HG122	7500	5900	3900	2825	Poor
128	HG123	-	5700	900	5750	Poor
129	HG124	-	7700	2025	4350	Poor
130	HG125	-	4467	1600	5550	Poor
131	HG126	-	10300	1775	3375	Poor
132	HG132	-	3400	1575	1950	Poor
133	HG133	-	1533	850	4150	Poor
134	HG134	-	3133	1383	9283	Poor
135	HG135	-	6933	1700	3767	Poor