INFLUENCE OF TREE CANOPY ARCHITECTURE AND MANAGEMENT REGIMES ON GROWTH AND YIELD OF UNDERCROPS IN HOMEGARDEN AGROFORESTRY SYSTEMS IN KERALA

Final Technical Report

Submitted by
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Submitted to
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

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Abstract

Ten agroforestry tree species namely *Albizia odoratissima, Ailanthus triphysa, Artocarpus hirsutus, Bombax ceiba, Bridelia crenulata, Erythrina indica, Grewia tiliifolia, Macaranga peltata, Terminalia paniculata* and *Xylia xylocarpa* growing in homesteads of Kerala were studied to analyse their growth and architecture at their successive stages in relation to intercept light conditions. On the basis of the study these ten species have been classified under six different architectural models. The models with examples are Troll's model (*Albizia odoratissima, Bridelia crenulata and Xylia xylocarpa)*, Rauh's model (*Artocarpus hirsutus. Erythrina indica* and *Macaranga peltata*) Roux's model (*Grewia tiliifolia*), Aubreville's model (*Bombax ceiba)*, Koriba's model (*Ailanthus triphysa*) and Scarrone's model (*Terminalia paniculata*). In the case of *Albizia odoratissima, Bridelia crenulata and Xylia xylocarpa* the main axis of the seedling was orthotropic in condition. When the seedlings of *Bridelia crenulata and Xylia xylocarpa* were 14-18 months old and those of *Albizia odoratissima* were 28-32 months old, the proximal part of the relay axis became erected and formed a part of the trunk while the distal part of the axis functioned as the lateral branch. Thus the shoots of this species is a structure consisting of the main axis and part of the relay axis. The saplings and mature trees of these species produced annually 4-5 relay axis and they contributed to the shoot formation and production of branches. The branching in *Artocarpus hirsutus, Erythrina indica* and *Macaranga peltata* was rhythmic and branch formation began when the individuals attained 18-20 cm gbh. The periodicity of rhythmic growth was considerable with branch production during the period between May and November and cessation of branch production during December -April. Thus the branch production coincides with the moist period while cessation of branch production is observed during the dry period. The branch production in *Artocarpus hirsutus* was by prolepsis, from dormant lateral buds close to the terminal bud protected by bud scales, while that in *Macaranga peltata* and *Erythrina indica* it was by syllepsis, with lateral axis developing during the phase of extension of terminal buds in the current shoot. In these species lateral flowering, an ecological adaptability for continuous branch growth was noticed. Architectural analysis of *Grewia tiliifolia* indicated that the main axis is orthotropic whiled the branches are plagiotropic in nature. Lateral flowering and continuous branching in this species may be an adaptation to r- and k- strategies according to the biotic feature of the biotype. The main axis of *Ailanthus triphysa* was also orthotropic. When the plant attained sapling phase, 6-8 axes at the branch level were formed. Among these axes, one axis showed significantly higher girth and length. Subsequently this specialised axis became erect, dominant and functioned as a relay axis. A monopodial trunk with rhythmic growth bearing whorled plagiotropic branch tier determined the architecture of

Bombax ceiba. In case of *Terminalia paniculata* properties like orthotropic main axis, rhythmic growth leading to production of a complex of orthotropic branches and terminal position of inflorescence determined its architecture.

The study also revealed that the extent of growth and branch display angle varied from species to species and alos the fact that in a given species there is plasticity in growth and branch display in relation to environment influence. For instance, length of the relay axis in species like *Albizia odoratissima, Bridelia crenulata and Xylia xylocarpa* was significantly more in the individuals growing in open than in shade. Thus individuals of these species exhibited dome shaped crown in the open in contrast to a narrow, conical crown in individuals growing in shade. Similarly, in case of *Xylia xylocarpa* branches of saplings of growing in the open were significantly longer than those growing in the shade. On the other hand, in case of *Artocarpus hirsutus, Erythrina indica* and *Macaranga peltata* branches of individuals growing in the shade were significantly longer than those of the saplings growing in the open. However, under the shade trees of these species tend to possess more erect branches, an adaptation to attain a superior competition position and exploit high light regime.

Effects of different pruning intensities and frequencies on girth increment and foliage and branch production patterns in all the ten tree species have been studied and results are reported. The present study did not support the common contention that a certain level of pruning promotes stem growth in trees. Monitoring of annual girth increment in gbh in different species indicated that as pruning severity increases the depression in growth increases. However, the effect of pruning on tree growth appeared to be declined at least at certain pruning intensities. For example, in some species (*Albizia odoratissima, Erythrina indica* and *Bridelia crenulata*), two years after pruning, no significant difference in terms of mean annual increment in gbh was recorded in pruned and un-pruned trees. Similarly, in the other species no significant difference between un-pruned trees and trees subjected 50% to 75% pruning intensity for the value obtained for annual increment in gbh was recorded. Responses to pruning in terms of biomass production varied from species to species. For example, the ratio between quantity of foliage and small branches produced in a year in pruned and un-pruned trees was less than 100% (*Albizia odoratissima, Ailanthus triphysa, Artocarpus hirsutus, Bombax malabaricum, Bridelia crenulata* and *Xylia xylocarpa*) or around 100% (*Grewia tiliifolia) or* more than 100% (*Erythrina indica, Macaranga peltata* and *Terminalia paniculata*). However, in all the species studied, the quotient ratio between quantity of foliage and small branches produced in two year period in pruned and un-pruned trees was more than 100% at least in one more pruning intensities. Based on these observations certain pruning strategies that could be adopted for better growth and foliage production on the sustainable basis were suggested.

A study was conducted to analyze the vegetative growth performance and rhizome yield patterns in ginger, turmeric and kacholam planted under the canopy of different tree species, which were subjected to different pruning intensity. Ginger yield was significantly more under un-pruned trees than under pruned trees of *Albizia odoratissima*, *Bridelia crenulata*, *Macaranga peltata and Xylia xylocarpa.* when no significant difference in the yield under pruned and un-pruned trees of *Ailanthus triphysa* and *Bombax ceiba* was observed. Similarly, turmeric crop yield under pruned and un-pruned trees of *Albizia odoratissima* and *Bombax ceiba* was not significantly different. However, turmeric cultivated under species like *Ailanthus triphysa*, *Artocarpus hirsutus*, *Bridelia crenulata*, *Grewia tiliifolia*, *Terminalia paniculata* and *Xylia xylocarpa* produced lesser quantity of rhizome under pruned trees than under un-pruned trees. Performance of kacholam as an under crop seemed to be different from that of ginger and turmeric. For instance, yield of kacholam was significantly more under un-pruned trees of *Ailanthus triphysa* and *Artocarpus hirsutus* than under pruned trees of the respective species. However, 75% pruning of trees of *Macaranga peltata*, *Terminalia paniculata*, *Xylia xylocarpa* and *Grewia tiliifolia* seemed to favour the growth of kacholam as an under crop as indicated by significantly more yield than under either un-pruned trees or trees subjected to other intensities of pruning. Similarly, 90% pruning of *Bombax ceiba* and 75% and 90% pruning of *Bridelia crenulata* and *Erythrina indica* favour the growth and yield of kacholam. Since a poor correlation between Photosynthetic Active Radiation (PAR) available below the canopy of trees of each species and yield of each crop species was recorded, it was concluded that the change in light intensity alone would not determine the growth and yield of crops growing under trees which were subjected to different intensity of pruning.

1. Introduction

Homegarden agroforestry characterised by intensive integration of trees and shrubs with food crops and often animals, is a predominant landuse system in Kerala. About 41,80,900 operational holdings with an average size of 0.43ha are under this landuse practice (KAU, 1989). The plants belonging to functional groups like timber, fruit, spices, plantation crops, annual crops and medicinal plants constitute the vegetation in homegardens of Kerala. The total density of perennial plants in homegardens of Kerala may range from 1716 to 4345 individuals ha^{-1} with 15.9% to 41.6% contribution from timber trees (Sankar and Chandrashekara, 2002). Homegardens of Kerala are also rich in species diversity with 26 to 60 plant species per homegarden. The estimated ratio between area of plant canopy and actual land area ranges from 139% to 477% (Sankar and Chandrashekara, 2002) which indicates the high degree of overlapping in the canopy in the different strata of homegardens. According to Fernandes and Nair (1986), such multi-tiered and multi-species homegardens use both aboveground and belowground resources efficiently. 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 homestead polyculture of the State, plants are usually planted in a haphazard manner (Kumar *et.al.*,1994) without giving adequate attention to the trees and crops interactions, ecological requirements of individual species and management practices, especially for tree components of the system. One of the steps to evolve ecologically sound agroforest suggested by Oldeman (1983) was to understand the growth and architectural patterns of forest tree components of the systems. According to Audo (1990) analysis of architectural models conformed by different tree components and architectural plasticity exhibited by such species would provide scientific base to identify suitable tree species/crop combinations in an agroforestry system. However, tree growth and architectural analysis were mainly restricted to shifting agriculture (Boojh and Ramakrishnan, 1982; Shukla and Ramakrishnan, 1986) and taungya systems (Audo, 1990). In fact mature trees of certain species in homegardens of Kerala were studied for their architectural patterns (Chandrashekara, 1997). The present study however, was designed to analyse the growth and architecture of a set of forest tree species of agroforestry importance at their successive growth stages in relation to intercept light conditions.

In a multi-species multi-layered landuse systems management of trees is expected to enhance productivity of both trees and understorey crops on a sustained basis (Ong et.al., 1991). Several workers have also emphasised the need of canopy management of different agroforestry tree species for optimizing their productivity (Kang *et.al.*, 1981; Muschler *et.al.*, 1993; Pinkard and Beadle, 2000; Kishen Kumar and Tewari, 2001;Thakur, 2002). Whether the canopy management option is live branch pruning, coppicing or pollarding, it is cautioned that such prescription/s should tend to be conservative and designed to ensure that the growth is not affected (Langstrom and Hellqvist, 1991). It may be mentioned here that in homegardens of Kerala, several species trees are subjected to live pruning. Here generally both the intensity and frequency of branch pruning is based on the discretion of farmer rather than based on any scientific prescription. In this context this study was conducted to determine the impacts of different intensity and frequency of pruning on the vigour and biomass production over the years by a set of tree species in the homegardens of Kerala.

Many annual crops are cultivated in the homegardens of Kerala. Number of annual crop species per homegarden may range from 5 to 12 (Sankar and Chandrashekara, 2001). Among them, ginger (*Zingiber officinale*), turmeric (*Curcuma longa*) and Kacholam (*Kaempferia galanga*) are the common rhizomatous crops. These three species are shade loving plants, however, their growth may be affected both at excessive and sub-optimal shade levels. On-farm experiments on cultivation of these rhizomatous short duration crops under bamboo in homegardens of Kerala indicated that yield of crops is good to moderate (Chandrashekara *et.al.*, 1997). The effect of varying shade levels on ginger production in integrated ginger-poplar (*Populus deltoides*) (Jaswal *et.al.*, 1998) and ginger-ailanthus (*Ailanthus triphysa*) (Kumar *et.al.*, 2001) have been evaluated. Bavappa (1982) and Nair (1983) reported that in multi-strata cropping, canopy shape and size and rooting habits of coconut, cacao, arecanut and other crop species intercept only a fraction of light and have a restricted zone. However, studies on growth and crop yield of rhizomatous crops under individual and managed trees of different species have not been undertaken. Thus the present study was also designed to analyse the growth and crop yield of rhizomatous species under both managed and unmanaged trees of different species in homegardens of Kerala.

2. Materials and Methods

2.1 Study area and climate

The field study was conducted in homegardens in the villages in low land (Kole land) (up to 7.5 m Above MSL) and mid land (7.5 to 75 m above MSL) agro-ecological zones of Thrissur District (lies between latitudes 9° 49'N and 11° 49'N and between longitudes 75° 62'E and 76° 50'E) in Kerala. The climate in these agroclimatic zones is typically monsoonal with an average annual rainfall of over 3220mm. 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 mean maximum temperature varies from 24.8°C (July) to 31.4°C (March) while the minimum temperatures varies from 21.1°C (January) to 23.1°C (April). The mean relative humidity is as high as 82% and average annual relative humidity is around 70%.

2.2 Selection of tree species

Based on the rapid rural appraisal conducted in the village of Kole and Central agroclimatic zones, a list of tree species growing in homegardens was prepared. Among them *Albizia odoratissima, Ailanthus triphysa, Artocarpus hirsutus, Bombax ceiba, Bridelia crenulata, Erythrina indica, Grewia tiliifolia, Macaranga peltata, 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.

By the end of June 1999, 114 homegardens spread over in 14 villages where the above mentioned species are available were selected. In the subsequent two years another 112 homegardens were selected in order to obtain required number replicates for saplings (10.1 to 30.0 cm girth at breast height: gbh, measured with tape at 1.37 m from the ground) and trees (above 30.1cm gbh).

2.3 Architectural analysis

Seedlings of each of the above species were raised in the nursery Kerala Forest Research Institute Sub Centre at Nilambur in two light conditions; under 45-50% light and in full light. Twenty-five seedlings of a species growing in each light condition were selected and monitored for three year period for their morphological features including leaf and branch display patterns. Height and girth of seedlings were recorded annually.

Saplings (10.1 to 30.0 cm gbh) and trees (above 30.1cm gbh) of the above mentioned species, growing in open as well as under the shade in homegardens, were also selected in order to monitor them for their branching patterns, branch display angle, position of inflorescence. In some species, individuals growing in the nursery themselves attained the sapling stage within three-year period of monitoring. In such cases, parameters such as branching patterns, branch display angle, position of inflorescence, whichever applicable were studied in the nursery conditions.

The parameters thus studied considering the seedlings, saplings and mature trees of each species were used to determine the architectural model of the given species. Thirteen principal morphological and reproductive features, which were considered to distinguish different architectural models, are given below.

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 inflorescence: lateral or terminal
6. Nature of plant growth: rhythmic or continuous
7. Growth after flowering: growth terminate 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

Above mentioned ten trees (*Albizia odoratissima, Ailanthus triphysa, Artocarpus hirsutus, Bombax ceiba, Bridelia crenulata, Erythrina indica, Grewia tiliifolia, Macaranga peltata, Terminalia paniculata* and *Xylia xylocarpa)* were assigned to different architectural models of Halle *et al.*, (1978). Values obtained for parameters such as branch length or branch angle for the individuals of a given species growing in open and in shade were compared using Student's t-test.

2.4 Responses to pruning by different tree species

2.4.1 Pruning intensity and frequency

Twenty-four trees of each species were selected. Size of these trees ranged from 35-45cm gbh. Out of twenty-four trees of a species, six were not pruned and used as control, while the rest were pruned. Just before branch pruning, the girth of each tree was measured and marked the gbh point on the tree. Following method was employed to indicate the pruning intensity. First, the total crown length was measured and divided into 20 equal parts and expressed in percentage. Thus if 1/20 of the total crown length from the crown base was pruned, it could be considered as 5% pruning. In this study, each species was subjected to three pruning intensities namely 50%, 75% and 90% pruning. It was decided to prune six trees of a given species for a given intensity of pruning in the year 1998. In many cases, required number of replicate trees did not available during that period. In addition, some trees selected and pruned could not be monitored as the biomass of some them were harvested either fully or partially while in some case farmers changed the landuse system either partially or completely. Thus the remaining replicate trees were selected and pruned in the year 1999 and 2000. Pruned trees were divided into two sets in order to determine the quantity of foliage and small branch biomass produced in one and two years after the first pruning. Thus the first set, which included nine trees per species, was pruned when each tree completed one year after the first pruning. Similarly, second set included another nine trees per species, which were pruned two years after the first pruning.

2.4.2 Annual girth increment

Girth at breast height (gbh) of un-pruned trees of each species was measured annually and difference in the values obtained between two successive years gave the annual increment in girth. In case of trees, which were pruned a year after the first pruning, the difference in the gbh values obtained at the time of first and second pruning gave the annual increment in girth. Whereas in trees pruned, which were pruned two years after the first pruning, the difference in the gbh values obtained at the time of first and second pruning divided by two gave the annual increment in girth. One-way ANOVA was adopted to compare the mean values obtained for trees of a species subjected to different intensity of pruning and LSD test was used to determine whether significant difference in the values were there or not.

2.4.3 Biomass production

After the first pruning, total crown length of each tree was divided into three equal parts. In each part, the first order branches were enumerated and half the total number of branches were labelled. These branches were monitored at monthly interval to label new small branches and foliage produced using tags and paint till they were harvested and quantified in the next pruning period i.e., one year and two years after first pruning in case of first and second set of trees respectively. Six trees for each species, considered as control (un-pruned), were divided into two sets of three trees each. In all these trees, total crown length of each tree was divided into three equal parts. In each part, the first order branches were enumerated and half the total number of branches were labelled. These branches in one set of trees were monitored at monthly interval to label new small branches and foliage produced in one-year period. Similarly, labeled branches in another set of trees were monitored at monthly interval to label new small branches and foliage produced in two-year period. Quantity of biomass thus produced in the stipulated period in each set of trees was estimated by harvest method.

Ratio between the quantity of foliage and small branch biomass produced in pruned and un-pruned trees in a given period was calculated as follows:

$$\frac{BP_1 \times 100}{BUP_1} = \frac{\text{Quantity of foliage and small branches produced in one year period after pruning} \times 100}{\text{Quantity of foliage and small branches produced in one year period in un-pruned trees}}$$

$$\frac{BP_2 \times 100}{BUP_2} = \frac{\text{Quantity of foliage and small branches produced in two year period after pruning} \times 100}{\text{Quantity of foliage and small branches produced in two year period in un-pruned trees}}$$

One-way ANOVA was adopted to compare the mean values obtained for trees of a species subjected to different intensity of pruning and LSD test was used to determine whether significant difference in the values were there or not.

2.5 Undercrop experiments

Experiments were conducted during May-June of 1999 and 2000 to evaluate the impact of tree branch pruning at different intensities on the growth and yield of zinger, turmeric and kacholam, which were cultivated as undercrop. Under each tree of a given species, subjected to a given intensity of pruning, nine beds each of size 2m x1m were raised within the crown area of the tree. Three random beds were used for growing a given crop. Propagules of the crop species were planted in May-June in small pits (4 to 5cm depth) at a spacing of 25cm x 25cm on beds. Cultural practices recommended (KAU, 1993) for each crop species were followed. Following methods were adopted to evaluate the growth parameters and yield of zinger and turmeric. During the last week of October (when the plants were about 5 months old) all the plants in each bed were monitored for recording number of tiller per plant, tiller height and number of leaves per plant. In case of kacholam only the number of leaves per plant was recorded. Area of each leaf was measured using leaf area meter. In the second week of January (when the plants were about 8 months old) the crops were harvested. Fresh and air dry weights of mature rhizomes were recorded after cleaning.

Values obtained for each growth parameter of a crop species cultivated under trees of a given species subjected to different intensities of pruning were analyzed following the analysis of variance technique (ANOVA). Mean values were compared using Duncan's least significant difference (LSD) test.

Photosynthetically active radiation (PAR) available below the canopy of trees of a given species which were subjected to different intensity of pruning was measured during mid day (12-13 hour) using a Line Quantum Sensor. Correlation coefficient between the PAR and different growth attributes of each crop species was calculated.

3. Results and Discussions

3.1 Morphological and architectural analysis

This study has identified six architectural models represented by ten tree species growing in agroforestry systems of Kerala. These models with examples are Troll's model (*Albizia odoratissima*, *Bridelia crenulata* and *Xylia xylocarpa*), Rauh's model (*Artocarpus hirsutus*, *Erythrina indica* and *Macaranga peltata*), Roux's model (*Grewia tiliifolia*), Aubreville's model (*Bombax malabaricum*), Koriba's model (*Ailanthus triphysa*) and Scarrone's model (*Terminalia paniculata*).

In case of *Albizia odoratissima*, *Bridelia crenulata* and *Xylia xylocarpa*, the main axis of the seedlings was orthotropic in condition. Here the leaf arrangement showed differences both between species and within a species at different stages of development. For instance, first few leaves in *Albizia odoratissima*, *Bridelia crenulata* and *Xylia xylocarpa* showed spiral, opposite and alternate arrangements respectively. These leaves in *Albizia odoratissima* and *Xylia xylocarpa* were unipinnate and paripinnate compound, while in *Bridelia crenulata* they were simple. However, when the seedlings of *Albizia odoratissima* were about 9-10 month old and about 20.6 $\pm$ 4.3cm in height, bi-pinnately compound leaves began to form. In all the subsequent stages of tree growth, new leaves formed were bi-pinnately compound. In case of *Xylia* *xylocarpa*, after the production of five to six such leaves, the seedlings began to produce bi-compound leaves, each leaf with 3-4 pairs of opposite leaflets. Leaves produced thereafter were of such type.

When the seedlings were 12-16 month old, in these three species a lateral bud was formed near the apical part of the seedling. The lateral bud developed into a plagiotropic branch, which in turn functions as the relay axis of the main axis. These relay axes were further monitored. When the seedlings of *Bridelia crenulata* and *Xylia xylocarpa* were 14-18 month old, and those of *Albizia odoratissima* were 28-32 months old, the proximal part of the relay axis becomes erected and forms a part of the trunk while the distal part of the axis functions as a lateral branch. Thus the shoots of this species is a structure consisting of the main axis and part of the relay axis. With these features *Albizia odoratissima*, *Bridelia crenulata* and *Xylia xylocarpa* conform to Troll's model. At the interface between the erected basal part and distal bent part, a lateral meristem was developed. The lateral meristem became functional and thus formed the successive axis. Further monitoring of the seedlings and saplings of these species indicated that annually 4-5 relay axes were produced and these axes contributed to the shoot formation and production of branches.

The study also indicated that 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 of each relay axis are all variables and be adjusted to environmental influence. This is best seen in each species studied. For instance, length of the relay axis was significantly more in the individuals growing in open (*Albizia odoratissima*: 16$\pm$3.2cm; *Bridelia crenulata*: 13.2$\pm$1.1 cm; *Xylia xylocarpa* 15.7$\pm$0.7 cm) than in shade (*Albizia odoratissima*: 5.9$\pm$1.2cm; *Bridelia crenulata:* 8.2$\pm$0.7 cm; *Xylia xylocarpa*: 9.2$\pm$ 1.3 cm). Thus the individuals exhibit a low dome shaped crown in the open in contrast to a narrow, conical crown in individuals growing in shade.

Individuals of three species (*Albizia odoratissima*, *Bridelia crenulata* and *Xylia xylocarpa*) whose girth ranges from 10.1cm to 15.2cm and growing in open and shade conditions were monitored for branching patterns. Among these three species, *Xylia xylocarpa* showed significant difference between individuals growing in open and in shade. In this species individuals growing in open produced 7-9 branches in a year while those growing in the shade produced 4-5 branches in the same period. The size, shape and arrangement of leaves growing on the main axis and branches were different. The leaves on the trunk were significantly smaller (6$\pm$1.2cm long and 3.7$\pm$ 0.9cm wide) than those on the branches (10.3$\pm$ 0.4cm long and 5.2$\pm$

0.3cm wide). When the leaves on the main axis were ovate to orbicular and arranged spirally, those on the branches were asymmetric and distichously arranged. These differences in the foliage of the trunk and branches were observed even in older saplings and trees. The girth and the length of these branches were measured when the branches were 1-year old. It was found that branches of saplings growing in the open were significantly longer (3.6$\pm$0.3m) than those of the saplings growing in the shade (2.2 $\pm$0.4m). Similarly the mean girth of the branch was also significantly more (12.2$\pm$1.2cm) in saplings growing in the open (6.3 $\pm$ 0.4cm) than that in saplings growing in the shade. Even the branch angle in individuals growing in open was significantly more (80$\pm$5^{O}) than that recorded in individuals growing under the shade (56$\pm$12^{O}). Since values obtained for a given parameter in individuals growing in the shade and open in other two species were not significantly different, values are not given here.

Monitoring of the seedlings of *Artocarpus hirsutus*, *Macaranga peltata* and *Erythrina indica* for 1-year period revealed that the seedlings were orthotropic and produced 6-8 simple leaves, which were arranged alternatively as in case of *Artocarpus hirsutus* and *Macaranga peltata* or spirally arranged as in case of *Erythrina indica*. However, in case of *Erythrina indica*, when the seedlings were 6-7 month old and attained a height of 25-30cm, alternately arranged tri-foliately compound leaves began to form. Further monitoring of seedling height and girth indicated that values for both parameters were more in the seedlings growing in the open than in the shade (Table 1). In case of *Macaranga peltata*, the mean leaf area was also significantly large in the case of individuals growing in open (300 $\pm$ 40cm^2) than those in shade (160 $\pm$ 36 cm^2).

The branching in these species was rhythmic and branch formation began when the individuals attain a gbh of 18 to 20cm.Totally 5-6 branches (in case *Erythrina indica*) or 6-7 (in case of *Artocarpus hirsutus* and *Macaranga peltata*) were produced during the period from May to November. However, during the period from December to April cessation of branch production was recorded in all these three species. Further monitoring of the seedlings and saplings indicated that another set of branches, which were also arranged in a distinct tier, was produced during May to November of the subsequent year. Thus it is also possible to conclude that the periodicity of rhythmic growth is considerable and branch production coincides with the moist period while cessation of branch production is observed during the dry period. However, *Artocarpus hirsutus* was different from *Macaranga peltata* and *Erythrina indica* in terms of mode of branch production.

Table 1. Stem height and collar girth of seedlings of different species growing under full light and under partial light (45%-50% light) conditions in the nursery. Values are mean ± standard error. N=25.

Species	Age of the seedlings	Light conditions: Full light	Light conditions: Partial light	LSD Value	Light conditions: Full light	Light conditions: Partial light	LSD value
		Seedling height (cm)			Collar girth (cm)		
Ailanthus triphysa	1-yr old	94±5	76 ± 6	5	8.4± 0.9	6.3±0.7	0.4
	2-yr old	176± 16	126±12	29	9.8±0.2	7.6±0.4	0.9
	3-yr old	242±24	176±20	34	14.2±1.2	9.9±1.3	0.7
Albizia odoratissima	1-yr old	37±4	33±2	4	8±1.6	7.4±0.5	0.3
	2-yr old	52±6	48±4	6	11.2±0.4	9.2±0.4	1.0
	3-yr old	94±7	76±3	9	14.3±0.5	12.1±0.5	0.4
Artocarpus hirsutus	1-yr old	60 ± 7	40 ± 3	7	6.7±0.4	5.9±0.2	0.2
	2-yr old	97±12	64±7	9	8.2±0.3	9.1±0.2	0.5
	3-yr old	156±16	116±4	14	12.3±0.2	11.4±0.1	0.3
Bombax malabarica	1-yr old	32± 6	36 ± 4	4	5.2±0.4	3.6±0.2	1.1
	2-yr old	258± 12	210 ± 26	14	8.4±0.4	5.2±0.1	0.4
	3-yr old	312+18	276±14	29	11.6±0.7	7.4±0.3	0.7
Bridelia crenulata	1-yr old	18± 2	16±1	4	7.3±1.2	4.6±0.2	1.0
	2-yr old	46±1	41±2	5	9.6±0.4	7.2±0.5	0.7
	3-yr old	94±1	86±4	4	10.3±0.2	9.2±0.4	0.4
Erythrina indica	1-yr old	94±12	64+8	11	5.2±0.3	4.1±0.2	0.5
	2-yr old	142±8	112±8	8	7.6±0.4	5.3±0.4	0.3
	3-yr old	176±12	134±4	14	13.4±1.2	8.6±1.0	0.7
Grewia tiliifolia	1-yr old	40± 3	21± 1	7	6.4± 0.4	5.2± 0.4	0.5
	2-yr old	57±1	39±3	10	8.4±0.3	7.1±0.2	0.4
	3-yr old	75±1	53±2	8	11.3±0.4	9.9±0.2	0.5
Macaranga peltata	1-yr old	126 ± 26	66 ± 19	17	7.2 ± 0.8	4.8 ± 0.4	1.2
	2-yr old	176±12	92±12	21	8.4±0.3	5.7±0.3	1.6
	3-yr old	257±8	132±12	35	13.4±0.6	8.2±1.2	2.1
Terminalia paniculata	1-yr old	48 ±4	27 ±9	7	3.6±0.2	2.1±0.3	0.3
	2-yr old	80±2	56±4	11	7.2±0.3	5.2±0.3	0.4
	3-yr old	112±6	89±2	14	9.4±0.3	7.4±0.4	0.7
Xylia xylocarpa	1-yr old	22+4	20+2	5	7.6+0.3	6.4+0.4	1.0
	2-yr old	56±6	32±4	7	9.2±0.2	7.2±0.3	0.4
	3-yr old	89±2	61±3	8	10.3±0.4	9.2±0.2	0.5

Table 2. Girth and length of different axes produced at a branch level in saplings of *Ailanthus triphysa* growing in open and in shade conditions. Gbh (Girth at 1.37m above the ground level) of the saplings ranged from 10.5 cm to 14.5 cm. N=25.

Sapling growing in the open area			Sapling growing in the shade		
Axes number			Axes number		
	Axes girth (cm)	Axes length (cm)		Axes girth (cm)	Axes length (cm)
1	7.5 ± 1.2^a	40 ± 2.4^a	1	6.2 ± 0.6^a	32.0 ± 2.0^a
2	6.3 ± 1.6^a	35 ± 3.6^a	2	6.7 ± 0.4^a	30.0 ± 3.4^a
3	5.4 ± 1.4^a	40 ± 3.2^a	3	5.7 ± 0.5^a	34.0 ± 2.4^a
4	6.1 ± 1.1^a	38 ± 2.1^a	4	6.4 ± 0.4^a	30.0 ± 2.1^a
5	7.0 ± 0.8^a	42 ± 3.4^a	5	5.6 ± 0.5^a	36.0 ± 1.4^a
6	6.4 ± 1.3^a	41 ± 3.0^a	6	8.3 ± 0.3^b	39.3 ± 0.6^b
7	6.7 ± 1.0^a	43 ± 2.8^a			
8	9.9 ± 0.4^b	57 ± 1.2^b			

When in case of *Artocarpus hirsutus* branches develop by prolepsis, from dormant lateral buds close to the terminal bud protected by bud scales, in *Macaranga peltata* and *Erythrina indica* it may be by syllepsis, with lateral axis developing during the phase of extension of terminal buds in the current shoot. Since in these three species a monopodial trunk, which grows rhythmically and so develops tiers of branches, develops the architecture, they conform to Rauh's model. In case of *Artocarpus hirsutus*, inflorescence produced in the foliage axillary; more towards the branch apex whereas in *Erythrina indica*, the flowers were in erect axillary racemes towards the branch apex when in case of *Macaranga peltata* flowering was observed mainly in the leaf axis of secondary and tertiary branches. Thus lateral flowering, another feature of these species belonging to Rauh's model, is considered as an ecological adaptability where flowering does not terminate branch growth.

As already indicated, in these three species the main trunk is orthotropic. Orthotropy enhances production of straight bole. Since the shoots are derived from a single apical meristem and the same control growth of the stem apical meristem (monopodial growth) trunk growth is indeterminate and leads to production of trees with straight bole. Rhythmic growth exhibited by these species intrinsically enables the species enables the tree to suspend growth seasonally under unfavorable conditions. The species come under the Rauh's model have tiers of branches and cast considerable amount of shade. Orientation of branch contributes much in shaping the overall geometry of the tree crown. For instance, in case of *Artocarpus hirsutus* and *Macaranga peltata*, branches at a given position were more erect when the trees were growing in the shade (*Artocarpus hirsutus*: $74.3^{\circ} \pm 6.8^{\circ}$; *Macaranga peltata:* $66.8^{\circ} \pm 3.5^{\circ}$) than the branches of trees growing in the open area (*Artocarpus hirsutus*: $86.6^{\circ} \pm 4.4^{\circ}$; *Macaranga peltata*: $84.3^{\circ} \pm 3.6^{\circ}$). The first set branches formed in the seedlings of *Erythrina indica* were monitored for 1-year period. Here the branches of the seedlings growing in the shade were significantly longer (branch length: 6 ± 2cm) and erect (branch angle: $76^{\circ} \pm 4^{\circ}$) than those of the seedlings growing in the open area where branch length and branch angle were 3 ± 1cm and $84^{\circ} \pm 2^{\circ}$ respectively. In other words, trees of these species growing under shade tend to possess more erect branches. This tendency may be an adaptation to attain a superior competition position and exploit high light regime (Bruning, 1976). But in the open these species have wider crown with more angles in order to put out a large surface for harnessing more light energy.

In case of *Grewia tiliifolia,* whether the seedlings growing in the shade or in the open, the main axis was orthotropic, green and tomentose. The branch production began when the seedlings were 24-30 months old. 4-5 branches were formed continuously and they were plagiotropic in nature. Thus *Grewia tiliifolia* with monopodial orthotropic axis, continuous growth and plagiotropic branching pattern represent the Roux's model. According to Halle et.al., (1978) species conforming to this model could also show difference between the leaves borne on trunk and branches. In the seedlings, leaves were ovate, simple, 5-ribbed and spirally arranged. The differences observed in *Grewia tiliifolia* were that the leaves on the trunk were simple, symmetric, ovate while on the branches the leaves were simple, asymmetric, obliquely ovate, base oblique. The leaves on the trunk were smaller (21.2 ± 3.4 cm^2) than those on the branches (96.4 ± 12.3 cm^2). Lateral flowers and continuous branching in this species may help this species to adopt k- or r-strategy according to the biotic features of the biotype. In addition, in terms of seedling height and collar girth, species performed comparatively well in open area (Table 1) than in shade indicating the species tendency for an adaptation to attain a superior competitive position and exploit a high light regime.

In case of *Ailanthus triphysa,* as in the case of above mentioned species, seedlings, whether growing in shade or in open area, were orthotropic. They were green and minutely tomentose. However, first few leaves in the seedlings growing in open and in shade were different in terms of leaf arrangement and number of leaflets per leaf. While the seedlings in open consisted of alternate imparipinnate leaves with 5-7 leaflets in each leaf, those growing in shade possessed sub-opposite and trifoliate leaves. These differences in seedlings were diminished as the seedlings grew and became about 20 - 24 months old when the leaves formed were alternate and paripinnate with 6-8 leaflets. Study also indicated that the seedlings growing in the open were significantly taller than those in the shade (Table 1) were. The branch formation began when the individuals were 28 to 34 months old.

Saplings growing in homegardens were studied for the branching patterns. While in the saplings growing in open area eight axes at a branch level were formed in the case of saplings growing in shade six axes were formed. Length and girth attained by these axes in a year were recorded. Among a set of axes studied, one axis showed significantly higher girth and length, both in individuals growing in the shade and in the open (Table 2). This specialized axis subsequently became erect and dominant and thus functioned as a relay axis to produce new whorl of axis in the months of March and April. Thus, *Ailanthus triphysa* with monopodial orthotropic axis, formation of three-dimensionally initially equivalent 6-8 axes at a branch level and change of one of those axis into a relay axis conform the Koriba's model

In case of *Bombax ceiba*, seedlings were orthotropic, terete with alternate leaves. First one or two leaves were simple and the subsequent five leaves were 3-foliate. When the seedlings were 2-3 month old 5-foliate digitately compound leaves began to produce. However, when the seedlings were 14-15 month old digitately compound leaves, each with 5-7 leaflets began to produce. When the seedlings were 24 to 28 months old, 5-6 branches in a whorl were formed. Later in the next growing season another tier of 5-6 branches was formed. Thus in case of *Bombax ceiba*, architecture is determined by a monopodial trunk with rhythmic growth bearing whorled branch tiers. Observation on flower bearing trees showed that the inflorescence is lateral. These are the features of Aubreville's model .

All branch modules of *Bombax ceiba* are leafy, potentially even the oldest by virtue of their indeterminate growth and lateral inflorescence. A whorl of newly produced branches in the young saplings were monitored for one year period for their length, girth near the base of the branch, and branch angle. The length of the branches was significantly more in the case of saplings growing in the open (156 ± 8 cm) than in the shade (95 ± 12 cm). Branches of the saplings growing in the shade were ascending (branch angle: $68\pm3^{\circ}$) while those growing in the open were pendulous (branch angle: $112\pm9^{\circ}$). These features indicate that the species adopt for a larger capacity for assimilation by changing its branch display angle and in turn adopt a mechanism to compromise between K- and r-strategy.

The main axis of the seedling of *Terminalia paniculata* was orthotropic with simple alternate leaves. Further monitoring of seedling height and girth indicated that values for both parameters were more in the seedlings growing in the open than in the shade (Table 1). The first branch was developed in the seedlings when they were 20-24 month old. In the two and three year old plants annually three to four branches were produced. On the other hand in saplings, five branches were produced in a year. Thus the rhythmic growth in *Terminalia paniculata* produces complex of branches. In this species, inflorescence was terminal and therefore it stimulates further onward growth from lateral buds. Properties like rhythmic growth leading to production of a complex of branches and terminal position of inflorescence not only conform *Terminalia paniculata* to Scarrone's model but also indicate the fact that this species has an ability to adapt to an intermediate phase between r- and k-strategy.

Since branches in *Terminalia paniculata* are in tiers, upper tier of branches can cast considerable amount of shade on the lower tier of branches. However, it seems that the orientation of branches in this species is contributing much not only in shaping the overall geometry of the tree crown but also represent the adaptive strategy of the tree crown for optimal light interception. Monitoring of the growth and display angle of the branch indicated that, both in the seedling growing in the shade and in the open, the branches were pendulous and bent over towards the ground. No significant difference display angle of branches of seedlings growing in the open (132 ± 9^0) and in the shade (119 ± 19^0) was observed. However, comparison of length of 1-year old branches indicated that branches of seedlings growing in the open (12.6 ± 2.1cm) were significantly longer than that of seedlings growing in the shade (6.2 ± 0.3cm). Thus in the open these species will have larger crown area in order to put out a large surface for harnessing more light energy. Monitoring of the branches in saplings also indicated that their growth patterns were similar to those described for the 1st branch produced when the seedlings were 2 year old.

3.2 Stem girth increment

It has been suggested that a certain level of pruning promotes stem growth in trees (Stein, 1955). However, the present study did not support this contention. For instance, in case of *Ailanthus triphysa* and *Artocarpus hirsutus* annual girth increment in gbh is significantly less in trees subjected to different intensity of pruning than that in the un-pruned trees ((Table 3). In case of *Bombax ceiba, Erythrina indica, Macaranga peltata and Xylia xylocarpa* the values in un-pruned trees and trees subjected 50% pruning are not significantly different. On the other hand in these species, tree subjected to 75% and 90% pruning showed significantly low values. Similarly, in case of *Bridelia crenulata*, *Grewia tiliifolia* and *Terminalia panicualta* annual stem girth increment in un-pruned trees and that in trees subjected 50% and 75% pruning are not significantly different when those subjected to 90% pruning had lower values for the parameter. All these observations indicate that as pruning severity increases the depression in growth increases. However, the effect of pruning on tree growth appeared to be declined at least at certain pruning intensities. For example, in some species (*Albizia odoratissima*, *Erythrina indica* and *Bridelia crenulata)*, two years after pruning, no significant difference in terms of mean annual increment in gbh was recorded in pruned and un-pruned trees. Similarly, mean annual increment in gbh recorded two years after pruning in trees of *Ailanthus triphysa*, *Artocarpus hirsutus* was not significantly different in un-pruned and trees subjected to 50% pruning. In case of *Bombax ceiba*, *Grewia tiliifolia*, *Terminalia paniculata*, *Macaranga peltata and Xylia xylocarpa* similar observation was made even in trees subjected to 75% pruning.

Table 3. Stem girth (gbh) increment (cm yr^{-1}) in un-pruned and pruned trees of four species. In a given species, mean values with same letter in the superscript for a given treatment are not significantly different.

Species	**Treatment***	**Pruning intensity**				
		Control	50%	75%	90%	LSD
Ailanthus triphysa	G_1-G_0	11.73^a (1.96)	7.17^b (0.21)	4.6^c (0.35)	3.35^c (0.15)	1.89
	G_2-G_0/2	10.73^a (1.15)	9.23^a (1.52)	5.93^b (0.68)	5.2^b (0.69)	2.01
Albizia odoratissima	G_1-G_0	8.87^a (1.65)	5.5^a (0.46)	4.12^a (0.25)	7.53^a (4.66)	4.68
	G_2-G_0/2	8.03^a (1.93)	11.53^a (5.97)	6.6^a (0.36)	5.8^a (2.17)	6.3
Artocarpus hirsutus	G_1-G_0	4.13^a (0.32)	3.26^b (0.26)	2.37^c (0.12)	1.03^d (0.76)	0.82
	G_2-G_0/2	4.50^a (0.62)	3.73^{ab} (0.35)	3.3^{bc} (0.46)	2.8^c (0.1)	0.81
Bombax ceiba	G_1-G_0	10.87^a (1.53)	8.2^a (0.17)	4.3^b (2.51)	3.87^b (3.15)	3.06
	G_2-G_0/2	9.37^a (0.31)	8.03^a (0.29)	7.57^a (0.85)	4.13^b (2.74)	2.73
Bridelia crenulata	G_1-G_0	5.17^{ab} (1.08)	5.80^a (0.2)	4.13^b (0.31)	2.3^c (0.46)	1.16
	G_2-G_0/2	5.12^a (0.49)	7.2^a (0.44)	6.13^a (1.04)	5.43^a (0.77)	2.37

----Cont'd----

Table 3 (Cont'd). Stem girth (gbh) increment (cm yr^{-1}) in un-pruned and pruned trees of four species. In a given species, mean values with same letter in the superscript for a given treatment are not significantly different.

Species	Treatment*	Pruning intensity				
		Control	50%	75%	90%	LSD
Erythrina indica	G_1-G_0	9.23^a (0.51)	8.7^{ab} (0.36)	7.17^b (0.25)	4.87^c (0.25)	0.68
	G_2-G_0/2	9.63^a (0.40)	9.37^a (1.36)	8.47^a (0.25)	8.23^a (0.47)	1.43
Grewia tiliifolia	G_1-G_0	6.13^a (0.91)	5.63^a (0.15)	4.37^a (1.24)	2.20^b (1.08)	1.78
	G_2-G_0/2	5.87^{ab} (0.50)	6.73^a (0.87)	4.85^b (0.17)	2.07^c (0.15)	0.97
Macaranga peltata	G_1-G_0	8.9^a (0.62)	7.37^a (1.29)	5.23^b (0.47)	4.8^b (0.7)	1.56
	G_2-G_0/2	8.4^a (0.61)	8.63^a (0.95)	7.4^{ab} (1.18)	6.87^b (0.93)	1.77
Terminalia paniculata	G_1-G_0	3.77^{ab} (0.06)	4.03^a (1.68)	3.42^b (0.79)	1.77^c (0.25)	0.36
	G_2-G_0/2	4.00^a (0.44)	3.78^a (0.31)	3.03^a (0.21)	2.11^b (0.66)	0.82
Xylia xylocarpa	G_1-G_0	3.63^a (0.40)	3.7^a (0.3)	2.23^b (0.40)	1.37^b (0.87)	1.02
	G_2-G_0/2	3.83^a (0.47)	4.60^a (0.44)	4.63^a (0.42)	1.97^b (0.11)	0.73

* G_1-G_0= Gbh measured one year after pruning - Gbh measured at the time of pruning

G_2-G_0/2= (Gbh measured two years after pruning - Gbh measured at the time of pruning)/2

3.3 Biomass production

There are several studies to indicate that following pruning the biomass production of the remaining crown increases at least in the short term. In order to determine the way in which some of the tree species in agroforestry systems of Kerala respond, the quotients (in %) between weight of biomass of foliage and small branches produced in a given period both in pruned and un-pruned trees were calculated and given in Table 4. This study indicated the fact that responses of pruning in terms of biomass production vary from species to species. For instance, in case of *Albizia odoratissima, Ailanthus triphysa, Artocarpus hirsutus, Bombax malabaricum, Bridelia crenulata* and *Xylia xylocarpa,* the ratio between quantity of foliage and small branches produced in a year in pruned and un-pruned trees was less than 100%. However, in case of *Grewia tiliifolia* the value was around 100%. On the other hand in *Erythrina indica, Macaranga peltata* and *Terminalia paniculata,* the value was significantly more than 100%. These increases could be driven by changes in photosynthetic capacity, leaf properties and crown structure (Reich *et al.*, 1993). In all the species studied, the quotient between the quantity of foliage and small branches produced in two year period in pruned and un-pruned trees was significantly more at least in one or more pruning intensities (Table 4). Exception being *Bombax ceiba*, where the value in each pruning intensity was less than 100%. In case of *Ailanthus triphysa*, and *Bridelia crenulata* the value was significantly high in the trees subjected to 50% pruning than in those subjected to higher intensity of pruning.

Table 4. Ratio (in %) between foliage and small branch production in a given period of time in the pruned trees and that in the un- pruned trees different species. Mean values with same letter in the superscript in a given treatment in the given species are not significantly different.

Species	**Treatment***	**Pruning intensity**			
		50%	**75%**	**90%**	**LSD**
Ailanthus triphysa	$\frac{BP_1 \times 100}{BUP_1}$	20.59^{a} (5.0)	30.92^{a} (10.31)	34.29^{a} (2.79)	13.60
	$\frac{BP_2 \times 100}{BUP_2}$	121.36^{a} (17.0)	109.67^{a} (16.42)	100.07^{a} (18.36)	34.52
Albizia odoratissima	$\frac{BP_1 \times 100}{BUP_1}$	57.16^{a} (1.34)	71.05^{b} (6.16)	61.41^{ab} (8.46)	12.17
	$\frac{BP_2 \times 100}{BUP_2}$	311.31^{a} (56.34)	257.25^{a} (15.16)	303.36^{a} (42.10)	82.99
Artocarpus hirsutus	$\frac{BP_1 \times 100}{BUP_1}$	58.72^{a} (3.36)	64.90^{a} (6.64)	62.09^{a} (7.46)	13.88
	$\frac{BP_2 \times 100}{BUP_2}$	118.52^{a} (8.78)	104.41^{b} (1.10)	110.63^{ab} (5.44)	11.98
Bombax ceiba	$\frac{BP_1 \times 100}{BUP_1}$	28.13^{a} (4.51)	32.27^{a} (7.46)	31.42^{a} (1.72)	10.25
	$\frac{BP_2 \times 100}{BUP_2}$	85.45^{a} (7.94)	82.99^{a} (5.75)	73.67^{a} (1.83)	11.51
Bridelia crenulata	$\frac{BP_1 \times 100}{BUP_1}$	64.60^{a} (6.67)	76.31^{ab} (9.44)	83.38^{b} (2.61)	13.67
	$\frac{BP_2 \times 100}{BUP_2}$	151.38^{a} (25.63)	106.61^{a} (20.85)	106.95^{a} (25.29)	47.99
Erythrina indica	$\frac{BP_1 \times 100}{BUP_1}$	125.27^{a} (6.99)	119.45^{ab} (8.45)	109.08^{a} (8.76)	16.19
	$\frac{BP_2 \times 100}{BUP_2}$	207.75^{a} (17.00)	189.99^{a} (4.82)	187.95 (2.56)	20.59
Grewia tiliifolia	$\frac{BP_1 \times 100}{BUP_1}$	107.36^{a} (11.70)	107.31^{a} (0.89)	101.45^{a} (4.67)	5.82
	$\frac{BP_2 \times 100}{BUP_2}$	170.52^{a} (6.05)	150.71^{b} (2.47)	175.83^{a} (4.63)	9.24

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Table 4. Ratio (in %) between foliage and small branch production in a given period of time in the pruned trees and that in the un- pruned trees different species. Mean values with same letter in the superscript in a given treatment in the given species are not significantly different.

Species	Treatment*	Pruning intensity			
		50%	75%	90%	LSD
Macaranga peltata	$\frac{BP_1 \times 100}{BUP_1}$	161.91^{a} (25.38)	144.81^{a} (6.10)	135.34^{a} (0.75)	30.12
	$\frac{BP_2 \times 100}{BUP_2}$	228.63^{a} (13.31)	188.70^{b} (8.61)	188.85^{b} (12.95)	23.61
Terminalia paniculata	$\frac{BP_1 \times 100}{BUP_1}$	105.59^{a} (3.95)	118.28^{b} (3.57)	118.69^{b} (7.72)	10.83
	$\frac{BP_2 \times 100}{BUP_2}$	157.52^{a} (7.76)	133.49^{b} (6.82)	127.67^{b} (12.21)	18.45
Xylia xylocarpa	$\frac{BP_1 \times 100}{BUP_1}$	66.65^{a} (2.64)	93.71^{a} (10.98)	69.30^{a} (29.53)	36.47
	$\frac{BP_2 \times 100}{BUP_2}$	166.70^{a} (8.39)	134.44^{b} (12.89)	126.63^{b} (12.94)	23.19

* $\frac{BP_1 \times 100}{BUP_1} = \frac{\text{Quantity of foliage and small branches produced in one year period after pruning} \times 100}{\text{Quantity of foliage and small branches produced in one year period in un-pruned trees}}$

$\frac{BP_2 \times 100}{BUP_2} = \frac{\text{Quantity of foliage and small branches produced in two year period after pruning} \times 100}{\text{Quantity of foliage and small branches produced in two year period in un-pruned trees}}$

3.4 Undercrop experiment

A study was conducted to analyse the vegetative growth performance and rhizome yield patterns in ginger, turmeric and kacholam planted under the canopy of different tree species, which were subjected to different pruning intensity. Mean tiller height of ginger was between 29.6cm and to 63.3cm when the number of tillers per clump ranged from 14 to 26. Total leaf area per clump was between 4,485 cm^2 and 11,152 cm^2 while the ginger rhizome yield (dry) at final harvest was between 2.9 kg/10m^2 to 5.7 kg /10m^2 (Table 5). Mean values obtained for a given parameter for ginger growing under trees of a species subjected to different pruning intensities were compared using LSD test. Vegetative characters of ginger such as tiller height, number of tillers per clump and number and area of foliage per clump did not vary significantly or in consistence under some trees subjected to different intensity of pruning. These species include *Ailanthus triphysa, Albizia odoratissima, Bombax ceiba, Bridelia crenulata, Macaranga peltata* and *Xylia xylocarpa.* However, the ginger yield was significantly more under un-pruned trees than under pruned trees of *Albizia odoratissima, Bridelia crenulata, Macaranga peltata and Xylia xylocarpa,* when no significant difference in the yield under pruned and un-pruned trees of *Ailanthus triphysa* and *Bombax ceiba* was observed. On the other hand tiller height, number of tillers per clump and rhizome yield were significantly more under the un-pruned trees of

Erythrina indica, *Grewia tiliifolia* and *Terminalia paniculata* than under trees of subjected to different intensities of pruning. The study also indicated that the leaf area per clump of ginger growing under trees subjected to different intensities of pruning did not vary significantly with respect to any tree species considered.

Table 5. Tiller height, number of tillers/clump, total number of leaves, total leaf area and rhizome yield of ginger under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Parameter	Intensity of branch pruning				
	0%	50%	75%	90%	LSD
Ailanthus triphysa					
Mean tiller height (cm)	57.0 ±6.3	45.6±6.4	51.0±10.0	46.1±3.7	11.2
Number of tillers /clump	22.0±3.6	18.7±2.5	20.4±3.6	21.7±4.2	5.7
Number of leaves /clump	87.3±11.6	75.3±7.1	79.3±21.4	73.7±8.7	21.5
Total leaf area/clump (cm^2)	7513±264	6741±385	7227±222	7596±569	617
Rhizome yield (Kg /$10m^2$)	4.8±0.4	3.9±0.2	4.2±0.5	3.8±0.2	0.6
Albizia odoratissima					
Mean tiller height (cm)	56.0±2.7	49.6±1.5	40.9±4.9	47.9±4.3	5.8
Number of tillers /clump	22.3±2.6	19.0±0.7	22.0±1.6	21.1±1.7	2.8
Number of leaves /clump	80.0±3.5	73.0±4.0	63.3±4.5	70.3±5.1	6.9
Total leaf area/clump (cm^2)	5280±281	5212±386	5293±348	5253±273	522
Rhizome yield (Kg /$10m^2$)	5.2±0.2	3.8±0.2	4.1±0.4	3.8±0.3	0.4
Artocarpus hirsutus					
Mean tiller height (cm)	47.6±4.8	36.9±2.5	44.3±5.6	31.9±3.3	6.8
Number of tillers /clump	23.1±3.7	16.7±3.1	21.6±0.8	14.1±1.4	4.1
Number of leaves /clump	115.7±6.5	85.3±7.0)	93.3±8.1	83.7±5.5	11.0
Total leaf area/clump (cm^2)	11055±1060	7359±193	10043±842	7703±668	1222
Rhizome yield (Kg /$10m^2$)	2.9±0.6	3.7±0.1	4.4±0.2	3.6±0.1	0.5
Bombax ceiba					
Mean tiller height (cm)	35.3±6.9	40.0±3.9	37.6±3.8	29.6±1.9	7.2
Number of tillers /clump	19.2±2.1	15.9±1.6	19.2±1.5	16.3±2.0	2.9
Number of leaves /clump	63.8±4.7	60.0±10.0	47.1±4.2	59.2±6.4	10.8
Total leaf area/clump (cm^2)	5542±131	5103±507	4485±822	5149±288	816
Rhizome yield (Kg /$10m^2$)	4.7±0.5	4.0±0.3	3.9±0.6	4.1±0.3	0.7

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Table 5 (cont'd). Tiller height, number of tillers/clump, total number of leaves, total leaf area and rhizome yield of ginger under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Parameter	Intensity of branch pruning				
	0%	50%	75%	90%	LSD
Bridelia crenulata					
Mean tiller height (cm)	54.2±6.7	41.9±3.1	49.4±4.4	36.8±2.9	7.3
Number of tillers /clump	22.3±1.6	14.2±2.1	23.1±1.5	14.8±0.9	2.5
Number of leaves /clump	96.7±6.8	78.7±3.1	87.1±4.4	73.3±1.7	7.1
Total leaf area/clump (cm^2)	7523±1970	6747±739	8266±1191	6403±443	1191
Rhizome yield (Kg /10m^2)	5.7±0.5	4.6±0.9	4.0±0.8	4.5±0.5	1.1
Erythrina indica					
Mean tiller height (cm)	61.3±1.5	50.5±3.6	49.8±5.7	48.6±3.2	6.1
Number of tillers /clump	26.1±3.6	19.6±2.6	21.2±4.8	18.4±2.0	5.5
Number of leaves /clump	87.3±7.6	85.3±8.3	78.7±15.0	74.0±4.0	15.4
Total leaf area/clump (cm^2)	7679±45	7300±572	7655±1856	6919±612	1635
Rhizome yield (Kg /10m^2)	5.1±0.7	3.9±0.2	4.0±0.3	4.0±0.2	0.7
Grewia tiliifolia					
Mean tiller height (cm)	63.3±3.3	50.6±3.1	46.4±4.7	49.9±3.6	6.0
Number of tillers /clump	25.0±2.2	18.7±2.0	19.1±5.3	19.5±1.8	5.1
Number of leaves /clump	102.2±9.7	87.7±4.0	89.0±7.0	97.7±12.5	14.2
Total leaf area/clump (cm^2)	9478±893	8062±294	9506±1750	9408±1482	1989.5
Rhizome yield (Kg /10m^2)	5.7±0.4	4.0±0.2	4.4±0.3	3.9±0.1	0.4
Macaranga peltata					
Mean tiller height (cm)	43.2±4.7	39.7±2.0	40.0±5.0	35.6±1.6	5.9
Number of tillers /clump	22.4±5.1	14.4±2.7	22.3±1.5	16.4±1.1	4.9
Number of leaves /clump	76.0±6.6	70.7±3.8	92.3±2.1	57.7±5.7	7.8
Total leaf area/clump (cm^2)	7377±1566	7320±432	8784±1819	5514±874	2079.8
Rhizome yield (Kg /10m^2)	5.1±0.6	4.2±0.2	4.0±0.2	4.2±0.2	0.6
Terminalia paniculata					
Mean tiller height (cm)	59.6±2.2	53.4±3.7	51.0±3.4	52.6±3.8	5.4
Number of tillers /clump	25.3±1.3	18.5±1.7	21.1±3.3	23.7±2.2	3.6
Number of leaves /clump	97.0±9.5	86.0±4.6	85.7±9.1	96.0±5.3	12.0
Total leaf area/clump (cm^2)	11152±1178	8265±355	8928±1404	9896±717	1605
Rhizome yield (Kg /10m^2)	5.1±0.7	4.1±0.3	4.1±0.1	4.1±0.4	0.7

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Table 5 (cont'd). Tiller height, number of tillers/clump, total number of leaves, total leaf area and rhizome yield of ginger under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Parameter	Intensity of branch pruning				
	0%	50%	75%	90%	LSD
Xylia xylocarpa					
Mean tiller height (cm)	49.0±2.9	37.9±4.5	47.0±3.4	37.6±7.8	8.1
Number of tillers /clump	23.1±3.1	15.4±4.3	22.8±1.7	14.1±4.0	5.5
Number of leaves /clump	92.3±8.5	73.3±16.2	99.3±22.0	58.0±6.1	23.5
Total leaf area/clump (cm^2)	9329±2209	7800±2195	9609±2055	6072±1550	3244
Rhizome yield (Kg /$10m^2$)	5.4±0.6	3.8±0.4	4.5±0.1	3.5±0.3	0.6

Turmeric planted under pruned and un-pruned trees of different species were monitored for their vegetative growth and rhizome yield after harvest. Mean tiller height of turmeric ranged from 16.6 cm to 38.4 cm while number of tillers per clumps ranged from 4 to 6.8. Total leaf area measured 100 to 120 days after planting was from 9916 cm^2 to 17887 cm^2/clump. The turmeric yield (dry) at final harvest ranged from 9.1 kg/$10m^2$ to 17.4kg/$10m^2$ (Table 6). Turmeric did not show significant difference in terms of its vegetative growth and yield when cultivated under trees of *Erythrina indica,* which were subjected to different intensity of pruning. Despite the fact that some of the vegetative growth parameters had higher values in the crops grown under un-pruned trees, crop yield under pruned and un-pruned trees of *Albizia odoratissima* and *Bombax ceiba* was not significantly different. However, turmeric cultivated under species like *Ailanthus triphysa*, *Artocarpus hirsutus*, *Bridelia crenulata*, *Grewia tiliifolia*, *Terminalia paniculata* and *Xylia xylocarpa* produced lesser quantity of rhizome under pruned trees than under un-pruned trees. Similarly, number of tillers per clump was also more under un-pruned trees of *Artocarpus heterophyllus*, *Bridelia crenulata, Terminalia panicualta* and *Xylia xylocarpa.* In case of *Macaranga peltata*, turmeric rhizome yield was more under un-pruned and trees subjected to 25% pruning.

In case of Kacholam, only leaf per clump 100 to 120 days after planting and rhizome yield after final harvest was estimated. Mean leaf area ranged from 102.7 m^2 to 256.7m^2 per clump while the rhizome yield ranged from 4.3 kg/$10m^2$ to 7.7.kg/$10m^2$. Different trends were observed in terms of leaf area and yield (Table 7). For instance, both the leaf area and yield of kacholam were significantly more under un-pruned trees of *Ailanthus triphysa* than under pruned trees of the same species.

Table 6. Tiller height, number of tillers/clump, total number of leaves, total leaf area and rhizome yield of turmeric under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Parameter	Intensity of branch pruning				
	0%	50%	75%	90%	LSD
Ailanthus triphysa					
Mean tiller height (cm)	27.1±1.6	26.3±2.1	24.1±3.2	25.1±2.0	3.7
Number of tillers /clump	5.0±0.4	4.7±0.5	4.5±0.7	4.5±0.4	0.8
Number of leaves /clump	55.3±8.3	42.7±3.1	49.7±6.0	48.3±4.7	9.4
Total leaf area/clump (cm^2)	16547±2216	11220±722	13342±1889	12410±1199	2594
Rhizome yield (Kg /10m^2)	15.9±1.2	9.5±1.0	11.0±1.4	9.1±0.7	1.8
Albizia odoratissima					
Mean tiller height (cm)	27.5±0.9	25.1±1.9	23.1±3.8	24.4±2.7	4.1
Number of tillers /clump	6.2±1.2	4.6±0.9	4.5±0.7	4.4±0.2	1.4
Number of leaves /clump	64.7±7.0	46.7±3.1	42.0±1.7	50.0±7.2	8.6
Total leaf area/clump (cm^2)	14033±1182	11290±1055	11273±870	12093±1851	2077
Rhizome yield (Kg /10m^2)	12.8±0.9	10.9±1.2	11.3±1.0	10.2±2.2	2.2
Artocarpus hirsutus					
Mean tiller height (cm)	41.9±4.6	29.7±3.2	32.3±2.8	27.6±0.7	5.1
Number of tillers /clump	6.4±0.8	4.8±0.5	5.1±0.4	4.9±0.6	0.9
Number of leaves /clump	63.3±5.0	54.0±2.0	53.3±4.6	50.0±2.0	5.9
Total leaf area/clump (cm^2)	16527±620	13440±2222	15187±1106	13740±282	2067
Rhizome yield (Kg /10m^2)	17.4±2.4	12.2±1.4	12.1±0.7	10.1±0.5	2.3
Bombax ceiba					
Mean tiller height (cm)	27.8±1.0	21.7±1.0	22.7±2.7	20.2±1.4	2.7
Number of tillers /clump	5.8±1.0	4.7±0.3	4.9±0.6	4.3±0.6	1.0
Number of leaves /clump	54.7±3.1	48.7±3.1	50.7±5.0	44.0±2.6	5.7
Total leaf area/clump (cm^2)	12493±766	10863±811	12237±1104	11657±825	1424
Rhizome yield (Kg /10m^2)	12.6±1.1	10.9±0.6	11.5±1.1	12.1±1.2	1.7
Bridelia crenulata					
Mean tiller height (cm)	38.4±1.4	26.0±1.6	32.3±1.8	25.8±1.5	2.5
Number of tillers /clump	6.8±0.5	5.0±0.4	4.4±0.2	4.0±0.4	0.6
Number of leaves /clump	56.0±7.2	47.3±5.7	53.7±2.5	42.7±2.1	7.8
Total leaf area/clump (cm^2)	16633±961	11615±1616	14747±428	10383±556	1611
Rhizome yield (Kg /10m^2)	16.2±1.3	12.4±0.6	11.9±1.5	11.2±1.3	2.0

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Table 6 (cont'd). Tiller height, number of tillers/clump, total number of leaves, total leaf area and rhizome yield of turmeric under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Parameter	Intensity of branch pruning				
	0%	50%	75%	90%	LSD
Erythrina indica					
Mean tiller height (cm)	29.8±2.7	28.9±5.1	28.4±1.1	29.8±2.0	5.0
Number of tillers /clump	5.1±0.4	4.3±0.3	5.1±0.2	4.5±0.2	0.5
Number of leaves /clump	42.7±3.1	38.0±3.6	44.7±1.5	43.0±3.0	4.7
Total leaf area/clump (cm^2)	12520±1091	9918±1576	11392±1077	11175704	1853
Rhizome yield (Kg /10m^2)	13.0±1.6	10.6±0.8	10.9±1.3	11.7±1.3	2.1
Grewia tiliifolia					
Mean tiller height (cm)	33.4±1.2	31.9±2.3	28.5±2.1	31.1±1.7	3.0
Number of tillers /clump	6.2±0.4	5.3±0.1	5.2±0.4	4.6±0.3	0.5
Number of leaves /clump	60.7±3.1	50.7±4.7	54.7±1.2	49.0±1.0	4.7
Total leaf area/clump (cm^2)	15833±1365	13468±1952	14113±879	11690±1097	2221
Rhizome yield (Kg /10m^2)	16.3±0.5	10.9±1.5	13.0±1.2	10.7±1.9	2.2
Macaranga peltata					
Mean tiller height (cm)	28.1±1.2	27.6±0.9	31.5±1.2	24.2±3.6	3.3
Number of tillers /clump	6.5±0.7	5.2±0.3	5.0±0.2	4.2±0.4	0.7
Number of leaves /clump	60.0±4.0	57.7±2.1	54.7±5.1	51.3±2.1	5.7
Total leaf area/clump (cm^2)	17887±1248	15175±1757	14353±1274	11938±1546	2362
Rhizome yield (Kg /10m^2)	13.6±1.1	11.7±1.7	11.4±1.0	11.5±0.9	1.9
Terminalia paniculata					
Mean tiller height (cm)	32.3±3.9	24.8±3.0	31.5±1.1	28.4±0.9	4.1
Number of tillers /clump	6.2±0.4	5.2±0.3	5.5±0.1	4.3±0.4	0.5
Number of leaves /clump	58.7±5.0	52.0±2.0	43.7±3.8	50.7±1.5	5.4
Total leaf area/clump (cm^2)	13727±794	13063±565	11891±1376	12639±945	1552
Rhizome yield (Kg /10m^2)	16.6±0.9	12.1±0.8	12.8±2.2	10.5±0.8	2.1
Xylia xylocarpa					
Mean tiller height (cm)	16.6±0.9	31.4±4.1	33.5±3.1	26.9±2.5	4.7
Number of tillers /clump	5.8±0.4	5.2±0.4	4.9±0.2	4.3±0.2	0.5
Number of leaves /clump	62.7±4.2	45.0±3.0	50.7±1.2	44.7±1.5	4.4
Total leaf area/clump (cm^2)	16920±453	12338±330	13571±374	10255±1201	1106
Rhizome yield (Kg /10m^2)	16.4±1.7	13.5±0.9	12.9±1.8	10.7±0.5	2.2

Yield of kacholam was more under un-pruned trees of *Artocarpus hirsutus* than under pruned trees when no such clear trend was observed for leaf area. Among different types of treatments, 75% pruning of trees of *Macaranga peltata, Terminalia paniculata, Xylia xylocarpa* and *Grewia tiliifolia* seemed to favour the growth of kacholam as an under crop. This is clear from the fact that leaf area and yield of kacholam were significantly more under trees subjected to 75% pruning than under either un-pruned trees or trees subjected to other intensities of pruning. Similarly, 90% pruning of *Bombax ceiba* and 75% and 90% pruning of *Bridelia crenulata* and *Erythrina indica* favour the growth and yield of kacholam.

Table 7. Total leaf area and rhizome yield of Kacholam under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Species	Intensity of branch pruning				LSD
	0%	50%	75%	90%	
Ailanthus triphysa					
Total leaf area/clump (cm^2)	256.7±25.7	188.7±20.8	203.3±18.6	203.3±20.2	34.5
Rhizome yield ($Kg/10m^2$)	7.7±0.4	4.3±0.8	5.6±0.8	4.5±0.5	1.0
Albizia odoratissima					
Total leaf area/clump (cm^2)	200.0±20.0	166.7±30.6	182.0±27.1	163.3±73.7	69.5
Rhizome yield ($Kg/10m^2$)	5.2±0.5	4.7±0.4	5.3±0.4	5.60.4	0.7
Artocarpus hirsutus					
Total leaf area/clump (cm^2)	145.3±10.0	120.0±30.0	161.3±32.6	188.0±28.8	43.2
Rhizome yield ($Kg/10m^2$)	7.0±0.3	5.2±0.2	6.0±0.1	5.1±0.3	0.4
Bridelia crenulata					
Total leaf area/clump (cm^2)	113.3±27.0	124.7±24.2	172.0±20.9	210.0±36.6	18.0
Rhizome yield ($Kg/10m^2$)	4.9±0.4	4.5±0.3	4.8±0.4	5.7±0.2	0.5
Bombax ceiba					
Total leaf area/clump (cm^2)	110.0±15.0	124.7±26.9	155.3±31.0	177.3±24.0	40.0
Rhizome yield ($Kg/10m^2$)	4.9±0.6	4.7±0.2	5.7±0.7	5.2±0.4	0.8
Erythrina indica					
Total leaf area/clump (cm^2)	105.0±22.6	118.0±35.2	165.3±8.3	160.3±15.5	36.4
Rhizome yield ($Kg/10m^2$)	5.3±0.7	4.9±0.3	4.8±0.6	4.9±0.6	0.9
Grewia tiliifolia					
Total leaf area/clump (cm^2)	114.7±27.3	120.7±17.2	177.3±38.4	144.0±30.2	47.0
Rhizome yield ($Kg/10m^2$)	4.8±0.9	4.7±0.6	5.7±0.4	4.7±0.2	0.9

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Table 7 (Cont'd). Total leaf area and rhizome yield of Kacholam under trees of different species subjected to different intensity of pruning. Values are mean ±SE. N=3.

Species	Intensity of branch pruning				LSD
	0%	50%	75%	90%	
Macaranga peltata					
Total leaf area/clump (cm^2)	102.7±8.1	104.0±19.1	188.3±34.1	145.3±6.4	32.5
Rhizome yield ($Kg/10m^2$)	5.0±0.6	4.9±0.2	6.0±0.4	5.5±0.3	0.6
Terminalia paniculata					
Total leaf area/clump (cm^2)	119.3±19.4	112.0±24.0	192.0±14.0	142.7±16.7	30.3
Rhizome yield ($Kg/10m^2$)	4.7±0.6	4.4±0.2	6.0±0.2	5.4±0.2	0.5
Xylia xylocarpa					
Total leaf area/clump (cm^2)	108.7±26.6	125.3±30.0	200.0±21.2	152.3±28.0	42.8
Rhizome yield ($Kg/10m^2$)	4.5±0.2	4.4±0.2	6.0±0.3	5.5±0.3	0.4

Parameters like total leaf area per clump and rhizome yield of each crop species were correlated with the PAR available below the canopy of trees of each species (Table 8). The correlation coefficient between PAR and Leaf area of ginger and PAR and crop yield of ginger ranged from 0.021 to 0. 545 and from 0.527 to 0.793 respectively. In the case of turmeric, the values obtained for PAR and Leaf area and PAR and crop yield were between 0.187 and 0.836 and between 0.086 to 0.877 respectively. Similarly, the correlation coefficient between PAR and Leaf area of Kacholam ranged from 0.106 to 0.776 while that between PAR and crop yield was between 0.123 to 0.855. The poor correlation between PAR and leaf area or crop yield indicate that the change in light intensity alone will not determine the growth and yield of crops growing under trees which were subjected to different intensity of pruning. Soil physical and chemical characteristics, present and previous land management practices could be few other factors, which might have the bearing on the growth and yield of the under crops.

Table 8. Correlation between PAR and total leaf area and crop yield of ginger, turmeric and kacholam growing under trees subjected to different intensity of pruning

Species	Ginger		Turmeric		Kacholam	
	Total leaf area	Crop yield	Total leaf area	Crop yield	Total leaf area	Crop yield
Ailanthus triphysa	0.143	-0.543	-0.510	-0.680	0.776	0.855
Albizia odoratissima	-0.021	-0.649	-0.446	-0.615	-0.138	-0.065
Artocarpus hirsutus	0.545	0.626	-0.526	-0.877	0.106	-0.340
Bombax ceiba	-0.347	-0.566	-0.254	-0.086	0.663	0.471
Bridelia crenulata	-0.184	-0.630	-0.739	-0.812	0.751	0.500
Erythrina indica	-0.276	-0.602	-0.187	-0.240	0.600	-0.123
Grewia tiliifolia	-0.040	-0.793	-0.613	-0.525	0.455	0.324
Macaranga peltata	-0.218	-0.542	-0.778	-0.487	0.640	0.503
Terminalia paniculata	-0.093	-0.527	-0.549	-0.780	0.521	0.552
Xylia xylocarpa	-0.354	-0.732	-0.836	-0.778	0.590	0.639

4. Conclusions

Homegardens of Kerala have been considered as one of the landuse systems with rich species diversity (Babu *et.al.*, 1992; Sankar and Chandrashekara 1997; Kumar *et.al.*, 1994). Ten tree species studied here represented six architectural models. Thus it may be possible to predict that species diverse homegardens also diverse in terms of plants representing diverse plant architectural models. In this context, further studies may be undertaken to analyse the architectural models of all plant components in the homegardens systems.

The present study also enabled to identify the relevance of tree growth and architectural analysis for establishing and managing an agrisilvicultural system in which more shade demanding components are used. Properties like formation of straight bole due orthotropy, and erect and short branches under moderate light conditions in species like *Artocarpus hirsutus*, *Albizia odoratissima*, *Terminalia paniculata* and *Xylia xylocarpa etc.* may be useful to straight timbers of these species. Many species studied here also have the plasticity in terms of their branch display angle and branch length in relation to available light. Thus these species have the tendency to adopt for optimizing light resource use in multi-species landuse systems.

Based on the analysis of effects of green pruning on foliage and branch production and on stem girth increment patterns certain strategies for thee sustainable pruning in ten tree species can be suggested. In case of *Erythrina indica*, *Macaranga peltata* and *Terminalia panicualta annual* foliage and branch production in pruned trees was significantly more than that of the un-pruned trees of the given species. However, no significant difference in the annual stem girth increment in un-pruned trees and trees subjected to 50% pruning was noticed. Thus, the appropriate pruning strategy for the trees of above mentioned species would be to o remove annually 50% of green crown length. In these species, estimation of annual stem girth increment two years after pruning indicated that the values obtained for trees subjected up to 75% pruning were not significantly different. Thus it may be recommended that if the trees were subjected to 75% pruning, the next pruning should be done only after two years, allowing trees to recover from previous pruning events. In case of species like *Ailanthus triphysa*, *Albizia odoratissima*, *Artocarpus hirsutus*, *Bridelia crenulata*, *Grewia tiliifolia* and *Xylia xylocarpa*, only two years after pruning, the quantity of foliage and branch produced annually in trees subjected to one or more pruning intensities was either equal or significantly more than that in the un-pruned trees. Thus once in two years, pruning trees of *Ailanthus triphysa*, *Albizia odoratissima* and *Grewia tiliifolia* to remove 50% green crown length is recommended. Similarly, the harvest of 75% and 90% green crown length once in two years in *Xylia xylocarpa* and *Bridelia crenulata* respectively may be appropriate. In the case of *Bombax ceiba*, foliage production in pruned trees was significantly less than in un-pruned trees even two years after pruning. Thus green pruning once in two is not advisable for this species.

Quantification of crop yield of ginger and turmeric indicated that the yield is generally more under un-pruned trees than under pruned trees. On thee other hand, crop yield of kacholam is significantly more under trees subjected to 75% pruning than under un-pruned trees of species like *Bridelia crenulata*, *Bombax ceiba*, *Erythrina indica*, *Grewia tiliifolia*, *Macaranga peltata*, *Terminalia panicualta* and *Xylia xylocarpa*. However, poor correlation between PAR available below the canopy of trees of each species and yield of any given crop recorded. Thus future studies could focus on analysing the changes induced by pruning which would have the bearing on reducing the yield of crops growing under trees.

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Appendix 1. Utilisation classes and important uses of trees selected for study in the lowland and midland agroclimatic zones in Thrissur District, Kerala (based on Krishnankutty, 1990 and Kumar *et.al.*, 1994).

Species	Family	Common Malayalam name	Utilisation 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
Bombax ceiba L.	Bombacaceae	Mullilavu	T4	9
Bridelia crenulata Roxb.	Euphorbiaceae	Mulluvenga	T2	1,3,4,5
Erythrina indica Lamk.	Fabaceae	Mullumurikku	M4	3,5,6,9
Grewia tiliifolia Vahl	Tiliaceae	Chadachi	T2	1,3,5
Macaranga peltata (Roxb.) M.-A.	Euphorbiaceae	Vatta	M4	1,3,4,5
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, Tannin

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)