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Effects of pruning on radial growth and biomass increment of trees growing in homegardens of Kerala, India

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Abstract To evaluate the effects of pruning on stem radial growth increment and leaf and twig biomass production, an experiment with four pruning intensities (0, 50, 75 and 90%) on ten locally important tree species (*Ailanthus triphysa*, *Albizia odoratissima*, *Artocarpus hirsutus*, *Bombax malabarica*, *Bridelia crenulata, Erythrina indica, Grewia tiliifolia, Macaranga peltata, Terminalia paniculata* and *Xylia xylocarpa*), was carried out. The results did not support the contention that a certain level of pruning promotes stem growth in trees. Instead, all species have a level of pruning that reduces annual increment in stem diameter. In *Ailanthus triphysa* and *Artocarpus hirsutus* trees subjected to different pruning intensities showed a decline in the annual increment in stem diameter while in other species diameter increment reduced when the pruning intensity was 75% and 90%. Response to pruning in terms of biomass production also varied from species to species. In *Erythrina indica, Macaranga peltata* and *Terminalia paniculata* annual foliage and branch production in pruned trees was significantly more than that of the un-pruned trees. However, in *Ailanthus triphysa*, *Albizia odoratissima*, *Artocarpus hirsutus*, *Bridelia crenulata*, *Grewia tiliifolia* and *Xylia xylocarpa* pruned trees produced comparatively more amount of foliage and branches produced annually than that by the un-pruned trees when the pruning was carried out once in 2 years. Based on these observations it is recommended that trees of *Erythrina indica*, *Macaranga peltata* and *Terminalia paniculata* may be pruned at 50% level annually while the trees of *Ailanthus triphysa*, *Albizia odoratissima*, *Artocarpus hirsutus*, *Bridelia crenulata*, *Grewia tiliifolia* and *Xylia xylocarpa* may be pruned at the same pruning intensity once in 2 years.

Keywords Annual increment in stem diameter · Green pruning · Foliage and branch production · Tree management

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Introduction

Homegarden agroforestry characterized by intensive integration of trees and shrubs with food crops and often animals is a predominant landuse system in Kerala (Kumar and Nair 2004). About 5.4 million operational holdings with an average size of 0.43 ha are under this landuse practice (KSLUB 1995). Plants belonging to different functional groups like timber, fruit, spices, plantation crops, annual crops and medicinal plants abound in the homegardens of Kerala (Kumar et al. 1994). A unique feature of the homegarden, however, is the high total density of perennial plants often ranging from 1716 to 4345 individuals ha^{-1}. The estimated ratio between the area of plant canopy and the corresponding land area ranges from 139% to 477% indicating a high degree of overlapping among the different components (Sankar and Chandrashekara 2002). In such multi-species multi-layered landuse systems, management of trees is paramount to optimize the productivity of not only the trees but also the understorey crops. It will also ensure optimum utilization of the resources (Chandrashekara 1997). In addition, tree management alters the crown shape of trees as well as wood quality (Pinkard and Beadle 2000). Several workers have emphasized the need of tree canopy management in different agroforestry systems (Kang et al. 1981; Muschler et al. 1993; Bandara et al.1999; Kishan Kumar and Tewari 2001; Thakur 2002). Whether the canopy management is through live branch pruning, coppicing or pollarding, it has been cautioned that such prescription/s should be conservative and must not affect growth (Langstrom and Hellqvist 1991). It may be mentioned that in the homegardens of Kerala, tree branch pruning is a common management strategy to obtain green manure, forage, fodder and fuel wood (Sankar and Chandrashekara 1997). However, the intensity and frequency of branch pruning are based on farmer's discretion/convenience rather than any scientific principles. In addition, impact of pruning on trees of other agroforestry systems are well documented (Duguma et al. 1988; Erdmann et al. 1993), while such studies are lacking in homegardens. In this context, a study to determine the impacts of different intensity and frequency of pruning on the vigour and biomass production by a set of tree species in the homegardens of Kerala over the years, was undertaken.

Materials and methods

Study area and climate

The field study was conducted in the lowland (up to 7.5 m above MSL) and midland (7.5–75 m MSL) zones of Thrissur District (between latitudes 9°49′ N and 11°49′ N and 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 3220 mm. Much (75.6%) of the rainfall occurs during the south-west monsoon from mid-May to August end. Mean maximum temperature ranges from 24.8°C (July) to 31.4°C (March) while the minimum temperature varies from 21.1°C (January) to 23.1°C (April). The average annual relative humidity is around 70%. Soils are acidic (pH 5.1–5.8), sandy to sandy loam in homesteads of lowland zone while gravelly loam to gravelly clay loam in the homesteads of midland zone. In general, soils in both zones are poor in total nitrogen (0.12–0.18%), available phosphorous (14–18 mg g^{-1}), exchangeable potassium (35.12–43.18 mg g^{-1}) and organic carbon (0.76–2.09%).

Selection of homegardens and tree species

Four meetings participated by around 80 farmers from the villages of lowland and midland zones were conducted. The help of students and teachers of two local primary schools were also taken for inviting the farmers and organizing the meetings. The purpose of the meeting included (a) preparation of a list of tree species growing in the homegardens of the two agroclimatic zones, (b) prioritization of tree species for undertaking the pruning experiments, and (c) identification homegardens where the pririotised tree species are available. Thus during the meetings a list of tree species growing in homegardens was prepared and also ten species namely *Ailanthus triphysa* (Dennst.) Alston., *Albizia odoratissima* (L.f.) Benth., *Artocarpus hirsutus* Lamk., *Bombax malabarica* L., *Bridelia crenulata* Roxb., *Erythrina indica* Lamk., *Grewia tiliifolia Vahl.*, *Macaranga peltata (Roxb.)M.-A.*, *Terminalia paniculata* Roth, and *Xylia xylocarpa* (Roxb.) Taub., were selected for the pruning experiments. Subsequently with the help of participant farmers, school children and teachers and by conducting field visits, 226 homegardens where individuals of one or more above mentioned tree species are growing were selected. Thus the selection of homegardens was purposive with main emphasis on availability of trees of species selected for the study.

Pruning experiments

Pruning intensity and frequency

In the selected 226 homegardens, 76–184 trees of each species were identified. For each species, 24 trees, size ranging from 10.1 cm to 14.5 cm diameter at breast height (dbh: measured at 1.37 m from the ground) were selected and tagged with numbered aluminium label. Tags were fixed above 1.37 m level to avoid interference with dbh measurement. The line of dbh measurement was marked with paint. Out of 24 trees of a given species, six each were subjected to the following four pruning intensities;

- Control (No pruning)
- 50% pruning (pruning 50% of the total crown length from the crown base)
- 75% pruning (pruning 75% of the total crown length from the crown base)
- 90% pruning (pruning 90% of the total crown length from the crown base)

Six trees of a given species subjected to a given intensity of pruning were further divided into two sets of three trees each. While the first set of trees were pruned a year after the first pruning, the second set of trees were pruned 2 years after the first pruning. Thus the quantity of foliage and small branch produced in 1 year and 2 years after the first pruning were estimated.

Annual increment in tree diameter

Diameter at breast height of un-pruned trees of each species was measured annually and differences in values between two successive years gave the annual increment in radial growth. In case of trees, which were pruned a year after the first pruning, the difference in the dbh values obtained at the time of first and second pruning gave the annual increment in radial growth. Whereas in trees, which were pruned 2 years after the first pruning, the difference in dbh values obtained at the time of first and second pruning divided by two gave the annual increment in radial growth. One-way ANOVA was adopted to compare the mean values obtained for trees of given species subjected to different intensity of pruning and LSD test was used to determine whether significant difference in the values were there or not.

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 selected randomly and 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., 1 year and 2 years after first pruning. The six control trees from each species were further subdivided into two sets of three each. Total crown length of each tree was divided into three equal parts, and in each part, the first order branches were enumerated and half the total number of branches were labeled as before. These branches in one set of trees were monitored at monthly intervals and the new small branches and foliage produced in 1-year period were labeled. Similarly, labeled branches in another set of trees were monitored at monthly intervals and new small branches and foliage produced in the 2-year period were tagged. 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:

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

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

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.

Results and discussion

Annual increment in stem diameter

It has been suggested that a certain level of pruning promotes stem growth in trees (Stein 1955). However, the present results did not support such a contention. Instead, the study showed that in *Ailanthus triphysa* and *Artocarpus hirsutus* annual increment in radial growth was significantly lower in the trees subjected to pruning than that of the un-pruned trees, while the remaining eight species showed variation with respect to the level of pruning that reduces the radial increment in stem (Table 1). For instance, in *Bombax malabarica*, *Erythrina indica*, *Macaranga peltata* and *Xylia xylocarpa*, the values in un-pruned trees and trees subjected 50% pruning were not significantly different. On the other hand in these species, the trees subjected to 75% and 90% pruning, however, showed significantly lower values. Similarly, for *Bridelia crenulata*, *Grewia tiliifolia* and *Terminalia paniculata* the annual increment in stem diameter in un-pruned trees and that in trees subjected 50% and 75% pruning were not significantly different while those subjected to 90% pruning had lower values. No significant difference between un-pruned trees and trees subjected to certain level of pruning may be the result of a short term increase in biomass production of the remaining crown of pruned trees (Pinkard and Beadle 2000). Depletion of carbohydrate reserves in storage organs such as stems and roots of woody plants after pruning as these reserves are used for the initial re-growth are also reported (Yamashita 1986; Gregory and Wargo 1986; Erdmann et al. 1993). Monitoring of pruned trees also indicated that the effect of pruning on tree growth declined when the pruning interval was increased from 1 year to 2 years (Table 1).

Biomass production after pruning

In order to determine the response of different tree species to pruning in terms of changes in biomass production, the quotients (in %) between weight of foliage and small branches biomass produced in a given period both in the pruned and un-pruned trees were calculated (Table 2). These values indicated that responses to pruning in terms of biomass production vary from species to species. For instance, in *Albizia odoratissima*, *Ailanthus triphysa*, *Artocarpus hirsutus*, *Bombax malabarica* 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%. On the other hand, in *Erythrina indica*, *Grewia tiliifolia*, *Macaranga peltata* and *Terminalia paniculata*, the value was significantly more than 100%. Such an increase in biomass production in pruned trees could be driven by increase in photosynthetic capacity (Hoogesteger and Karlsson 1992) and leaf area (Trumble et al. 1993). In majority of the species studied, in general, the quotients between the quantity of foliage and small branches produced in 2-year period in pruned and un-pruned trees were significantly high. Such a benefit of increase in the duration between two successive prunings to crown recovery following the previous pruning events was also recorded in *Euclayptus nitens* (Pinkard et al 1999). However, the present study also indicated that in species like *Bombax malabarica* (subjected to different pruning intensities) and *Ailanthus*

Table 1 Annual increment in radial growth 1 year and 2 years after pruning for trees in the homegardens of Kerala, India

Species	Pruning intervals	Intensity of pruning			
		0%	50%	75%	90%
		Annual increment in stem diameter (cm ± SE)[1]			
Ailanthus triphysa	1 year	3.74 ± 0.62[a]	2.29 ± 0.06[b]	1.79 ± 0.11[b]	1.06 ± 0.04[c]
	2 years	3.43 ± 0.18[a]	2.94 ± 0.25[a]	2.80 ± 1.48[a]	2.01 ± 0.22[a]
Albizia odoratissima	1 year	2.88 ± 0.54[a]	1.75 ± 0.16[a]	1.32 ± 0.08[b]	2.40 ± 1.48[a]
	2 years	2.56 ± 0.31[a]	3.67 ± 0.95[b]	2.10 ± 0.06[a]	1.85 ± 0.35[a]
Artocarpus hirsutus	1 year	1.42 ± 0.29[a]	1.08 ± 0.10[b]	0.76 ± 0.03[c]	0.25 ± 0.13[d]
	2 years	1.77 ± 0.83[a]	1.19 ± 0.06[a]	1.05 ± 0.08[a]	0.84 ± 0.10[a]
Bombax malabarica	1 year	3.41 ± 0.42[a]	2.61 ± 0.06[a]	1.37 ± 0.80[b]	1.23 ± 1.00[c]
	2 years	2.97 ± 0.06[a]	2.56 ± 0.05[ab]	2.41 ± 0.14[b]	1.32 ± 0.44[c]
Bridelia crenulata	1 year	1.66 ± 0.35[ab]	1.82 ± 0.04[a]	1.31 ± 0.10[b]	0.68 ± 0.09[c]
	2 years	1.81 ± 0.41[ab]	2.41 ± 0.07[b]	2.08 ± 0.17[b]	1.73 ± 0.12[a]
Erythrina indica	1 year	3.19 ± 0.46[a]	2.77 ± 0.13[a]	2.28 ± 0.06[b]	1.53 ± 0.03[c]
	2 years	2.88 ± 0.06[a]	2.91 ± 0.25[a]	2.17 ± 0.02[b]	1.79 ± 0.07[b]
Grewia tiliifolia	1 year	1.94 ± 0.29[a]	1.79 ± 0.05[ab]	1.39 ± 0.40[ab]	1.21 ± 0.39[b]
	2 years	1.81 ± 0.04[ab]	2.86 ± 1.12[a]	1.21 ± 0.03[b]	0.98 ± 0.03[b]
Macaranga peltata	1 year	2.83 ± 0.19[a]	2.36 ± 0.41[a]	1.67 ± 0.14[b]	1.53 ± 0.22[b]
	2 years	4.52 ± 0.00[a]	3.70 ± 0.15[a]	3.31 ± 0.19[a]	1.82 ± 1.39[b]
Terminalia paniculata	1 year	1.20 ± 0.02[ab]	1.28 ± 0.53[a]	0.67 ± 0.25[bc]	0.56 ± 0.08[c]
	2 years	1.28 ± 0.07[a]	1.21 ± 0.05[a]	0.97 ± 0.03[b]	0.83 ± 0.11[b]
Xylia xylocarpa	1 year	1.15 ± 0.13[a]	1.18 ± 0.10[a]	0.65 ± .0.07[b]	0.44 ± 0.27[c]
	2 years	1.22 ± 0.07[a]	1.46 ± 0.06[a]	1.47 ± 0.07[a]	0.97 ± 0.03[b]

$n = 3$ Diameter of the tree was measured at 1.37 m from the ground level

[1] For a given species, in a given pruning interval, values with same alphabet in the superscript are not significantly different ($P < 0.05$)

triphysa and *Bridelia crenulata* (subjected 75% and 90% pruning) biomass production after pruning remained less than that in un-pruned trees even 2 years after pruning.

Conclusion

Based on an analysis of the effects of green pruning on foliage and branch production and on stem girth increment patterns, certain strategies for sustainable growth and green biomass production from trees in ten species can be suggested. In case of *Erythrina indica*, *Grewia tiliifolia*, *Macaranga peltata* and *Terminalia paniculata* annual foliage and branch production in pruned trees was significantly more than that of the un-pruned trees of the given species. However, in these species when there was no significant difference in the annual stem girth increment in un-pruned trees and trees subjected to 50% pruning, subsequent increase in intensity of pruning lead to decline in annual increment in stem diameter. Thus, the appropriate pruning strategy for the trees of above mentioned species would be to remove annually 50% of green crown length. In these species, estimation of annual stem girth increment 2 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 2 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 2 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 2 years, pruning trees of *Ailanthus triphysa*, *Albizia odoratissima* and *Grewia tiliifolia* at 2 year interval to remove 50% green crown length is recommended. Similarly, the harvest of 75% and 90% green crown length once in 2 years in *Xylia xylocarpa* and *Bridelia crenulata* respec-

Table 2 Green biomass produced in pruned trees in the homegardens of Kerala, India, as percentage of un-pruned control levels (n = 3)

Species	Pruning intervals	Ratio (in % ± SE)		
		Intensity of pruning		
		50%	75%	90%
Ailanthus triphysa	1 year	21.46 ± 1.07[a]	24.98 ± 6.51[a]	39.87 ± 8.32[b]
	2 years	117.49 ± 3.26[a]	109.42 ± 6.80[b]	101.34 ± 3.85[c]
Albizia odoratissima	1 year	56.95 ± 2.78[a]	106.52 ± 44.91[a]	95.59 ± 54.44[a]
	2 years	303.99 ± 24.42[a]	249.61 ± 20.89[b]	303.42 ± 25.08[a]
Artocarpus hirsutus	1 year	59.27 ± 2.43[a]	57.79 ± 4.03[a]	77.07 ± 21.93[a]
	2 years	110.42 ± 9.32[a]	97.91 ± 7.76[b]	107.05 ± 5.10[ab]
Bombax malabarica	1 year	30.19 ± 2.03[a]	51.27 ± 16.04[ab]	71.99 ± 33.58[b]
	2 years	88.68 ± 10.22[a]	82.25 ± 8.86[a]	71.47 ± 0.96[a]
Bridelia crenulata	1 year	59.72 ± 2.45[a]	107.30 ± 3.07[b]	143.91 ± 29.26[c]
	2 years	154.74 ± 8.12[a]	103.37 ± 3.54[b]	104.41 ± 4.08[b]
Erythrina indica	1 year	122.18 ± 11.15[a]	154.66 ± 35.81[b]	147.57 ± 50.73[b]
	2 years	207.79 ± 7.37[a]	188.76 ± 4.18[b]	195.50 ± 11.28[ab]
Grewia tiliifolia	1 year	107.15 ± 6.74[a]	153.58 ± 44.52[ab]	179.51 ± 23.60[b]
	2 years	160.52 ± 32.57[a]	149.00 ± 11.62[a]	166.37 ± 16.70[a]
Macaranga peltata	1 year	163.39 ± 8.36[a]	222.73 ± 48.44[b]	220.28 ± 23.83[b]
	2 years	232.27 ± 5.83[a]	201.63 ± 13.72[b]	188.10 ± 7.66[b]
Terminalia paniculata	1 year	105.88 ± 4.51a	210.16 ± 45.37[b]	361.74 ± 30.96[b]
	2 years	145.86 ± 4.49[a]	133.76 ± 11.66[ab]	128.79 ± 5.96[b]
Xylia xylocarpa	1 year	67.72 ± 7.56[a]	90.07 ± 26.36[a]	75.34 ± 20.38[a]
	2 years	150.72 ± 1.90[a]	127.93 ± 7.95[b]	120.73 ± 6.29[b]

[1] For a given species, in a given pruning interval, values with same alphabet in the superscript are not significantly different ($P < 0.05$)

tively may be appropriate. In the case of *Bombax malabarica*, foliage production in pruned trees was significantly less than in un-pruned trees even 2 years after pruning. Thus green pruning once in 2 years is not advisable for this species.

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