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STUDIES ON GROWTH AND ARCHITECTURE OF TREE SPECIES OF HOMEGARDEN AGROFORESTRY SYSTEMS OF KERALA

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ABSTRACT

Characters such as crown architecture, growth, leaf phenology and branch display were studied in nine forest trees namely *Ailanthus triphysa, Albizia odoratissima, Artocarpus hirsutus, Grewia tiliifolia, Macaranga peltata, Mangifera indica, Tectona grandis, Terminalia paniculata* and *Xylia xylocarpa* grown in homegardens of Panancherry Panchayat, Kerala, with a view to assess their suitability as components in homegarden agroforestry systems. On the basis of the study these nine species of trees have been classified under different architectural models propounded by Halle *et al.* (1978). Among these *Albizia* and *Xylia* fall under Troll model, while *Grewia* and *Ailanthus* come under Roux and Koriba models respectively. *Mangifera* and *Terminalia* grown under the shade and in the open exhibited different architectural models namely Scarrone under shade and Leeuwenberg in the open. *Artocarpus, Macaranga* and *Tectona* conform Rauh model. *Albizia, Grewia* and *Xylia* showed the low and dome shaped crown under the shade in contrast to a narrow and conical crown in the open. On the other hand, *Artocarpus, Macaranga, Mangifera, Tectona* and *Teminalia* have the tendency to develop wider crown in the open in contrast to a narrow and conical crown under shade.

The growth and architectural characteristics and of all these species have relevance especially in agrisilvicultural systems in which more shade demanding components are used. The study reveals that *Albizia, Grewia* and *Xylia* could be introduced in the early stages of perennial crop establishment as these trees are having the tendency to grow straight with a narrow conical crown under less shade. In the case of *Artocarpus, Mangifera, Tectona* and *Terminalia* orthotropy enhances production of straight timber. But in the early stages of establishment of polyculture agroforestry systems these species may not be suitable as they have the tendency to develop wider crown in relatively open area. However, these trees when introduced in the established agroforestry system may produce straight timber and less crown

spread. The study also indicated that foliage phenology is also important in deciding appropriate crop mixture. Some of the species such as *Tectona*,*Macaranga*,*Xylia*, *Terminalia* and *Grewia* are deciduous in nature and leafless for 3-4 months. There is scope for cultivating light demanding short duration crops under such trees.

1. INTRODUCTION

Homegarden (syn. homestead farm) agroforestry is a predominant land use system in Kerala (Nair and Sreedharan, 1986). About 4 1,80,900 operational holdings with an average size of 0.43 ha are under this land use practice (Kerala Agricultural University, 1989). Homestead agroforestry is characterised by an intensive integration of trees and shrubs with food crops and often animals, having the basic objective of ensuring sustained availability of multiple products such as food, vegetables, fruits. fodder, fuel, timber, medicines and/or ornamentals (Michon et al., 1983), besides generating employment and cash income (Babu et al., 1992; Jose, 1992; Singh, 1987). According to Krishnankutty (1990), homegardens of Kerala play an important role in the wood economy of the State by providing nearly 75% of the requirements in wood. It has also been stated that tree components along with field crops lead to the more efficient use of sunlight, moisture and plant nutrients in agroforestry systems than in monocropping of either agricultural or forestry crops (Fernandes and Nair, 1986). One of the biological reasons of interest in agroforestry systems like homestead farming is that trees use portions of the biosphere that annual crops or animals generally do not, resulting in increased aggregate biomass production. For majority of the farmers of the State, these ecological and economic advantages of the integration of trees in homestead farming are the main attractions for deliberate introduction, domestication and retention of trees. However, according to Nair and Sreedharan (1986), the homegardens of Kerala are not as productive as they are ought to be. This is due to the fact that, in the homestead polyculture of the State, plants are usually planted in a haphazard manner (Kumar et al., 1993) without giving adequate attention to the ecophysiological requirements of the individual species of the system resulting in reduced yield of individual crops and in turn in the low productivity of the system. In this context, for evolving ecologically sound agroforests, an attempt should be made primarily to understand the growth and architecture patterns of forest tree components of the systems (Oldeman, 1983). It may also be pointed out here that the ecological approach to studies on tree architecture and growth patterns and their relationship to successional status, for example in the case of north temperate deciduous trees (Marks, 1975) and north Indian tropical (Shukla and Ramakrishnan, 1986) and subtropical (Boojh and Ramakrkhnan, 1982) forests has resulted in a better understanding of growth strategies of developing forest communities and of the plasticity in the growth behavior of the species in relation to irradiance. Audo (1990) made an attempt to relate the architectural concepts applied to tropical (especially woody) plants (Halle et al., 1978) to trees of interest to the foresters and the villagers engaged in the 'taungya' system in the Western African forest zone. This work has helped to determine the range of architectural models presently represented in 'taungya' in West Africa and to explore the possibility of finding out alternative tree species/crop combinations which serve better the felt need of the local communities. The present study on the architecture and growth characteristics along with foliage phenological information of forest tree components will be useful not only to underpin the body of basic principles of each species but also to improve the existing agroforestry system through proper management practices based on the results.

In homegardens of Kerala, several forest trees can be encountered (Kumar et al., 1994; Krishnankutty, 1990). Among them *Ailanthus triphysa*, *Albizia odoratissima*, *Artocarpus hirsutus*, *Grewia tiliifolia*, *Macaranga peltata*, *Mangifera indica*, *Tectona grandis*, *Terminalia paniculata* and *Xylia xylocarpa* are some of the important tree species. Utilisation classes and important uses of these species are given in Appendix 1. The study was designed 1) to assign appropriate architecutural model to each of the above mentioned nine species, 2) to analyse their foliage phenological and growth patterns and 3) to examine their suitability to agroforestry systems based on the results obtained from this study on growth and architecture.

2. STUDY AREA AND CLIMATE

The field study was conducted six selected homegardens with coconut-based farming systems in the Panancherry Panchayat ($10^{o}32'$ N, $76^{o}20'$E, altitude: 100m) fiom December 1993 to November 1995. The climate is typically monsoonal with an average annual rainfall of over 2700 mm. The major portion (75.6%) of the annual rainfall occurs during south-west monsoon, which starts from the middle of May and continues till the end of August. The maximum temperatures recorded during the year varies fiom 30.4°C(July) to 39°C (March) while the minimum temperatures varied from 19°C (January) to 23°C (April). Relative humidity ranges from 42% to 88% during the year. From January to March the number of hours of sunshine is high while in June and July it is low due to monsoon clouds (Kallarackal and Somen, 1994, 1995).

3. METHODS

3.1 Tree architecture

There are thirteen principal morphological and reproductive features whereby different architectural models (Appendix 2) can be distinguished:

1. Tree type: branched or unbranched
2. Branches per axis
3. Location of branches basal or distal to the axis
4. Parity of vegetative shoot: equivalent or different
5. Location of inflorescences: lateral or terminal
6. Nature of plant growth: rhythmic or continuous
7. Growth after flowering growth terminates or continues
8. Branching pattern: dichotomous or auxiliary
9. Orientation of shoots: erect or horizontal
10. Manner of height growth: sympodial or monopodial
11. Branching: through substitution growth or not
12. Longevity of branches: short lived or long-lived with an obsession scar
13. Shoot differentiation: mixed on germination or mixed later.

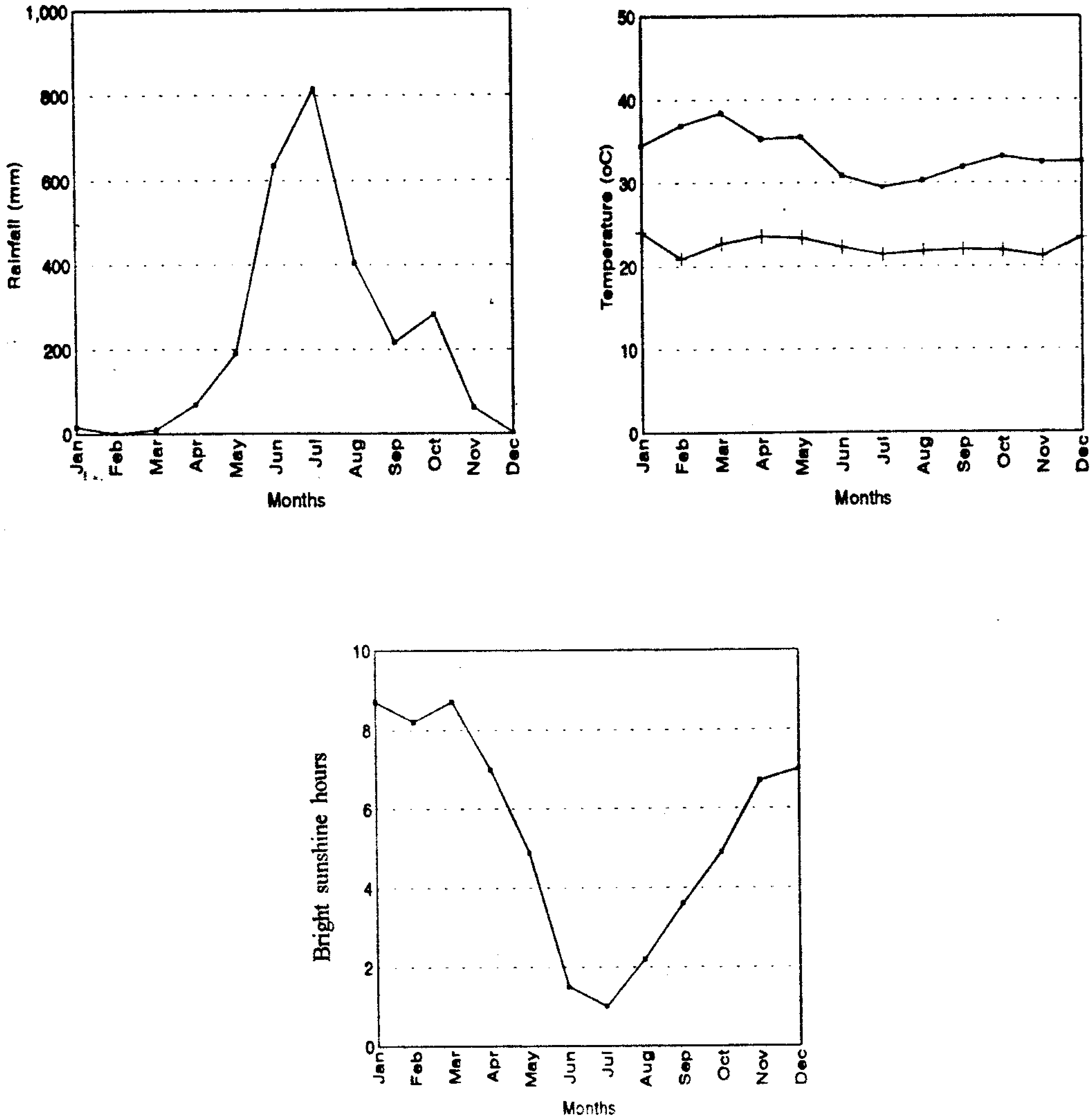

Figure 1. Average monthly rainfall, temperature (o, mean monthly maximum; +, mean monthly minimum) and bright sunshine hours for the period 1993-1995 at Peechi, Panancherry Panchayat, Kerala.

Definition of specialised architectural terms are given in Appendix 3. Nine tree species selected for the study *(Ailanthus triphysa, Albizia odoratissima, Artocarpus hirsutus Grewia tiliifolia, Macaranga peltata, Mangifera indica, Tectona grandis, Terminalia paniculata* and *Xylia xylocarpa)* seen in homegardens were assigned to different architectural models of Halle et.al. (1978). The generic names of the species are used hereafter.

3.2 Growth pattern

For each species, three trees in a relatively open area where the adjacent trees do not overlap and three trees in closed area where the adjacent trees were partially or fully overlapping the crown were selected. Total tree height (from tree base to tip), height to the base of the crown and diameter at breast height (dbh) were measured. The projected crown area was estimated from the vertical projection of the outermost point of the crown at eight cardinal compass bearings. Ratio between the crown height and total tree height as well as between crown height and crown diameter was calculated and expressed in percentage. Growth of trees were monitored from January 1994 to June 1995.

The branches of each tree were ordered according to Strahler's (1957) method. Thus each ultimate branch was designated as first order; where two first order branches come together, the resulting proximal segment was designated as a second order; where two second order branches come together, the resulting proximal segment was designated as a third order; and so on down the tree. Where two branches of unequal order meet, the resulting branch maintains the identity of higher order branch.

Ten first-order branches each from lower and upper-canopy positions for each tree were randomly selected and marked with paint at the base. Annual increase in shoot elongation of the selected branches was recorded using measuring tape. Increment in length of lower- and upper- canopy shoots were statistically analysed using Student's -t test.

Angles of ten first-order branches located in the upper-and lower- canopy of the tree were measured by using plumb bob and protractor, and the values were expressed in degrees. Branch angles at a given canopy position of trees growing under shade and in the open were compared using Student's t-test. Similarly, Student's t-test was used to compare the branch angles at upper- and lower- canopy position of a tree growing in a given microclimatic condition.

For estimating number of first-order branches and their length at the end of the growing season three main branches were randomly selected in each of the three replicate trees of a given species. All the branches were divided into different orders and assigned to the length classes 0-10 cm, 10.1-20cm, etc. The number of branches in each length class was counted and expressed as percentage of total number of branches.

3.3 Phenology of foliage

Phenological observations were taken fortnightly. During the fortnightly visits, marked individuals were qualitatively characterised for the three leaf phenological events i.e., production of young leaves, maturation of leaves and abscission of leaves. The phenostage of a species was determined by considering the status of at least two individuals. The duration of a phenological event in a species was computed by obtaining the number of days required for the completion of an event from the date of the fortnightly visit when the event was first noticed. For each species, interphenophase durations, i.e., periods between successive phenological events were then obtained (Prasad and Hegde, 1986).

4. RESULTS

4.1 Architecture

Trees belonging to the nine species studied are branched with two distinct types of shoots i.e., trunk and branches. However, these trees could be separated into two principal groups:

- trees with vegetative shoots consistently differentiated (heterogeneous) into orthotropic and plagiotropic axes.
- trees with vegetative shoots consistently similar i.e., either all orthotropic or all mixed (homogenous).

Ailanthus and *Grewia* fall under the first group (Figures 2.1 and 2.2). In both species the distal branching leads to trunk formation. In the case of *Ailanthus,* growth in height involves division of the apical meristem to generate multiple shoots which are initially similar. Eventually one of these shoots emerges as the leading shoot and the others become branches. Thus the species exemplifies the Koriba's model. On the other hand, in the case of *Grewia*, growth in height is as a result of the division of a single apical meristem and the branches are inserted continually and these branches are long-leaved. With these features *Grewia* can be classified under Roux's model. In both species the inflorescences are lateral.

Albizia, Artocarpus, Macaranga, Mangifera, Teminalia, Tectona and *Xylia* come under the second group. In the case of *Artocarpus, Macaranga, Tectona, Mangifera* and *Terminalia.* the vegetative axes are orthotropic and retain the original orientation (Figures 2.3 to 2.7). Furthermore, in these species trunk growth takes place as a result of the division of a single apical meristem and growth is rhythmic. But in *Artocarpus, Macaranga* and *Tectona* the inflorescences are lateral and flowering does not terminate branch growth, and thus they come within the norms of Rauh's model.

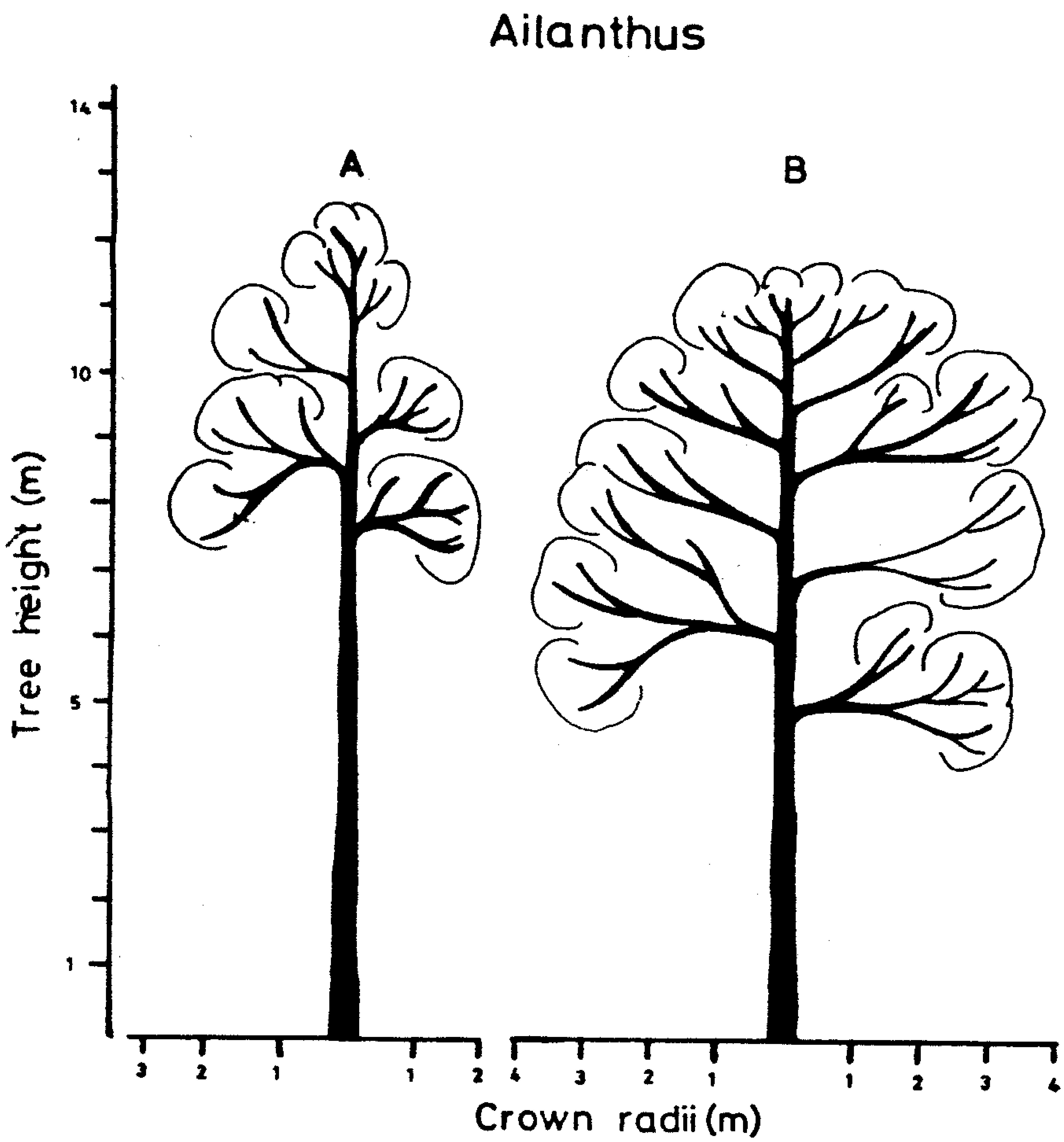

Figure 2.1 Architectural model of *Ailanthus triphysa* (Koriba's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

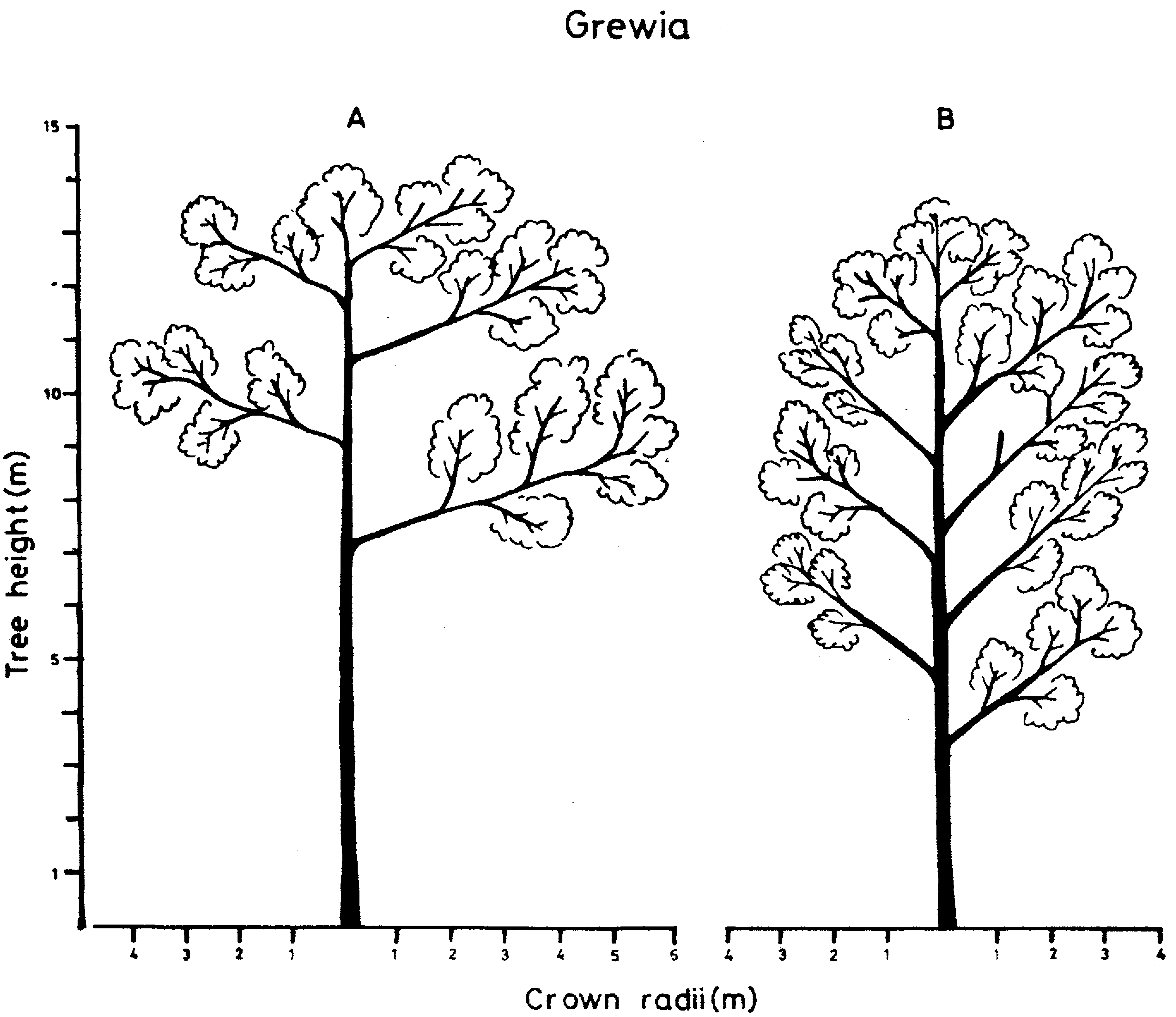

Figure 2.2 Architectural model of *Grewia tiliifolia* (Roux's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

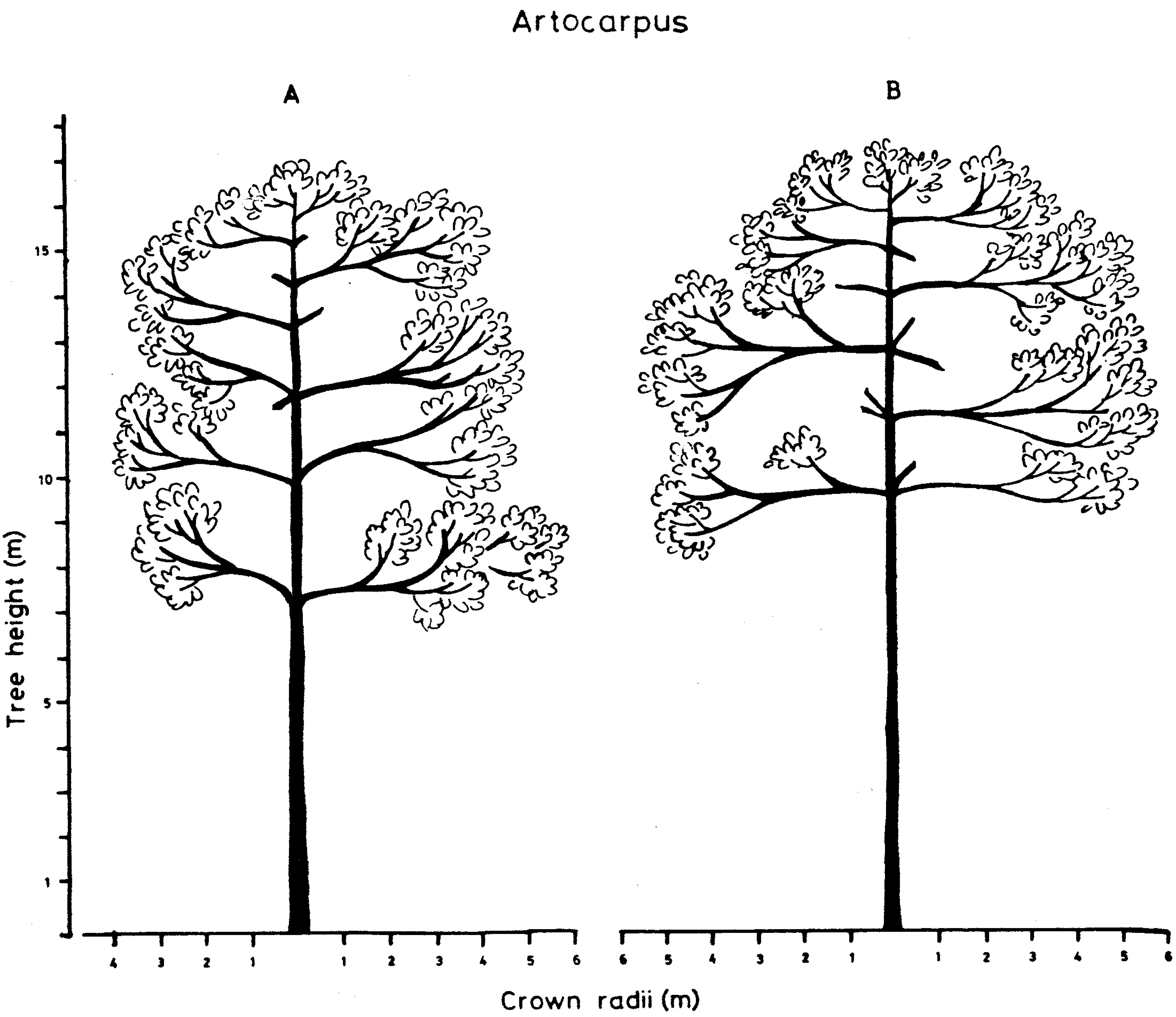

Figure 2.3 Architectural model of *Artocarpus hirsutus* (Rauh's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

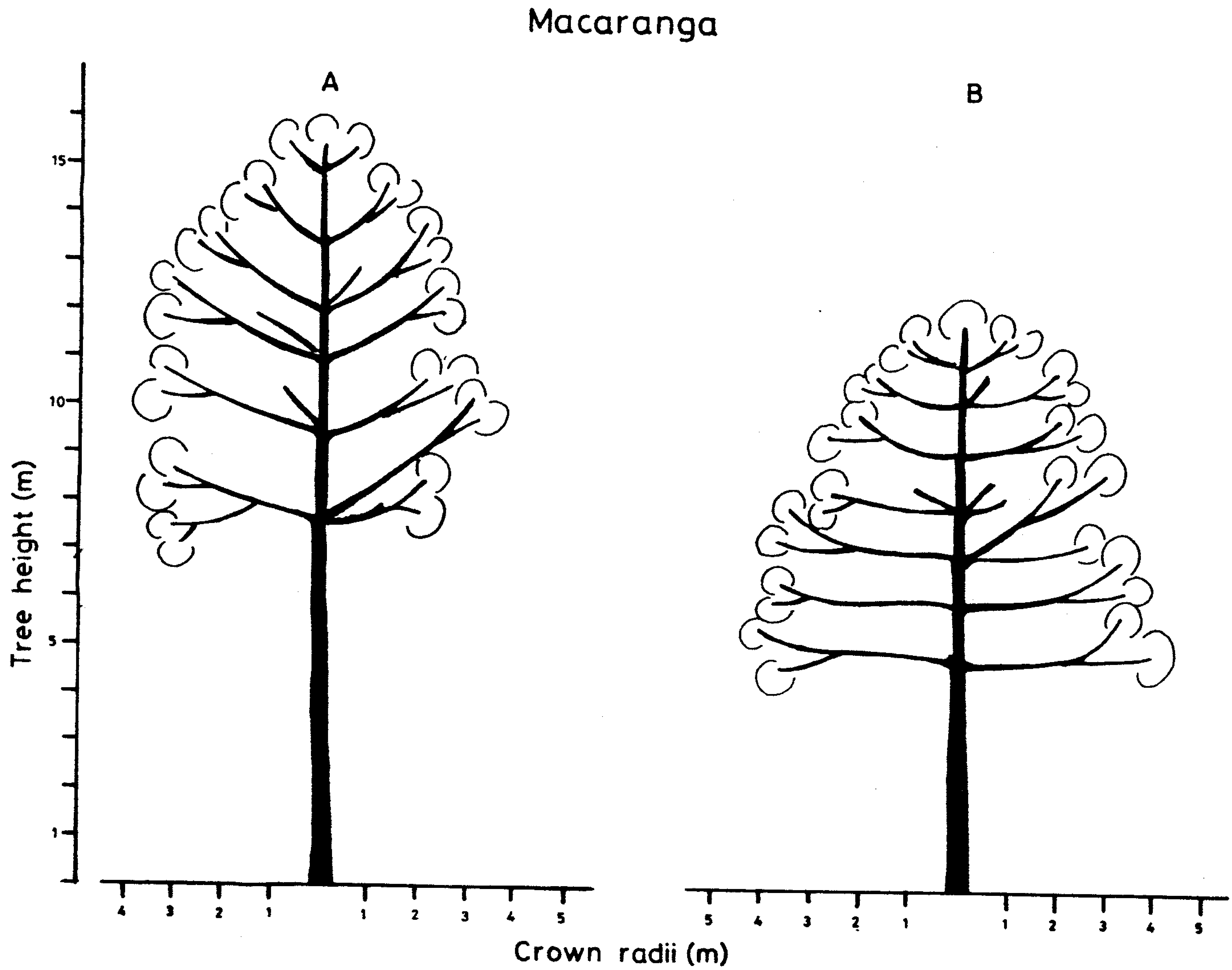

Figure 2.4 Architectural model of *Macaranga peltata* (Rauh's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

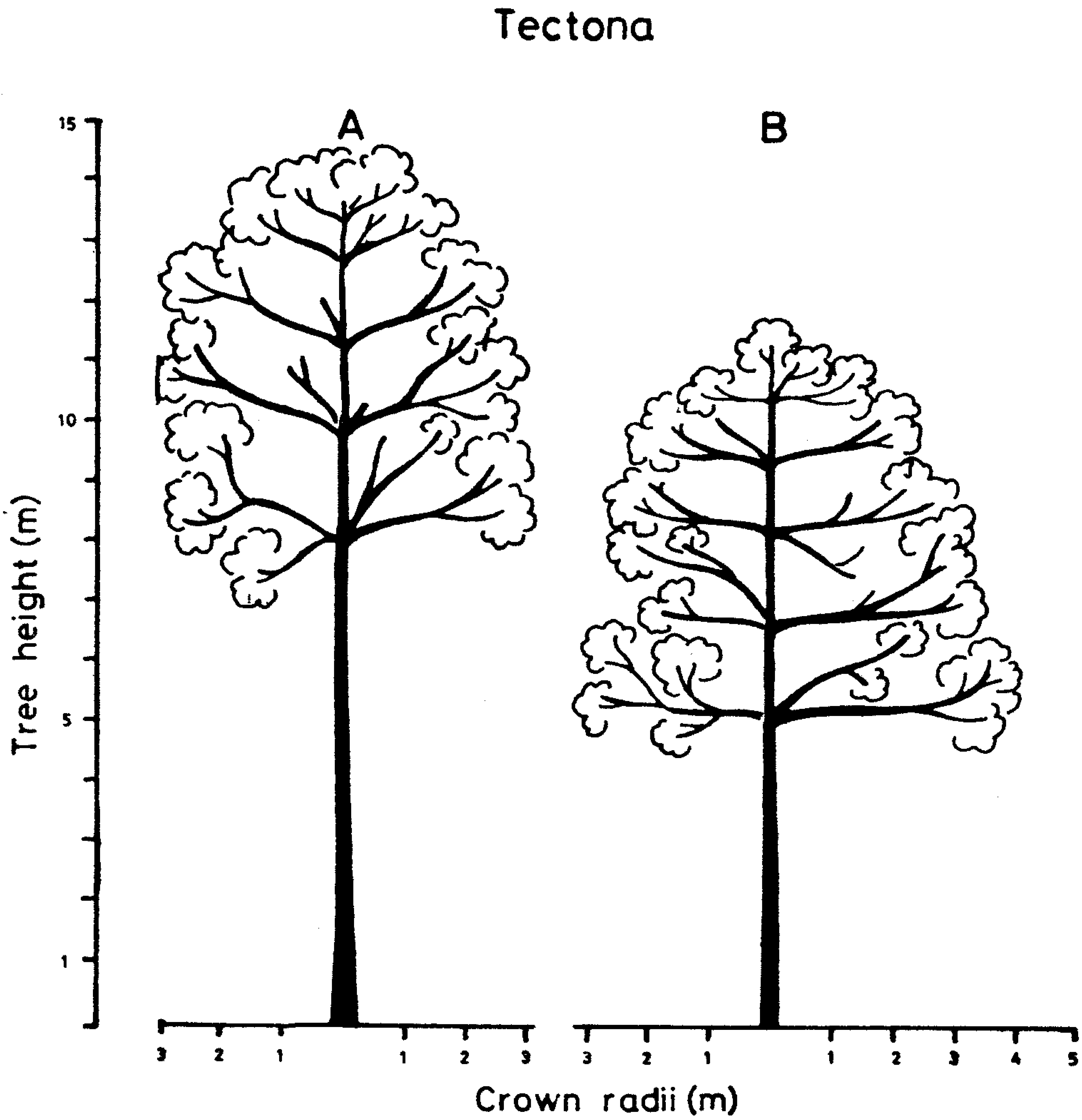

Figure 2.5 Architectural model of *Tectona grandis* (Rauh's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

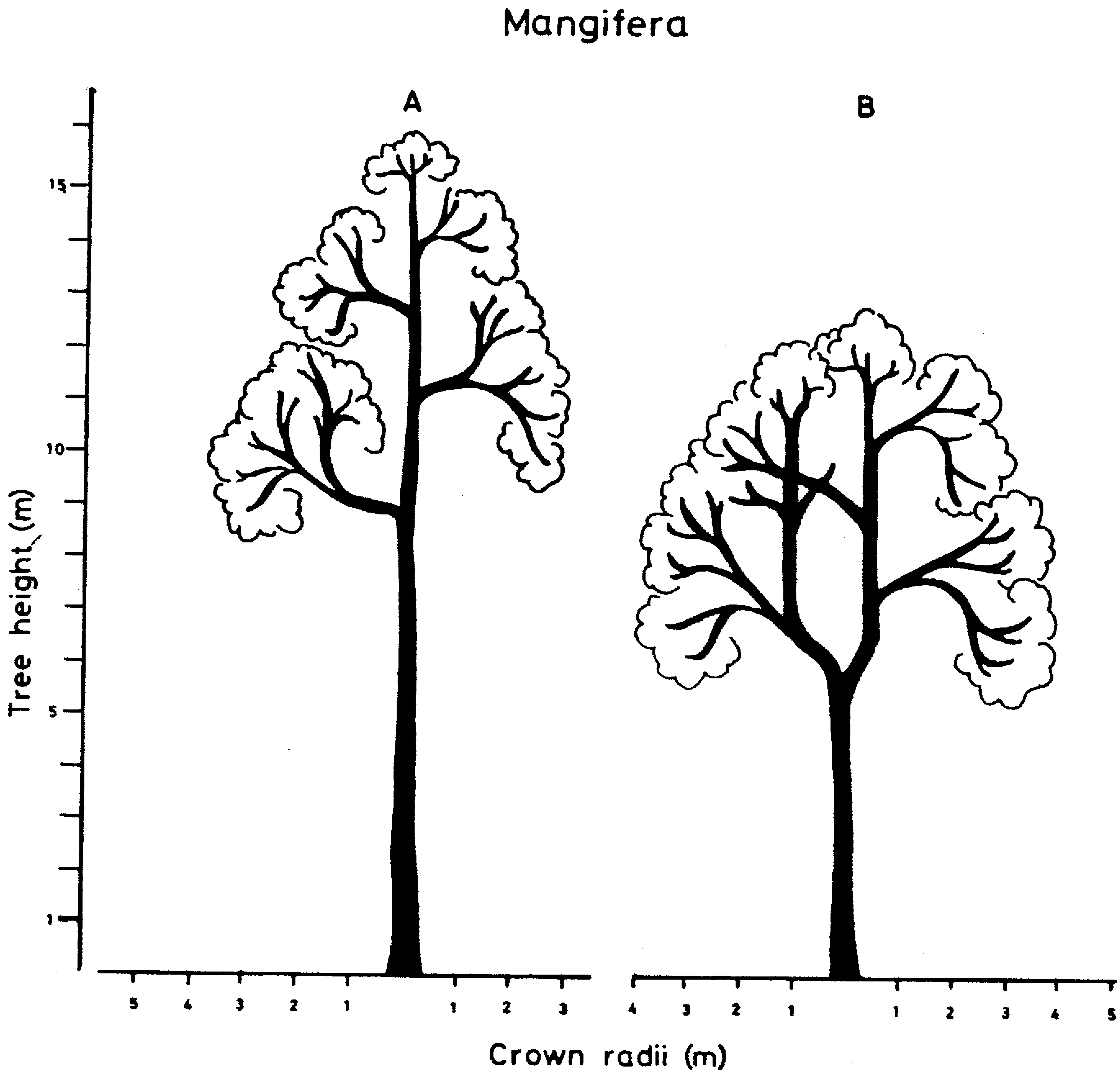

Figure 2.6 Architectural models of *Mangifera indica* growing under shade (A) (Scarrone's model) and in the open area (B) (Leewenberg' model) in homegardens of Panancherry Panchayat, Kerala.

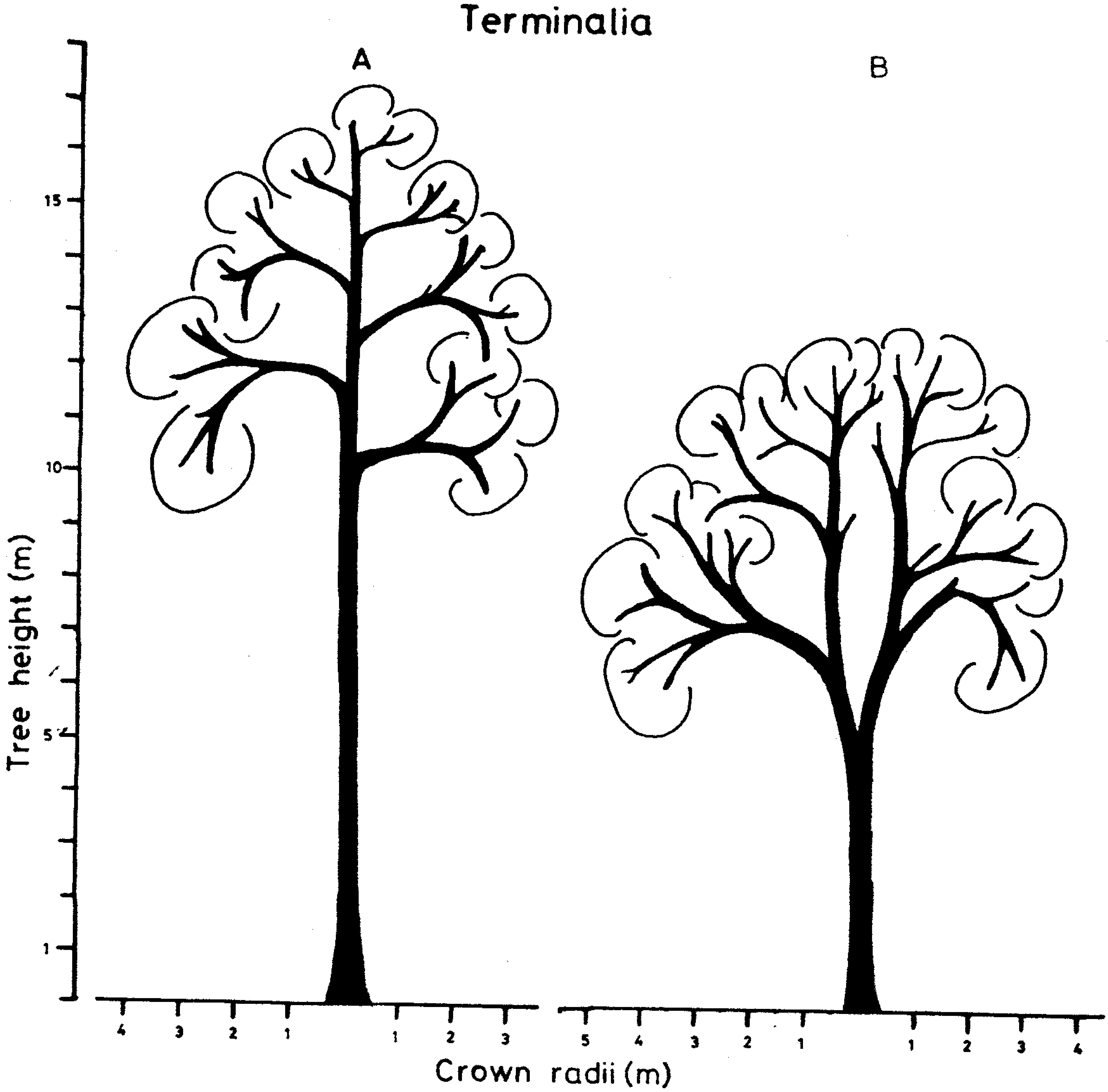

Figure 2.7 Architectural models of *Terminalia paniculata* growing under shade (A) (Scarrone's model) and in the open area (B) (Leewenberg' model) in homegardens of Panancherry Panchayat, Kerala.

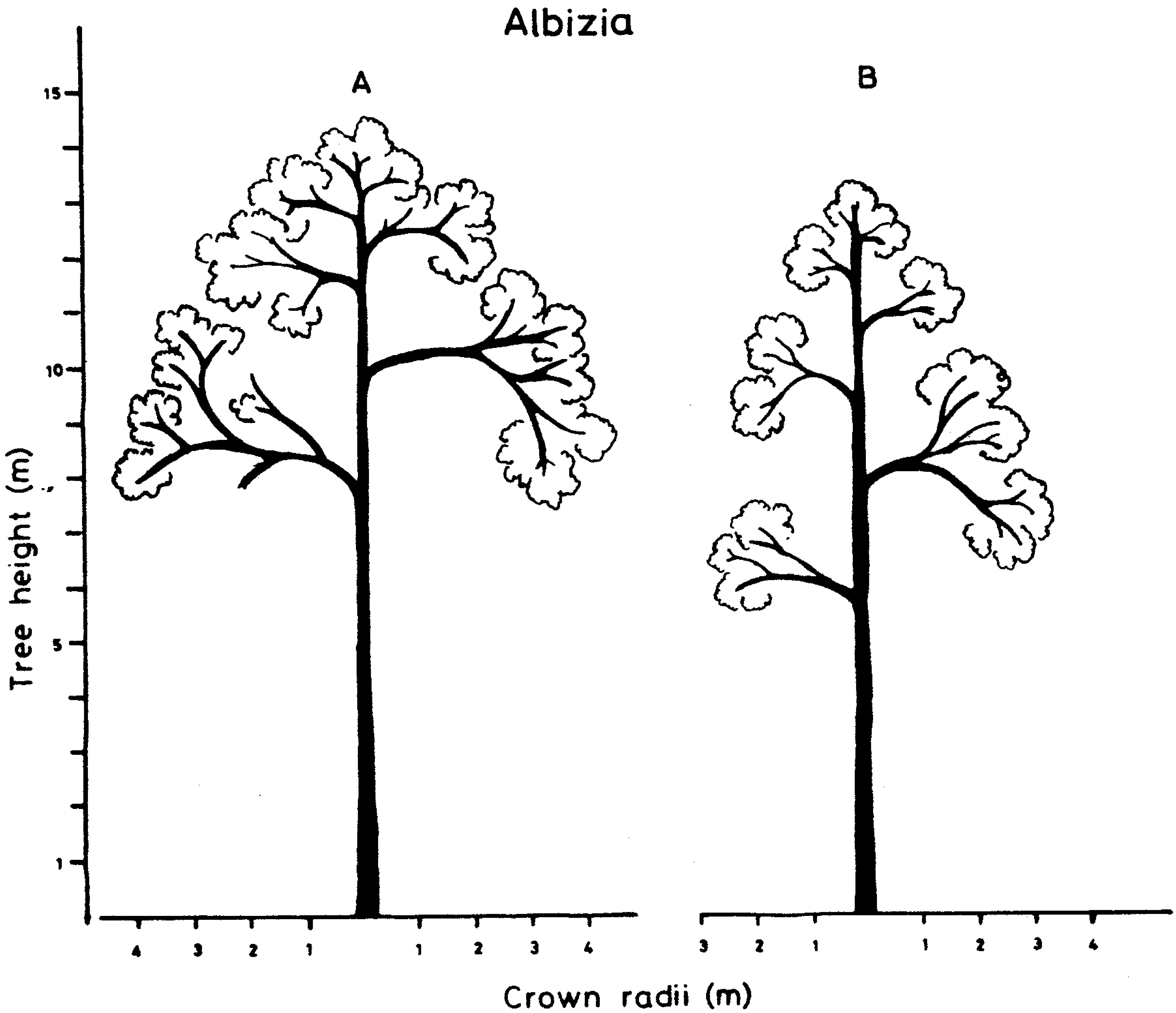

Figure 2.8 Architectural model of *Albizia odoratissima* (Troll's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

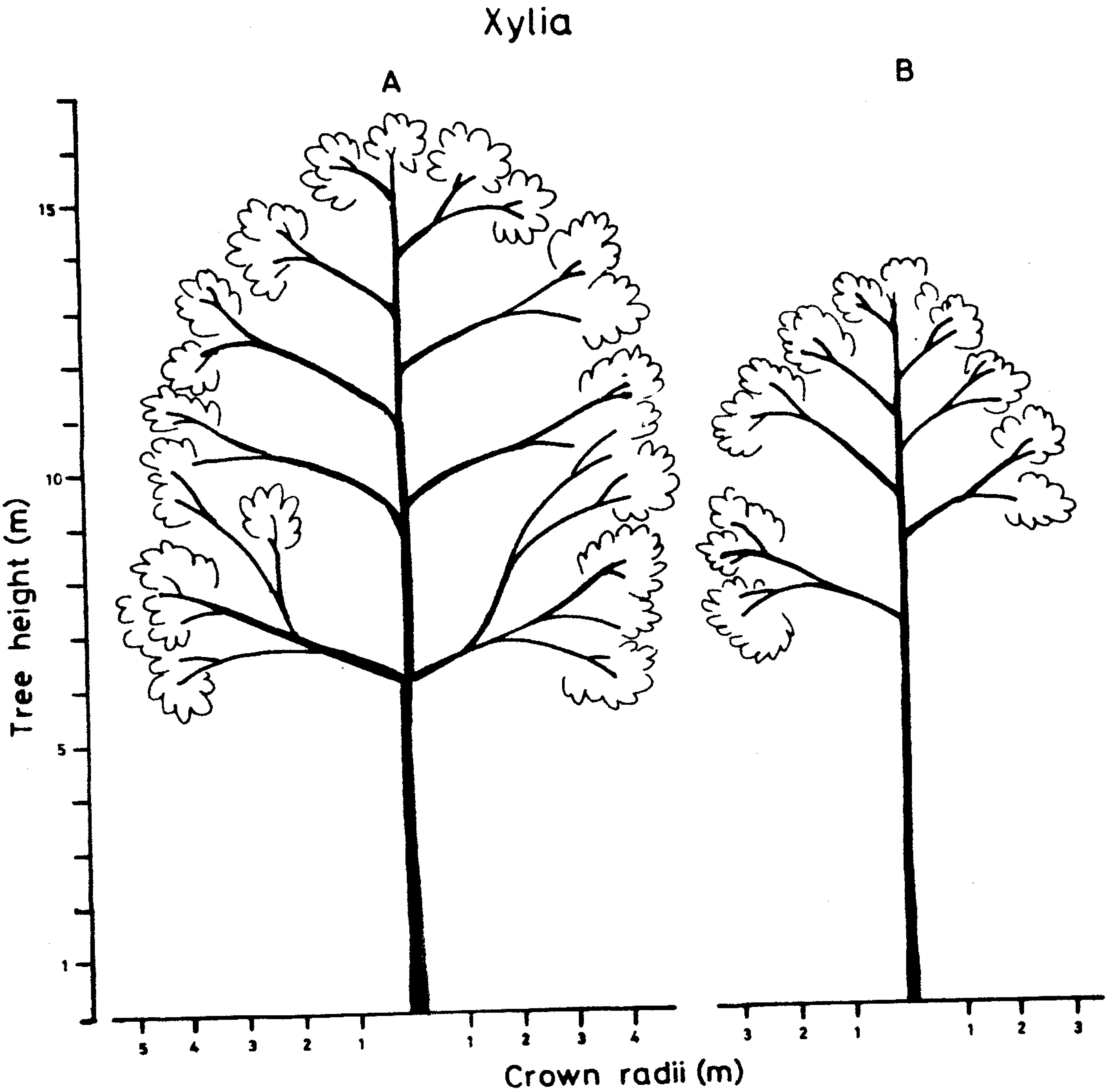

Figure 2.9 Architectural model of *Xylia xylocarpa* (Troll's model) growing under shade (A) and in the open area (B) in homegardens of Panancherry Panchayat, Kerala.

Table 1. General growth features recorded for selected trees growing under shade and in the open area in homegardens of Panacherry panchayat, Kerala. Values in parentheses are for trees growing in the open. All values are mean ± S.E...n=3.

species	Total height (TH) (m)	dbh (cm)	Crown height (CH) (m)	Crown area (m^2)	CH X 100 / TH	CH X 100 / Cd*
Ailanthus	11.9± 0.5 (11.0± 0.5)	23.92+ 0.5 (30.0± 2.3)	4.3± 0.3 (6.1± 0.2)	10.521.5. (29.8±3.5)	36.8±3.7 (54.8±4.1)	119.2±1.6 (99.2±2.9)
Albizia	13.9± 0.4 (13.120.2)	34.8± 0.2 (38.820.4)	5.8± 0.3 (7.420.3)	53.9±5.3 (20.1±3.2)	41.8±2.4 (58.0±2.6)	89.6±1.3 (115.9±6.2)
Artocarpus	16.220.6 (16.3± 0.7)	33.3± 1.5 (36.0± 0.4)	8.8± 0.4 (6.520.3)	34.6±5.4 (25.0±2.0)	54.3±0.7 (40.3±1.0)	134.2±8.0 (116.3±1.9)
Grewia	13.1± 0.4 (12.220.8)	31.3± 0.4 (28.4± 0.4)	5.8± 0.2 (8.720.2)	54.7±1.5 (26.0±4.0)	44.8±2.5 (74.0±1.4)	90.4±1.6 (116.8±1.4)
Macaranga	15.6± 0.4 (11.5± 0.8)	41.4± 3.2 (48.6± 1.0)	8.0± 0.6 (6.7± 0.3)	38.9±1.0 (51.4±5.4)	51.3±3.3 (37.2±2.5)	113.6±6.8 (87.7fl.6)
Mangifera	15.7± 0.4 (11.5± 0.8)	48.9216 (48.8± 1.2)	6.850.2 (5.8± 0.3)	28.8±3.4 (34.7±3.0)	43.4fl.4 (50.4±1.8)	113.2±3.8 (86.9±2.8)
Tectona	13.8± 0.2 (10.8± 0.2)	25.5± 0.4 (27.420.2)	5.7± 0.2 (5.620.4)	19 4±1.6 (30.9±6.4)	41.3±1.0 (51.3±3.3)	114.9±1.8 (86.0±2.6)
Terminalia	16.520.4 (11.420.6)	29.85 0.6 (28.7± 0.8)	6.3± 0.5 4.8± 0.1)	25.5±3.9 (24.5±2.8)	38.4±3.3 (42.5±2.4)	111.8±2.7 (87.2±3.6)
Xylia	15.920.2 (13.020.3)	22.5± 1.1 (18.8± 0.9)	9.8± 1.4 (7.1± 0.2)	49 7±5.0 (26.2±1.7)	41.9±1.4 (54.4±1.3)	89.3±2.4 (115.9±5.0)

Crown diameter.

The rhythmic trunk growth in *Mangifera* and *Terminalia* produces complexes of branches where the development of terminal inflorescences stimulates further outward growth from lateral buds. Thus these two species conform to Scarrone's model. However, the trees of *Mangifera* and *Terminalia* growing in the open, after attaining certain height, branched sympodially producing orthotropic branches. Further branching is three-dimensional and sympodial to produce the several equivalent modules. Inflorescences in both species are terminal. These are the features of Leeuwenberg's model and therefore *Mangifera* and *Terminalia* each belong to Scarrone's model conform Leeuwenberg's model when grown under open (Figures 2.6 and 2.7).

In the case of Albizia and Xylia the shoots consistently change from initially being horizontal (plagiotropic) to on erect orientation but without a marked change in leaf disposition and hence these two species belong to Troll's model (Figures 2.8 and 2.9).

4.2 Growth pattern

Comparison was made for the values of the ratio between crown height and total tree height expressed in percentage (Table 1) obtained for trees growing under shade and in the open In the case of Albizia, Ailanthus, Grewia, Mangifera, Terminalia and *Xylia* the values were more for trees growing in the open than under shade. But opposite trend was recorded for other three species (Artocarpus, Macaranga and Tectona). On the other hand, crown of trees of Albizia, Grewia and Xylia growing under shade were broader than those growing in the open However, in case of other species crown was narrow in trees growing under shade and spreading in the open (Figures 2.1 to 2.9).

4.3 Leaf phenology

Of the nine species studied, *Albizia, Artocarpus* and *Mangifera* were evergreen and the rest were deciduous (Table 2). The leaf production in deciduous species was seasonal and peaked in January-February. The abscission of leaves for all the species commenced in November and continued up to January with a peak in December. The duration ofleaf maturation varied from 3 to 4 weeks. The period between maturation and abscission of leaves ranged fiom 276 days in *Macaranga* to 317 days in *Xylia*. Many species remained for quite a long perod while *Terminalia* and *XyIia* retained the aged leaves till the newly emerged ones attained the full size. A direct relationship between the leafing and leaf maturation and the rise in temperature was noticed.

4.4 Shoot growth

In the case of *Ailanthus*,*Albizia*, *Artocarpus*,*Terminalia* and *Xylia* shoot growth was initiated with bud burst and the flushing of new leaves in late January while in *Grewia*, *Macaranga*,*Mangifera* and *Tectona* it was observed in late February. Both in the open and shade areas ofhomegardens the order of annual shoot extension was *Ailanthus* > *Macaranga* > *Mangifera* > *Tectona* > *Artocarpus* > *Albizia* > *Terminalia* > *Grewia* > *Xylia*. Comparison of the species studied showed that shoot growth in the upper and lower canopies varied significantly ($P<0.05$) among most of the species (Table 3). In each species, the growth of upper canopy shoots both in trees growing in open and closed areas, was greater than in the lower-canopy shoots ($P<0.05$). The quotient of extension growth of trees of a given species growing in open area and under shade was calculated. But no significant difference among different species studied for the quotient values was recorded .

Table 2. Interphenophase durations, period of emergence and abscission of leaves for tree species growing in homegardens of Panancheny Panchayat, Kerala.

Species	Interphenophase durations (in days) YL to ML'	ML to AL	Leaf emergence	Leaf abscission
			Months	
Ailanthus	28	316	Feb	Dec-Jan
Albizia	-	-	-	-
Artocarpus	-		-	-
Grewia	38	282	Feb	Nov-Dec
Macaranga	31	192	March-April	Nov-Dec
Mangifera		-	-	-
Tectona	28	302	Feb-March	Jan
Terminalia	29	285	Jan	Nov-Dec
Xylia	31	317	Feb	Dec-Jan

***YL, Young leaves; ML, Mature leaves; Al, abscission leaves.**

Table 3. Annual shoot extension of lower- and upper- canopy shoots in trees growing under shade and in the open area in homegardens of Panancherry Panchayat, Kerala. Values in parentheses are for trees growing in the open area. All values are means ± **SE** (n=10).

	Shoot length (cm)	
Species	**Lower canopy**	**Upper canopy**
Ailanthus	95.1± 2.2 133.3± 5.1)	126.6± 3.4 (179.0± 6.8)
Albizia	61.1± 2.5 (74.1± 3.8)	79.95 1.7 (99.1± 4.0)
Artocarpus	72.3± 2.6 (81.95 1.7)	89.2± 3.0 (107.92 3.0)
Grewia	39.95 1.4 (46.25 3.4)	43.72 1.9 (56.4± 2.1)
Macaranga	81.4± 2.7 (90.5± 3.5)	99.7± 2.4 (111.92 1.9)
Mangifera	80.1± 4.0 (102.1± 4.6)	102.02 1.8 (125.32 3.4)
Tectona	78.6± 1.7 (90.22 1.9)	98.0± 2.0 (114.72 3.6)
Terminalia	57.9± 1.9 (61.6± 2.0)	77.95 3.0 (101.4± 3.6)
Xylia	30.8± 1.7 (36.22 1.1)	42.3± 0.9 (58.8± 1.4)

4.5 Branch angle

In all species, the branch angle increased significantly ($P>0.05$) from the top of the canopy to its base (Table 4). In a given canopy position of a given species, a significant difference in branch angle was recorded between trees growing under shade and in the open area ($P>0.05$). In case of *Grewia*, *Albizia* and *Xylia*, branches of a given canopy position of trees growing in the open area are more erect than the branches of trees growing under shade. On the other hand, in case of *Tectona*, *Artocarpus* and *Macaranga* opposite trend was observed.

The number of first-order branches recorded among the species showed wide variation. More number of first-order branches were recorded in *Artocarpus* **(13763±252** per tree), *Mangifera* **(9204±55)** and *Xylia* **(8812±110),** followed by *Terminalia* **(6019±59),** *Tectona* **(5832±137),** *Grewia* **(5456±74),** *Macaranga* **(1854±64),** *Albizia* **(1460+53)** and *Ailanthus* (1087±57). On the basis of branch length frequency distributions three distinct groups of the species were recorded (Figure 3). The branch length class contributing 50 to 60% of branches was 0-40 cm in *Artocarpus*, *Mangifera* and *Xylia*, 40.1-70 cm in *Albizia*, *Grewia* and *Terminalia* and 70.1->100 cm in *Ailanthus*, *Macaranga* and *Tectona*.

5. DISCUSSION

This study has identified six architectural models represented by nine forest species growing in homegardens of Kerala. These models with examples are Troll *(Albizia* and *Xylia)*, Roux *(Grewia)*,Koriba *(Ailanthus)*, Scarrone *(Mangifera* and *Terminalia* growing under the shade), Leeuwenberg *(Mangifera* and *Terminalia)* and Rauh *(Artocarpus*,*Macaranga* and *Tectona)*.In the case of *Grewia*,*Albizia* and *Xylia* plagiotropy of the branches is pronounced. Since the plagiotropy is an adaptation for the greater efficiency of light interception (Halle et.al., 1978) the species may adopt to the understorey of the vegetation. However, the

Table 4. Mean branch angle (in degrees; means ± SE, n= 10) of first-order branches of trees growing under shade and in the open area in homegardens of PanancherryPanchayat, Kerala, Values in parentheses are for trees growing in the open area.

Species	Crown position Lower	Upper
Ailanthus	77.55 1.9 (80.6± 2.9)	72.0± 1.9 (67.9± 1.4)
Albizia	86.22 4.8 (70.2± 1.4)	74.8± 2.6 (62.7± 3.8)
Artocarpus	80.22 1.9 (92.6± 4.2)	74.32 2.0 (81.6± 2.4)
Grewia	71.8± 3.6 (54.7± 1.2)	63.9± 2.0 (51.5± 0.6)
Macaranga	76.42 1.9 (87.25 3.6)	61.5± 0.6 (80.1± 1.6)
Mangifera	69.4± 1.5 (70.12 2.6)	61.7± 0.9 (65.92 1.4)
Tectona	71.4± 1.4 (86.52 2.6)	66.3± 2.0 (78.42 2.6)
Terminalia	83.42 0.8 (86.2± 2.3)	76.92 0.8 (69.7± 2.3)
Xylia	69.0± 1.8 (60.72 2.4)	55.3± 1.8 (48.62 3.4)

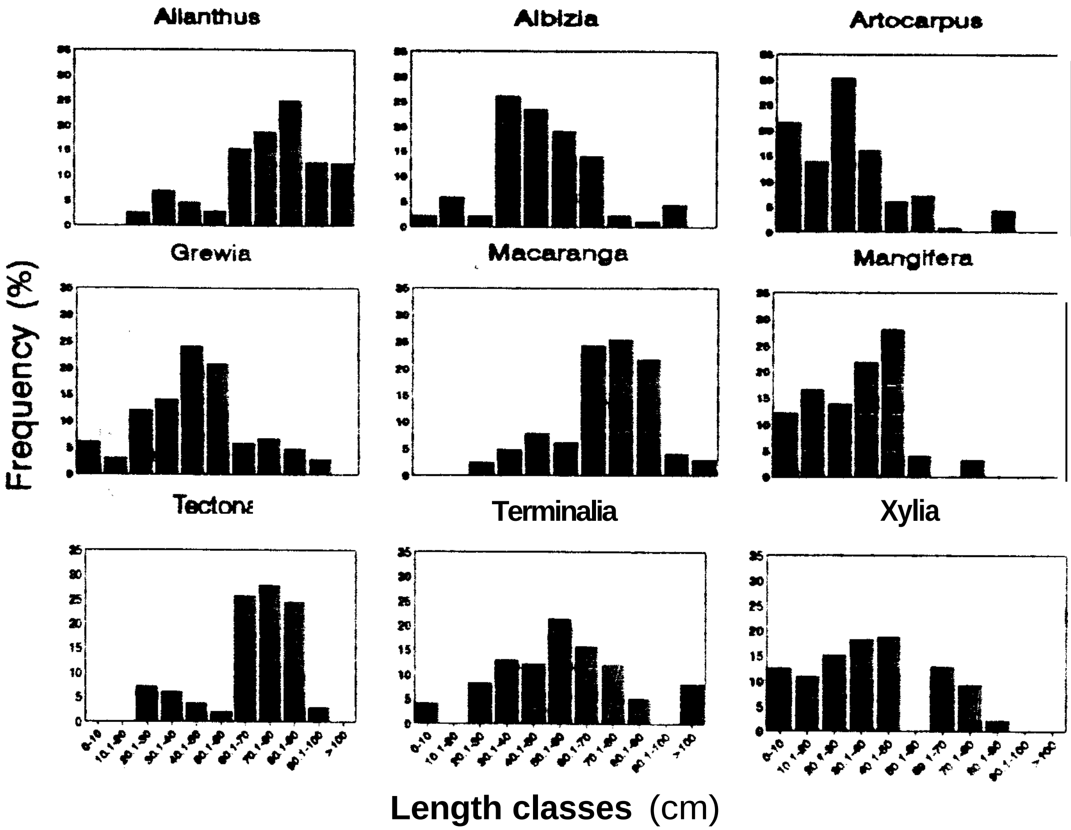

Figure 3. Percentage contribution of different branch-length classes to the total number of first order branches.

species can also adopt r-strategy because of its features like 1ateral inflorescence and continuous branching (Oldeman, 1990). According to Tomlinson (1978) the extent to which each relay axis contributes to growth in height, the position of the relay axis and the lateral extent of the branch phase of each axis are all variable and adjust to environmental influence. Variation in the growth rate among different species may be attributed to different adaptations to the climatic condition of the site. For example, in the present study, comparison of annual extension growth rate of different species revealed that while *Ailanthus*, *Macaranga* and *Mangifera* are having higher values *Grewia*, *Albizia* and *Xylia* are having lower values. But when the quotient of extension growth of trees of a given species growing in open area and under shade calculated no significant difference in quotient values of species such as *Grewia*, *Albizia* and *Xylia* which show low annual extension rate and species with with higher growth rates was recorded. Thus these species, depending upon the biotic features of the biotype, might serve either a K- or r-strategy. In the present study values obtained on branch angle and for the ratio between crown height and crown diameter as well as between crown height and total tree height in species such as *Grewia*, *Albizia* and *Xylia* indicated that trees growing under shade have greater branch angle than those growing in the open. This difference in branch orientation of these species may be attributed to the low and dome shaped crown under the shade in contrast to a narrow conical crown in the open. This is also an indication of flexibility of trees of these species in changing crown shape and size depending on the microclimatic conditions for capturing maximum amount of light energy.Thus these species can also perform well in open and disturbed sites by adopting different growth strategy.

In the case of *Artocarpus*, *Tectona*, *Macaranga*, *Mangifera* and *Terminalia* the main trunk is orthotropic. Orthotropy enhances production of straight timber. Since the shoots are derived from a single apical meristem and growth of the stem is controlled by the same apical meristem (monopodial growth) trunk growth is indeterminate and leads to production of trees with straight bole. Even if the trunk meristem is destroyed it is readily replaced usually by the upper-most lateral meristem or if the damage is more extensive, by the uppermost branch which rapidly substitutes as a leader axis (Horn, 1971). This is possible because all meristems are equivalent, regeneration then is carried out with a minimum of growth disturbance. Rhythmic growth exhibited by these species intrinsically enables the tree to suspend growth seasonally under unfavourable conditions. Species come under the Rauh and Scarrone models have tiers of branches and cast considerable amount of shade. But foliar phenological study of these species indicated that due to leaf fall the amount of shade of trees of *Tectona, Macaranga* and *Terminalia* is expected to be considerably low during the dry period.

The architectural model generally remains constant where'a tree grows in an environment that is relatively stable, but may differ in other circumstances. For example, the present study demonstrated that *Mangifera* and *Teminalia* conform Scarrone's model when growing under the shade and Leeuwenberg's model in the open area. Leeuwenberg's model consists of equivalent orthotropic modules, each of which is determined in its growth by virtue of the ultimate production of a terminal inflorescence. Branching is three-dimensional to produce the several equivalent modules and is correlated with flowering. These architectural features may be an indication of adaptation towards a r-strategy (Halle *et al.*, 1978). Thus *Mangifera* and *Terminalia* growing in the open may adapt an r-strategy. On the other hand, the same two species conform Scarrone's model with the monopodial trunk, the complexity of the orthotropic branches and terminal inflorescences correspond to an adaptation to an intermediate phase between r- and K-strategy.

Orientation of branches and leaf contributes much in shaping the overall geometry of the tree crown. Apart from this, it can also be related to the adaptive strategy of the tree crown for light interception (Bruning, 1976). Species such as *Tectona, Macaranga* and *Ailanthus* possess multilayered canopy. This feature can be attributed to the presence of long but comparatively less forked branches in these species. On the other hand, species like *Artocarpus*, *Mangifera* and *Xylia* have got a denser canopy with peripherally placed leaves due to their properties of having short branches with much forked branch axes. A significant increase in first-ordcr branch angle from the top of the crown to its base was recorded in different species. A greater branch angle down the tree increases the gap between the first-order branch complexes, opening the canopy for more light interception (Boojh and Ramakrishnan, 1982, Bisht and Toky, 1993). When trees of *Grewia*, *Albizia* and *Xylia* grown under shade and in open area are compared for the branch angle at a canopy position, significantly greater branch angle was recorded for each species in trees growing under shade. An increase in branch angle under low irradiance in these species may help in exposing the canopy for more efficient light absorption. On the other hand in the case of *Tectona*, *Artocarpus* and *Macaranga*, trees growing under shade tend to possess more erect branches, This tendency may be an adaptation to attain a superior competitive position and exploit a high light regime. But in the open these species have wider crown with more angle in order to put out a larger surface for harnessing more light energy.

In all the nine species, shoots of the upper-canopy showed significantly higher extension growth than shoots of the lower-canopy. This may be explained in terms of physiological age of shoots and competition among shoots for nutrients as suggested by Wareing (1956) and Kramer and Kozlowski (1960). Similar results were also reported for some multipurpose trees of arid region of India (Bisht and Toky, 1993).

In temperate trees, the time of growth initiation is relatively constant, whereas that of growth cessation is usually more variable (Kramer and Kozlowski, 1979). In the present study, the time of bud burst and flushing of new leaves showed more variation. For example, in the case of *Ailanthus*, *Albizia*, *Artocarpus* and *Terminalia*, flushing of new foliage occurred during late January while in the case of *Macaranga* it occurred in late February. This suggests that the period of bud break is an intrinsic feature.

Foliage phenoiogical studies of tropical species have established that the leaf flush occur either with the onset of rain after a spell of dry period (Proctor, *et al.,* 1983) or early in the dry period (Whitmore, 1984).Deciduous species studied at homegardens of Panancherry produced new foliages during early part of the summer season. During this part of the year, temperature and hours of sunshine are at their maximum (Fig. 1). These environmental factors have been regarded as suitable for maximising photosynthesis and vegetative growth (Salisbury and Ross, 1974).Thus the emergence and maturation of leaves in the pre-monsoon period are prominent. The leaf fall patterns that appear to be beneficial adaptations have evolved in response to seasonal climatic changes. A large number of factors have been implicated to trigger leaf shedding in tropical trees, including water and cold stress (Boojh and Ramakrishnan, 1982), photoperiod (Bhat, 1990; Prasad and Hegde,1986) and intrinsic factors (Addicot, 1978). In Panancherry, short duration of sunlight and decreased temperature were recorded during the months June to August, whereas, leafabscission in species studied peaked during December. From the present study, it appears that maximum leaf shedding which occurs during the dry period may be an adaptation to avoid water stress.

The suitability of these species in agroforestry system and their degree of adaptability to different microclimatic conditions from the architectural and growth point of view can be discussed.For example, species which come under architectural models such as Troll *(Albizia* and *Xylia)* and Roux *(Grewia)* by having strong plagiotropy have relevance inagrisilvicultural systems where there is use of more shade demanding agricultural components, perhaps cash crops These species appear best suited to introduce in the initial stages of perenniai crop establishment as these trees are having the tendency to grow straight with a narrow conical crown under less shade conditions. In the case of *Artocarpus, Tectona, Mangifera* and *Terminalia,* orthotropy enhances production of straight timber. Since these species have the tendency to attain a superior competitive position and exploit high light regime when grown under shade, their introduction in the later stages of mixed farming systems may lead to tall and straight timber. On the other hand, introduction of these species with other perennial light demanding crops in the early stage of mixed farming system in the open area may not be suitable. This is because these trees have the tendency to develop wider crown in the open area unlike while growing under shade. Thus, due to competition for light and space, crop species may not be able to establish well. The branching pattern of species such as *Artocarpus*, *Macaranga*, *Mangifera*, *Tectona* and *Terminalia* make them suited for growing with shade-tolerant agricultural perennials rather than light demanding shade intolerant plants. However, apart from the architectural behavior, foliage phenology of these species is also important to consider the suitable crop mixture. Species like *Tectona*, *Macaranga*, *Xylia*, *Terminalia* and *Grewia* being deciduous species shed leaves during the dry period and will be in leafless stage for 3-4 months. Light demanding short duration crops may be grown during this period provided other plant requirements such as water and good soil are available and proper crop management practices are followed.

It may be concluded that although, this study analyses the patterns of architecture, growth and foliar phenology of some tree species seen in homestead farming systems, many questions in agroforestry systems, have to be answered for a deeper understanding of the suitability of these species in the system. Some of these aspects to be studied include influence of root distribution and root architecture of these trees species on field crops, contribution of these trees for the nutrient cycling in the system and the determination of tree crop/ field crop combination in an architectural sense based on on-farm experiments.

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Appendix 1. Utilisation classes and important uses of trees selected for study in homesteads in Panacherry panchayat, Kerala. (Based on Krishnankutty, 1990 and Kumar et al.1994).

Species	Family	Common Malayalam name	Utilization classes	Important uses
Ailanthus triphysa (Dennst.) Alston.	Simaroubaceae	Matti	T2	4,5,9
Albizia odoratissima (L.f.)Benth.	Mimosaceae	Kunnivaka	T2	1,3,4,6,8,9,10
Artocarpus hirsutus Lamk.	Moraceae	Anjili	T2	1,3,5
Grewia tiliifolia Vahl	Tiliaceae	Chadachi	T2	1,3,5
Macaranga peltata (Roxb.) M.-A.	Euphorbiaceae	Vatta	M4	1,3,4,5
Mangifera indica L.	Anacardiaceae	Mavu	M3	1,2,3,4,5,7
Tectona grandis L.f.	Verbinaceae	Thekku	T1	1,4,5,8,10
Terminalia paniculata Roth	Combretaceae	Maruthu	T2	1,4,5
Xylia xylocarpa (Roxb.) Taub.	Mimosaceae	Irul	T2	1,4,5,8,10

Uses codes: 1, Timber; 2, Food and beverages; 3, Fodder;
4, Fuel/Charcoal; 5, Green manure; 6, Nitrogen-fixer;
7, Apiculture; 8, Oil (essential/fatty), 9, Paper/pulp; 10, Tanin.

Utilisation classes : T- Primarily timber yielding species,
M- Multiple use species
(1,2,3,4- Classification based on natural durability : 1= Very durable, 2= Durable, **3**= Moderately durable, 4= perishable).

Appendix 2. Key to the tree architectural models (Based on Halle et al., 1978)

Trees unbranched	
Growth terminated, inflorescence terminal	Holttum
Growth indeterminate, inflorescence lateral	Corner
Trees branched	
Shoot similar (no clear difference between trunk and branches)	
Basitonic branching, inflorescence lateral or terminal	Tomlinson
Acrotonic branching	
Dichotomous branching	Schoute
No dichotomy	
One branch per shoot	Chamberlain
Two or more branches per shoot	Leeuwenberg
Shoot distinct (with clear difference between trunk and branches)	
Vegetative shoots consistently similar (either all orthotropic or all mixed)	
Trees with shoots retaining original orientation, vegetative axes all orthotropic	
Inflorescence lateral	
Trunk growth rhythmic	Rauh
Trunk growth continuous or diffuse	Attims
Inflorescence terminal	
Trunk growth rhythmic	Scarrone
Trunk growth continuous	Stone
Trees showing consistently a change in orientation	
Axes orthotropic initially later plagiotropic	
A change occur in leaf disposition from radial to bilateral	Mangenot
No change in leaf disposition	Champagnat

Axes plagiotropic initially later orthotropic. No change in leaf disposition	Troll
Vegetative shoots consistently different (differentiated into orthotropic and plagiotropic axes or complexes of axes)	
Basitonic, axes heterogeneous	McClure
Acrotonic	
Construction modular	
Growth in height sympodial	
Modules initially equal, trunk develops from branches	Koriba
Modules unequal from the start, trunk module appear later than branch modules, both quite distinct	Prevost
Growth in height monopodial, modular construction restricted to branches	
Growth in height rhythmic	Fagerlind
Growth in height continuous	Petit
Construction non-modular	
Trunk an orthotropic sympodium	Nozeran
Trunk an orthotropic monopodium	
Trunk with rhythmic growth and branching	
Branches plagiotropic by apposition	Aubreville
Branches plagiotropic not by apposition	
Trunk with continuous or diffuse growth and branching	
Branches long-lived	Roux
Branches short-lived with an abscission scar	Cook

Appendix 3. Definition of specialised architectural terms

Acrotony: Production of vegetative shoots at the distal part of the plant and above the ground.

Apposition growth: Growth of a plant where the branches are in horizontal complexes producing peripheral shoots which repeatedly outgrow the shoot from which they originate.

Architectural tree model: The visible, morphological expression of the genetic make up of a tree at any point in time is the architecture, and the successive architectural phases which are determined by the growth programme are the architectural model.

Basitony: Production of vegetative shoots by a plant at ground surface or below the ground.

Branched axes: Axes built by one or more apical meristerns and the vegetative part may comprise more than one axis.

Branch complexes: Although initiated as a single lateral meristem, a branch may proliferate and still continues to function as a lateral unit. Such proliferated structure is termed as branch complexes.

Continuous growth: Growth without visible rhythm producing shoots without distinct articulations.

Determinate branch: Termination of the growth of the branch by the production of a bud at the tip, usually an inflorescence.

Heterogeneous axes: Axes that are distinctly made up of trunk and branches. They could be products of one or more meristems.

Homogenous axes: Axes that have no distinction between the trunk and which show uniform composition.

K-strategist: A species adapted to maximum survival of individuals at expense of reproductive capacity.

Mixed axes: Axes made up of horizontal and erect axes. A tree which exhibits both erect and horizontal axes during its growth phase is said to exhibit mixed growth.

Module: Shoot unit with determinate growth, either by apical abortion or conversion of apex to an inflorescence.

Modular construction: Way of building trees or branch complexes out of modules.

Monopodium: An axis established by a single indeterminate meristem, i.e., branches remain subordinate; hence monopodial growth, growth by continued activity of a single meristem.

Orthotropic shoots: Shoots which are erect, with essentially radial symmetry.

Plagiotropic shoots: Shoots which are more or less horizontal with dorsiventral symmetry.

r-strategist: A species adapted to high rates of sexual reproduction at expense of individual longevity.

Rhythmic growth: Growth of an axis determined by a rhythm which results in periodic shoot extension alternating with dormancy.

Sympodium: A single axis formed by a series of lateral meristems in sequence; sympodial growth, growth from successive lateral meristems.

Unbranched axes: Axes whose aerial vegetative parts are built by one apical meristem and consist of one axis only.