Ecology of Two Selected Liana Species of Utility Value in a Lowland Rain Forest of Sri Lanka : Implications for Management

H. S. Kathriarachchi[1], K. U. Tennakoon[2], C. V. S. Gunatilleke[3], I. A. U. N. Gunatilleke[4]

Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

P. M. S. Ashton[5]

School of Forestry and Environmental Studies, Yale University, New Haven, CT 06511, USA

Author for corresponding: K. U. Tennakoon

Email : kushant@pdn.ac.lk

ABSTRACT

Calamus ovoideus Thw. and *Coscinium fenestratum* Colebr. are economically important, naturally growing liana species in the disturbed habitats of lowland rainforests in Sri Lanka. Harvesting their mature stems has jeopardized their survival and led to dwindling populations. Growth performance and population sizes of these species and their ecophysiology were examined under three different canopy removal treatments and a closed canopy control of a *Pinus caribaea* buffer zone plantation of the Sinharaja forest. These treatments were in gaps where three pine rows and one pine row were removed and under three pine rows with gaps on either side. The initial light intensities of treatments and control were 22, 10, 5 and 3 mol m^{-2} day^{-1} respectively. Population studies of *Calamus* spp. and *C. fenestratum* revealed that they survive and regenerate naturally in the disturbed habitats compared to the undisturbed forest.

After nine years, both liana species grew poorly in the *Pinus* understorey (control) compared to those of the treatments. During the study period, height increment of *C. ovoideus* was best in the three-row canopy removal treatment. In contrast to *C. ovoideus*, the ecophysiological features of *C. fenestratum* varied little among the canopy removal treatments, suggesting that they tolerate a wider range of light levels.

The study revealed that both species can be successfully introduced to the *Pinus caribaea* buffer zones, degraded areas of lowland rain forests in Sri Lanka, in order to conserve them in the wild, and managed them sustainably.

KEY WORDS : *Calamus*, canopy removal treatments, *Coscinium fenestratum*, disturbed forest, *Pinus* enrichment trial, Sinharaja MAB reserve

1. INTRODUCTION

The rain forests of Sri Lanka are of considerable interest in the historical biogeography of south and south-east Asia (Gunatilleke & Ashton 1987). Sri Lanka also has a wealth of economically important timber and non-timber forest species. Much of the original forests in Sri Lanka have been cleared for settlement, cultivation and production of timber. Out of this, only about eight per cent of lowland rain forests are now remaining in the island. These forests recognized as floristically one of the richest terrestrial biomes in south Asia are fragmented, degraded and isolated throughout the lowland wet zone in Sri Lanka (Gunatilleke *et al.* 1996). The remaining government land that borders these forests can be described as abandoned agricultural lands that were formerly forested and that have now reverted to fire-maintained scrublands or degraded lands. Therefore, restoration of these degraded lowland rain forests is an immediate necessity.

Some rural communities in Sri Lanka have a tradition in conservation practiced in harmony with and partial dependence on the natural forests. Thus, it provides an excellent setting to examine how these tropical rain forests can be managed for multiple uses, following a system that is socially acceptable, ecologically sustainable and economically viable (Gunatilleke, Gunatilleke and Abeygunawardena 1994). In the past, natural forests were largely used for the extraction of timber. Little attention was then paid to other useful resources, largely non-timber, that were traditionally being extracted and used by the peripheral communities around forests. Therefore, it is imperative to understand the ecology of rain forest species, which have a utility value other than the timber, so that they could be sustainably, managed for non-timber forest products on a scientific criteria. The need to select species that will be protected, planted and encouraged has been emphasized in all the studies on regeneration and restoration. Hence it is essential to understand the ecological, biological, physiological and silvicultural requirements in all the developmental stages of these species.

The lack of understanding of the requirements of individual species has been considered as the greatest gap in our knowledge (Gómez-Pompa & Burley 1991).

Calamus ovoideus Thw. and *Coscinium fenestratum* Colebr. are naturally growing economically important liana species around the disturbed sites of Sinharaja Man and Biosphere (MAB) reserve, Sri Lanka. *Coscinium fenestratum* (family – Menispermaceae) is a wide spread dioecious woody climber naturally growing in the lowland wet zone of Sri Lanka. It is locally known as 'Weniwalgeta' and grows in forest edges, gaps and disturbed habitats. The woody stem of this well-known medicinal liana contains the active compounds of berberine, jatrorhizine and palmatine and has antibiotic properties (Jayaweera 1982). It is extensively used in indigenous medicine as a bitter tonic for the treatment of fever and tetanus (Senerath 1990). The stems of *C. fenestratum* are used for cordage as a substitute for rope by the villagers. Most populations of this species has been exploited on a substantial scale in its natural habitats and it has not been cultivated so far. *Calamus ovoideus* (family – Arecaceae; sub family - Calamoideae), a thorny liana locally known as 'Tuda Rena' or 'Sudu Wewel', is an endemic cane species growing naturally in the wet zone of Sri Lanka (de Zoysa & Vivekanadan 1991). The stems of this liana have become an increasingly popular raw material for rural industries. It is used to make furniture, baskets, ornaments, house and kitchen utensils and also as a binding material. Most of these rattans are collected from the natural forests and cultivation is very scarce. According to the Sri Lanka Forestry Sector Master Plan (1995), except for two rattan species (*C. rotang* and *C. thwaitesii*), the rattan resources are certainly greatly depleted and now confined almost exclusively to protected areas in the lowland rain forests of Sri Lanka. However, de Zoysa & Vivekanadan (1991) reported that due to the illicit harvesting of good quality, large diameter rattan (*C. ovoideus*) that is preferred by the industry, is on the verge of near exhaustion in Sri Lanka.

This paper presents information on the ecological and silvicultural strategies of the liana species, *Coscinium fenestratum* and *Calamus ovoideus* which grows naturally in the Sinharaja rain forest of Sri Lanka. In our study we hope to clarify specifically the following: i) What is the population size and size class distribution of individuals of each of these species in a forest that has been selectively logged in the past and is at present regenerating? ii) Do they perform differently in different parts of selectively logged forest and in the undisturbed forest? iii) Do these two species respond differently to different size canopy gaps in a *Pinus* buffer zone enrichment stand? Do they show differences in their mortality, growth rates and ecophysiology in different size gaps? The answers to these questions will throw light on the silvicultural strategies that can be used to promote these two liana species in restoration trials of lowland rain forests of Sri Lanka.

2. Materials and Methods

2.1 *Study Sites*

The study was carried out in and around the Sinharaja Man and Biosphere (MAB) reserve (6° 21' N, 80° 21' E) in south west of Sri Lanka. The total conservation area of Sinharaja comprises 11, 187 ha including about 5,000 ha of primary forest, where over 60% of the tree species are endemic to the island (Gunnatilleke & Gunnatilleke 1996), secondary forests and fernlands. The rain forest adjacent to the study areas has been described as a mixed-dipterocarp forest type and belongs to the *Mesua* - *Shorea* forest type (Gunatilleke & Ashton 1987). The climate of this region is characterized as aseasonal and perhumid. Mean monthly temperature ranges between 18º C and 27º C with an annual rainfall of between 3,500 mm and 6,000 mm (Ashton 1992).

The population studies of the study species were carried out in the part of disturbed forest sites and some selected areas of the forest fringe where these species grow well. The disturbed area of the reserve was used for timber extraction for the supply of plywood between 1972 – 1977.

The study site for the investigation of growth performance of the two liana species in different size gaps was in the enrichment trial set up in part of a *Pinus caribaea* var. *hondurensis* (Sénécl) Barr. et Golf. plantation of the buffer zone bordering the northwestern part of the Sinharaja MAB reserve. This enrichment trial, established in 1991 in the *P. caribaea* buffer zone plantation (Gamage 1998) had been planted in 1978 and protected for the last twenty three years Before establishing the *P. caribaea* plantation, this area was originally an abandoned agricultural land (Ashton *et al*. 1997). The average slope of the study site is about 44^0, sloping towards the north-south direction. The *P. caribaea* trees were planted at a spacing of 2 m x 2 m in rows aligned in the north-south direction as described in Ashton *et al*. 1997).

2.2 *Sampling for Population Density and Size Distribution in the Disturbed Forest*

In part of the selectively logged forest, permanent plots (nine for *C. fenestratum* and 15 for *Calamus*) were established in 2000 / 2001 for population studies. Sampling sites were selected in different areas of the forest where these two species were present. Within a site, plots were randomly demarcated and the perimeter of each plot was marked by painting a ring around the stem of the border trees using water resistant yellow paint. In these plots all the enumerated individuals of the study species were permanently tagged using Aluminum number tags. For *C. fenestratum*, sampling was carried out in three different sites in the disturbed forest and in the forest fringe due to scarcity of this species in other areas. The site in the forest fringe was closer to a village in the perimeter of the reserve. For *Calamus* species, five different sites were sampled. For each species three transects, each 100 m x 4 m, were sampled in each site. Since well-grown cane lianas have a smooth woody stem once the leaf sheaths at the base perished, it was not possible to identify them to their respective species. The arrangement of spines on the leaf sheath enables their identification. The apex of the plants was high above the ground (> 20 m) and as stems of the different species were intermingled it was difficult to discern the identity of the individuals. The *Calamus* enumerated for population studies therefore belong to three species, *viz*., *Calamus ovoideus, Calamus zeylanicus* Becc. & Hook. f. and *Calamus thwaitesii* Becc. & Hook. f. Each individual was tagged at the root collar for future monitoring. For the cane species, the root collar diameter, shoot diameter (1 m above the root collar) of each of the stems in a clump and the number of stems per individual clump were recorded. In the case of *C. fenestratum,* the root collar diameter and shoot diameter (1 m above the root collar) were measured for each individual.

Size variation among individuals of the study species based on root collar diameter and shoot diameter was investigated. For both species, the site variation was tested using GLM (General Linear Model) procedure of Statistical Analysis System (SAS) version 6.12 (SAS Institute Inc. Cary, N. C.).

2.3 Ecophysiological Investigations in the Pinus Enrichment Trial

The *Pinus* enrichment trial, was the study site for the ecophysiological investigations of these two liana species. This enrichment trial has been set up as a split-plot design with a two factor factorial combination comprising three replicates (blocks). The main factor in the experiment is the different light treatments including the control, created by removal of the *Pinus* trees in 1991. The sub factor in the experiment is represented by the different study species (Gamage, 1998). Three replicates have been established for each light regime. The light treatments were obtained by the removal of a part of the *P. caribaea* canopy. In two of the treatments, three rows, and one row of pines were removed leaving a distance of three pine rows between these two treatments (Fig. 1). We also considered the gap exist with three pine rows between the two removal treatments as a third light treatment for our study. The control was the light level beneath the closed canopy of the *Pinus caribaea* without removing any pine rows. This control was located away from the canopy removal treatments to avoid any edge effects influencing the under planted seedlings. In May 1992, twenty individuals of each study species, *Calamus ovoideus* & *Coscinium fenestratum* were initially planted in the three rows removed, one row removed, three pine rows underplanting treatments (the pine rows between the three and one pine row removed treatment) and in the control per block.

The daily photosynthetic photon flux (DPPF) received at ground level by the canopy removal treatments and the control initially were as follows: three pine rows removed (22 mol m^{-2} day^{-1}), one pine row removed (10 mol m^{-2} day^{-1}), three pine rows under planting (5 mol m^{-2} day^{-1}) and the closed canopy, which served as the control (3 mol m^{-2} day^{-1}). Growth performance and physiological attributes of *C. fenestratum* & *C. ovoideus* plants established under the three different light regimes created by canopy removal and in the closed canopy control were examined.

The growth measurements of the study species have been annually recorded over nine years (1992-2001) since the inception of the enrichment trial. Their root collar diameters (RCD) were recorded using a vernier caliper and diameter tapes when they grew bigger. Plant heights of the surviving individuals were recorded only up to 1998, due to the difficulty of measuring the accurate height of the grown-up plants. Height was measured from the ground to the highest point of the plant using a surveying staff. Annual increments of RCD and height were calculated from records made between 1992 to 2001 and 1992 to 1998 for all the existing individuals respectively. Dead seedlings were counted and recorded at each sampling period. Since randomly selected seedlings were taken for destructive sampling two years after establishment of the trial (August, 1994), seedling mortality was calculated during the period 1995 to 2001 for both species.

The physiological measurements (photosynthetic rates and stomatal conductance) of the study species were recorded in February 2001. Gas exchange measurements were obtained using a closed system LiCor 6200 portable infrared gas analyzer (Li – 6200, Lincoln, Nebraska) following the method described in Ashton and Berlyn (1992). From each block three representative plants per species per treatment and the control were randomly selected for these studies. In each of these plants a single fully exposed, expanded, undamaged, intact leaf at about 2 m above the ground level was selected for subsequent physiological measurements. All measurements on these selected leaves were made under ambient conditions (CO_2 concentration of approximately 340 µmol mol^{-1}, relative humidity 50-55 per cent and when photon flux density was between 250 – 1200 µmol m^{-2} s^{-1}). For sampling, the one litre leaf chamber without the artificial light source was used. The leaf area of the chamber was set as 10 cm^2 for the broad-leafed *C. fenestratum* and as 6 cm^2 for narrow leafed *C. ovoideus.* The airflow rate was maintained at 500 µmol m^{-2} s^{-1} and the stomatal ratio was kept at 0.5. To avoid bias from diurnal effects, sampling was done between 9.00 am to 3.00 pm on sunny days as described in Ashton and Berlyn (1992) and Tennakoon *et al.* (1997). Each gas exchange measurement took place during a 40-90 s enclosure of the leaves of a species, taking care to avoid periods of rapidly changing light conditions before or during measurements. The study species did not show the mid day closure of stomata during the period gas exchange measurements were taken. The three replicates of each species in each light treatment were sampled within one day to avoid any sampling errors. Each replicate plant was sequentially measured, six times over this time period. Each measurement of a leaf comprised a set of three sequential readings. From these measurements, the net photosynthetic rates and stomatal conductance were determined.

Data on percentage mortality, growth over nine years, annual growth increments between 1992 - 2001 and leaf physiological measurements were analyzed by analysis of variance (ANOVA) procedure of the Statistical Analysis System (SAS) version 6.12 (SAS Institute Inc. Cary, N. C.). Analyses were tested for differences among light treatments, species, block effects and interactions between species and treatments at 5% significance level. Owing to some seedling mortality and missing values in growth parameters of some individuals data were subjected to unbalanced ANOVA, using GLM (General Linear Model) procedure of SAS. The effect of different canopy removal treatments on each of species was determined by one way analysis of variance and then multiple comparisons among means by the Duncan Multiple Range Test (DMRT) at $P < 0.05$ level using SAS procedures. All data on percentage seedling mortality were arcsine transformed prior to analysis. Data on growth over nine years, growth increments and physiological measurements which were not normally distributed, were transformed to their logarithmic values. The transformed data were used for analyses; where appropriate means of the raw data were used to plot the graphs.

3. RESULTS

3.1 Population Studies in the Disturbed Forest

A total of 199 individual clumps and 669 stems of *Calamus* spp. were found within the 0.6 ha sampled in the disturbed sites (study plots in the selectively logged area) of the Sinharaja forest. The number of individuals and stems varied considerably among the five sites. The highest number of individuals (63) and stems (183) were recorded within the site one (Table 1). Except at one site (site three), more than fifty per cent of the individuals had multiple stems. The number of stems per clump ranged between 2 – 18. Most individuals had 4 – 5 stems per clump. Mean root collar diameter (P = 0.021) and mean shoot diameter (P = 0.019) of the *Calamus* stems varied significantly among the five sites.

In their root collar diameter (RCD) distribution of the *Calamus* stems, size class 2 – 2.99 cm had over fifty per cent of the stems in all the sites sampled (Fig. 2). The proportion of stems having 3 – 3.99 cm RCD was more than twenty per cent and only 9.1 per cent and 6.3 per cent in the size classes between 1 – 1.99 cm and 4 – 4.99 cm respectively (Fig. 2).

In *C. fenestratum*, within the three different sites sampled in the disturbed forest, 100, 102 and 61 individuals were recorded. For all individuals sampled, the mean root collar diameter per individual was 3.0 cm and the mean shoot diameter per individual was 2.1 cm. Among the three different sites, the mean root collar diameter of the individuals did not vary significantly ($P = 0.142$) but the mean shoot diameter was significantly higher in sites one and two compared to that in site three ($P = 0.006$; see Table 2).

The proportions of individuals of *C. fenestratum* in different root collar diameter classes showed that, site three had a higher proportion of small individuals (28%) in the RCD size class 1 – 1.99 cm relative to that in site one and site two. Between 59 – 78 per cent of individuals in each site had RCD of 2 – 3.99 cm. However, those over 6 cm RCD were present only in sites two and three, where they represented 3% of each of these populations (Fig. 3). In each of the three sites, in contrast to RCD, the shoot diameters in 79 - 92 per cent individuals ranged between 1 – 2.9 cm, where as the proportions of individuals between 3 – 4.99 cm was less than twenty one per cent (Fig. 3).

3.2 Population Sizes of the Liana Species in the Selectively Logged and an Undisturbed Forest

In the 25 ha forest dynamic plot demarcated for the long term monitoring of the growth of species in an undisturbed area of the Sinharaja forest only 56 individuals of the cane species and none of the *C. fenestratum* were recorded (C. V. S. Gunatilleke & I. A. U. N. Gunatilleke, unpublished data). In the present study in contrast, we recorded as many as 199 individuals of *Calamus* spp. and 263 individuals of *C. fenestratum* in just 0.2 ha of the selectively logged forest. This supports the observations of the dearth of these two liana species in the undisturbed forests compared to the disturbed sites in Sinharaja.

3.3 Seedling Mortality and Growth Performance in Different Size Canopy Gaps

Results of seedling mortality during 1995 to 2001 failed to show any significant differences among canopy removal treatments. The percentage mortality of both study species in the closed canopy control was highest compared to results of the canopy removal treatments (Fig. 4).

As depicted in figure 5, the comparisons showed that, mean root collar diameter, mean height and their increments of *C. fenestratum* after nine years were significantly higher in canopy removal treatments compared to the closed canopy control. The differences of *C. fenestratum* among treatments were not significant except the annual root collar diameter increment which was significantly higher in the three rows removed treatment compared to the other two canopy removal treatments. The results showed that, mean height and its increment per year were significantly higher in canopy removal treatments than the control for *C. ovoideus*. The mean annual root collar diameter increment of *C. ovoideus* was higher in the closed canopy control (where *C. fenestratum* and *C. ovoideus* plants were established under intact *Pinus* plantation) compared to the canopy removal treatments (where the lianas were established under one and three pine rows removed areas and in a strip where only three pine rows were left behind).

3.4 Leaf Physiological Investigations

The results suggest that, each of the species had its best net photosynthetic rate under a different canopy removal treatments (Fig. 6). The highest mean net photosynthetic rate recorded for *C. ovoideus* was in the one pine row removed treatment, and for *C. fenestratum* it was in the three pine rows removed treatment and also in the control compared to the two remaining canopy removal treatments and where relevant to the control. Results of stomatal conductance reflected different trends between the species and among the canopy removal treatments. The stomatal conductance was significantly higher in the three pine rows removed treatment for the *C. ovoideus* and in the one pine row removed treatment and three rows underplanting treatments for *C. fenestratum* compared to the other treatments and control (Fig. 6).

4. DISCUSSION

Although commercial selective mechanized logging and disturbances associated with it caused some extent of destruction to the forest, the present study carried out 20 years after logging, showed that the study species could survive and regenerate naturally in the disturbed sites of the Sinharaja forest.

Results of this study further showed that regeneration of *Calamus* spp. in their natural habitats could have occurred either by seeds or vegetatively by buds at the rooting points. Single stem individuals may have possibly arisen from seeds dispersed by bats, polecats and other dispersers to sites far away from their mother plants. Seeds of both species have a pulp that attracts dispersal agents. On the other hand, individuals with multiple stems could have arisen from vegetative shoots arising at the rooting point, or from those plants that would have remained in a dormant state before logging. The growth rates of these multiple and single stem cane plants and their relationship with age in these habitats should be monitored to test for their growth differences if any. The more or less similar root collar diameter distributions shown by the individuals in different sites depict the low variability among sites. In contrast to cane, the natural regeneration of *Coscinium fenestratum* is known to be difficult due to the un-orthodox nature of the seeds, where the average moisture content is well over 25% and seeds cannot withstand desiccation. Studies have further shown that, seeds of *C. fenestratum* are extremely sensitive to low humidity levels (Bandara *et al*. 2004).

The performance of *C. fenestratum* varied among the three different sites sampled. Sites one and two were located within the forest reserve and the site three was located in the forest fringe, bordering the reserve. All the growth measurements measured in the site three were lower compared to those of the two sites that were within the forest. These differences between site three and other two sites could be attributed to the degree of disturbance in them due to removal of mature lianas by villages living in the vicinity. These results further showed that the mean root collar diameter of plants growing in all three natural forest habitats was greater than the maximum root collar diameter (2.4 cm) recorded after nine years growth in the three pine rows removed treatment of the *Pinus* buffer zone enrichment trial. Studies carried out by Senerath (1990) showed that mean density of the *C. fenestratum* in the forest fringe at Sinharaja was 14 per 125 m^2. However, the present study showed a reduction in the density of the individuals in the forest edge, where the value was 10 and 11 individuals per 125 m^2 in site one and site two respectively. According to a study conducted 10 years before the present investigation (Senerath ,1990), a higher proportion of the individuals sampled in the forest fringe of the Sinharaja forest had a shoot diameter ranging between 1 – 1.9 cm. In contrast, in the present study 56 % of the individuals sampled were represented by a shoot diameter of 2 – 2.9 cm. This could be due to the growth of individuals over the last ten years.

The different trends in most of the leaf physiological attributes in both species, among the treatments and control may be due to the comparatively similar light conditions (6.4 - 2.5 mol m^{-2} day^{-1}) at 2 m above the ground, the height at which the leaves were harvested for physiological studies. The spatial and temporal light variation of the understorey is a major factor that affects the physiological processes of the two species investigated. The study also demonstrates the changes between the initial light intensities at the commencement of the experiment (in 1992) and those at present (in 2001) due to the growth of the introduced plants and how these changes have affected the physiological responses of these plants. The existing average total daily photosynthetic photon flux (DPPF) 2 m above the ground level of the treatments investigated as a parallel study in the 3 rows removed, 1 rows removed, three rows underplanting treatment and the control were found to be 6.44, 4.31, 3.27 and 2.5 mol m^{-2} day^{-1} respectively.

In the 25 ha forest dynamic plot demarcated for the long term monitoring of the growth of species in an undisturbed area of the Sinharaja forest only 56 individuals of the cane species and none of the *C. fenestratum* were recorded (C. V. S. Gunatilleke & I. A. U. N. Gunatilleke, unpublished data). This supports the observations of the dearth of these two liana species in the undisturbed forests compared to the disturbed sites in Sinharaja.

The results of this study provide important information on the survival, growth and physiological responses of two native liana species in an enrichment trial of the *P. caribaea* buffer zone plantation. Previous studies (Gamage, 1998) have shown that three year old seedlings of these species can be established under suitable gap sizes of *P. caribaea* plantations. The results of this study confirm the ability of nine-year-old plants of the two study species (*C. fenestratum* and *C. ovoideus*) to grow successfully under suitable size gaps in the *P. caribaea* plantation in the buffer zone of the Sinharaja MAB reserve.

When one considers the two liana species, *C. fenestratum* and *C. ovoideus,* plant height is a good measure of their growth as well as of the quantity available for extraction because in both species the stem is harvested for their utility value. The results demonstrate that, even after nine years of growth, *C. fenestratum* and *C. ovoideus* grew poorly in the *Pinus* understorey than in the other canopy removal treatments, but they showed different growth strategies. The best height after nine years for *C. ovoideus* was observed in the three-row canopy removal treatment, compared to all the other treatments tested in this study. In contrast to cane, *C. fenestratum* showed only a small variation, mostly non-significant, in terms of growth and other ecophysiological features among the canopy removal treatments.

This depicts that *C. fenestratum* has a wider tolerance range where it grows better under the light intensities present in the three pine rows removed, one pine row removed and three pine rows under planting treatments. Although not significant, results showed that, both liana species had a poor percentage survival under the lowest light treatment *viz*., closed canopy control compared to any of the *Pinus* canopy removal treatments. The heights of both species and the root collar diameter of *C. fenestratum* increased considerably with the increase initial light level from 3-5 mol m^{-2} day^{-1}. Increases between 5-22 mol m^{-2} day^{-1} however, did not show much variation in these growth parameters. Therefore, based on the results, both liana species can be grown economically and successfully in *Pinus* stands, where every forth row of pines is removed. In these pine stands the lianas could be grown in the gap center as well as in the understory of the tree pine row left behind. This suggests that 9-10 years old plants of *C. ovoideus* and *C. fenestratum* are shade intolerant.

The root collar diameter is not a very successful growth measurement for *C. ovoideus* because the slower growing smaller *C. ovoideus* plants have a sheathing leaf base around the root collar. In the well-grown *C. ovoideus* plants the sheaths wear away and exposes the smooth cane stem. Hence the actual diameter of the root collar of mature cane plants become smaller due to the wearing off of the sheath.

The ecological, physiological and silvicultural findings of these native non-timber forest species should also be examined in the light of their sustainable extraction levels, yield and production in this type of manipulated mixed species plantation. Continuation of this investigation should provide valuable information on some of the economical aspects of these species and the production levels under these manipulated conditions.

The National forest policy (1995) of Sri Lanka (Sri Lanka Forestry Sector Master Plan, 1995), proposes the sustainable management of state forests for multiple uses, through involvement of local people who will participate in planning, implementing and benefiting from natural forest management. According to the recent forest classification (Sri Lanka Forestry Sector Master Plan, 1995), the class III forests are mainly to be used for multiple uses such as sustainable production of wood and non-timber forest products for the benefit of the local communities. This includes the buffer zones that protect (strictly conserved or preserved forests for non-extractive uses *i.e.* Class I and Class II forests. The Class IV forests comprise plantations and agro-forestry systems on state lands that would be managed for production of wood and non-timber forest products. The Forestry Sector Master Plan of Sri Lanka (1995) proposed programs on multiple use of forests that cover all these forest categories. Therefore, the results of the species investigated in the present study provide an insight to the best ways that could be implemented when these species are introduced or cultivated in the mixed species plantations of the buffer zones of lowland wet zone in Sri Lanka. It also provide an insight in to the subsequent management strategies that could be adapted in the low land wet zone forests that are assigned for production with the help of community participation. In addition the findings of this study are invaluable when drawing up the suitable silvicultural practices for implementation to enhance the growth of these species in their natural forest fringe habitats, or in degraded forests.

The information on population sizes of *Coscinium fenestratum* and *Calamus* spp. could be useful in developing silvicultural systems for these study species that are suitable for degraded and selectively logged forest habitats in the low land wet zone of Sri Lanka. This study indicate much variation in the densities of the two liana species and in turn the availability of these resources in different sites of the selectively logged forest and the forest fringe. This information is imperative to draw up guide lines for their sustainable extraction from the wild. The continued monitoring of the permanent plots demarcated in this study over a long period would further provide valuable information on their rate of growth, mortality and their regeneration strategies within the natural habitats.

5. ACKNOWLEDGEMENTS

Financial assistance provided by the NAGAO Natural Environment Foundation and NIES Japan, National Science Foundation, Sri Lanka and MacArthur Foundation, USA are gratefully acknowledged. We thank the Forest Department of Sri Lanka for granting permission to study in the Sinharaja Forest and to use the facilities at the field station.

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Table 1. Total number of individuals, stems, number of individuals with multiple stems, mean root collar diameter (RCD) and mean shoot diameter (SD) per stem of *Calamus* spp. sampled in five different sites of the disturbed forest in Sinharaja MAB reserve, Sri Lanka. Percentage of stems having multiple stems is given in parentheses. Letters qualitatively indicate (a<b<c) the significant differences among the sites at $P < 0.05$.

	Site 1	Site 2	Site 3	Site 4	Site 5	Sites 1-5
Total no.of individuals/0.12 ha	63	43	31	30	32	199
Total no. of stems / 0.12 ha	183	127	94	136	129	669
No. and (%) of individuals with multiple stems	32 (51)	24 (56)	11 (35)	20 (67)	22 (69)	109 (55)
Mean RCD/stem (cm)	2.7^{a}	2.6^{ab}	2.5^{b}	2.6^{ab}	2.6^{ab}	2.6
Mean SD/stem (cm)	2.1^{a}	1.9^{b}	2.0^{a}	2.0^{a}	2.1^{a}	2.0

Table 2. Total number of individuals, mean root collar diameter (RCD), mean shoot diameter (SD) per individual of *Coscinium fenestratum* in the three different sites of the disturbed forest in Sinharaja MAB reserve, Sri Lanka. Letters qualitatively indicate (a<b<c) the significant differences among the sites at $P < 0.05$

Measurements Recorded	Site 1	Site 2	Site 3
No. of individuals / 0.12 ha	100	102	61
Mean RCD (cm) / individual	3.0^{a}	3.1^{a}	2.9^{a}
Mean SD (cm) / individual	2.2^{a}	2.2^{a}	1.8^{b}

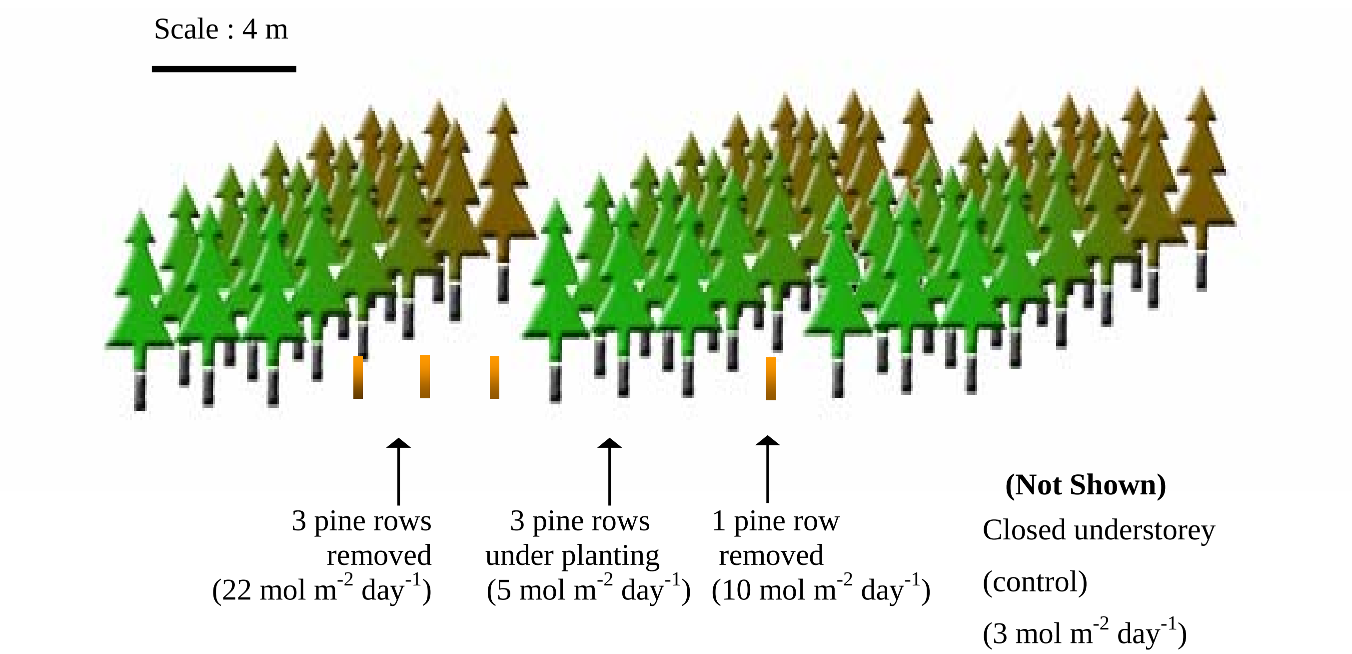

Figure 1. Stand profile of the canopy removal treatments and control (not shown here) of one block of the *Pinus* enrichment trial in the buffer zone of Sinharaja MAB reserve, with their respective light intensities (within parenthesis) at the ground level in 1991, when the trial was set up.

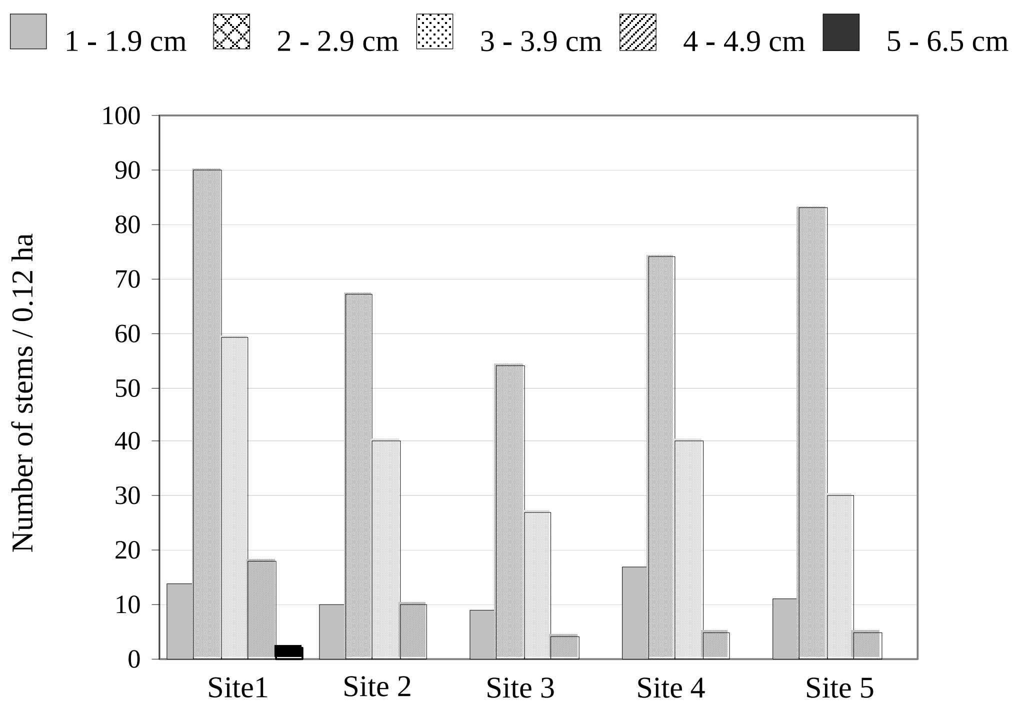

Figure 2. Root collar diameter distribution of *Calamus* spp. in five different sites of the disturbed forest in Sinharaja MAB reserve, Sri Lanka.

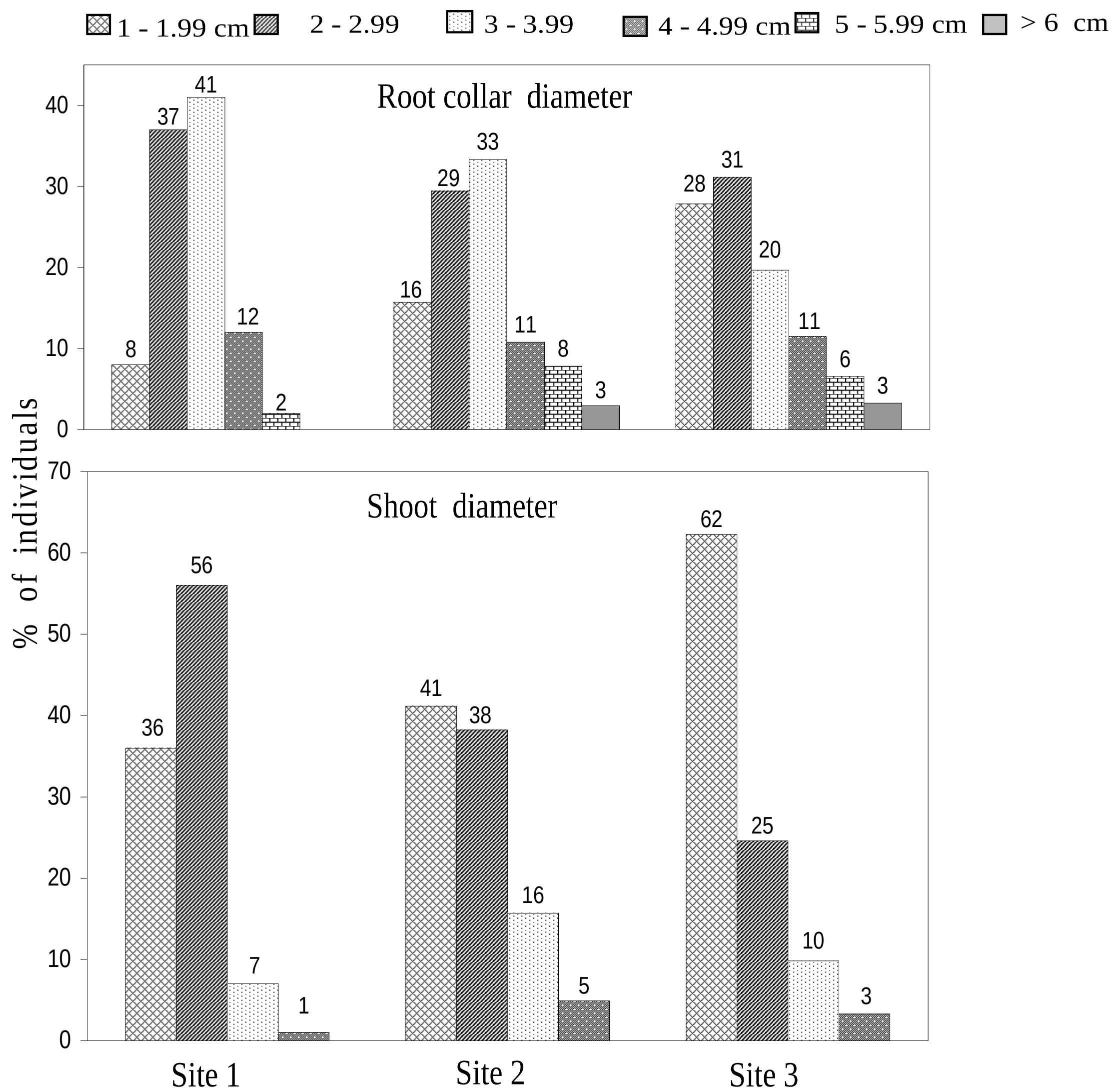

Figure 3. Root collar diameter and shoot diameter distributions of *Coscinium fenestratum* in three sites (sites 1, 2 and 3 where n= 100, 102 and 61 respectively) in part of the selectively logged and regenerating forest in the Sinharaja MAB reserve, Sri Lanka. Values above bars indicate the proportions of individuals in each size class in each site.

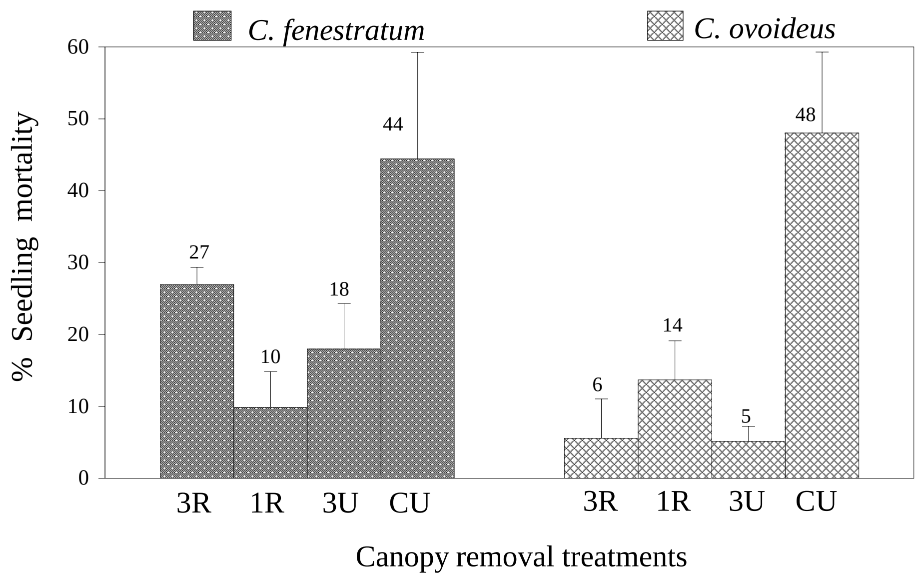

Figure 4. Mean percentage mortality of *C. fenestratum* and *C. ovoideus* from 1995 - 2001 when grown under different canopy removal treatments (3R- 3 rows removed, 1R - one row removed, 3U - 3 rows under planting and CU - closed canopy control) in the *Pinus* enrichment trial of the buffer zone of Sinharaja MAB reserve, Sri Lanka. Bars indicate the standard error of the mean. Values above show the mean percentage mortality of each species under each treatment.

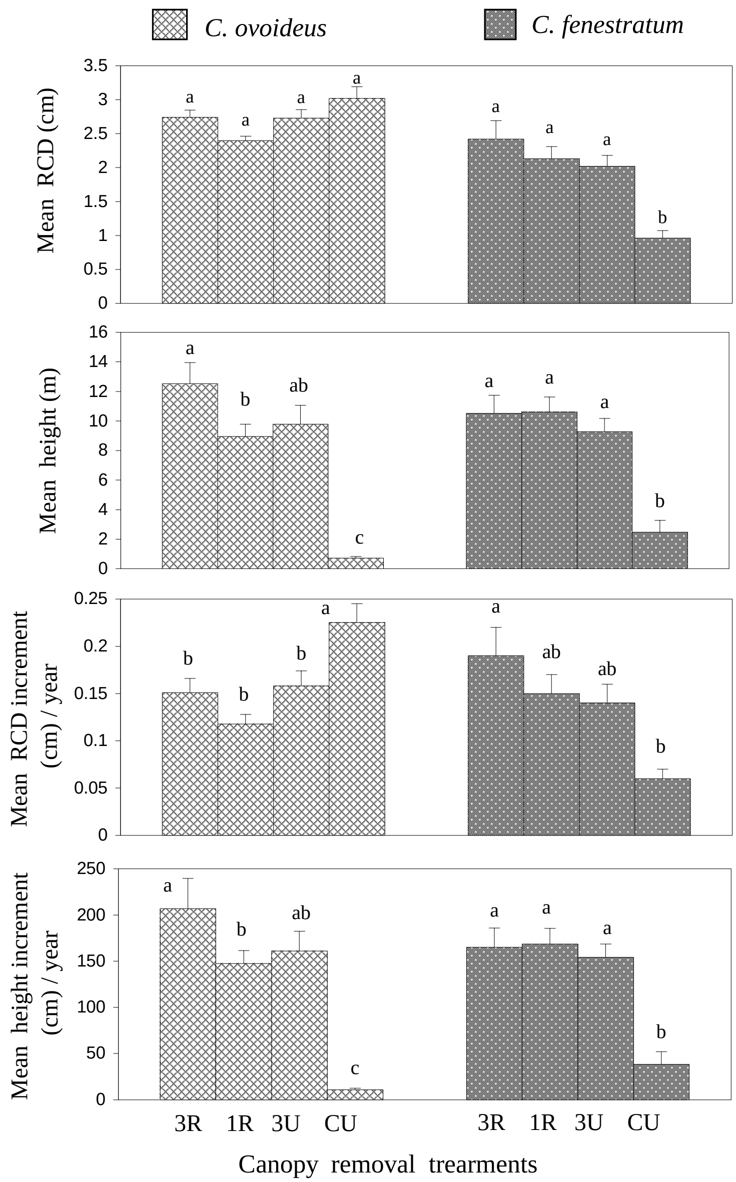

Figure 5. Mean root collar diameter (RCD), mean height and their increments per individual per year of *C. ovoideus* and *C. fenestratum* after nine years growth under different canopy removal treatments (3R - 3 rows removed, 1R - one row removed, 3U - 3 rows under planting and CU - closed canopy control) in the *Pinus* enrichment trial in the buffer zone of Sinharaja MAB reserve, Sri Lanka. Bars indicate the standard error of the mean. Letters qualitatively indicate significant differences (a>b>c) among treatments for each species according to Duncan's multiple range test ($P<0.05$).

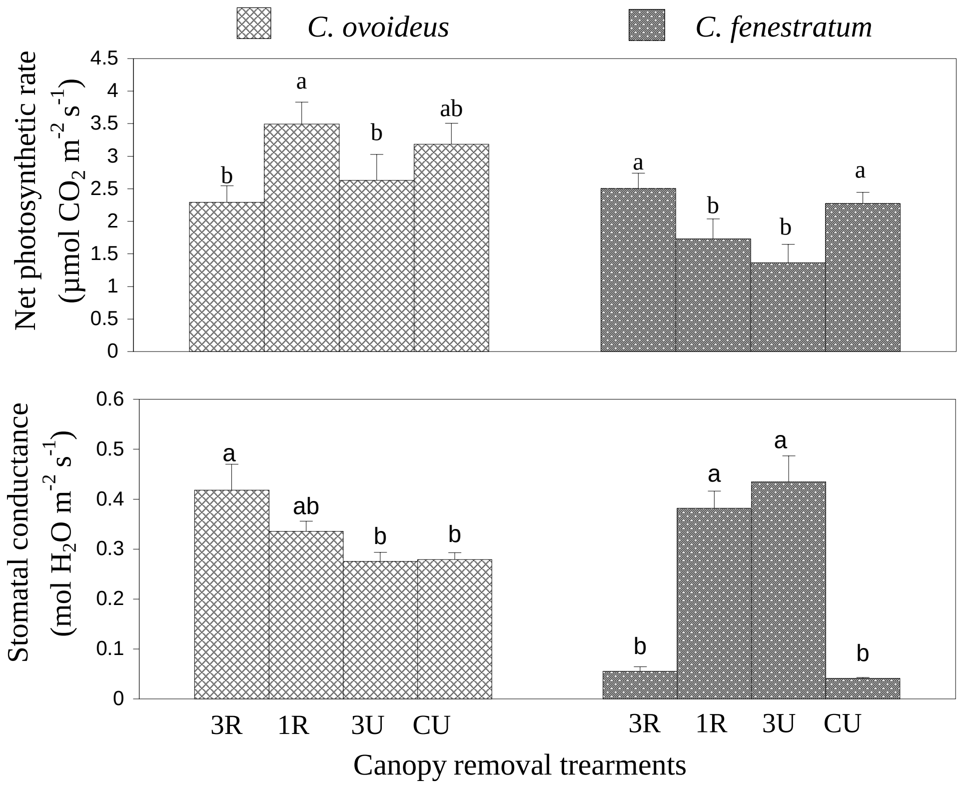

Figure 6. Net photosynthetic rate and stomatal conductance of *C. ovoideusand* and *C. fenestratum* under different canopy removal treatments (3R - 3 rows removed,1 row removed, 5R - 5 rows removed, 2R - 2 rows removed, 3U - 3 rows under planting and CU - closed canopy control) in the Pinus enrichment trial in the buffer zone of Sinharaja MAB reserve, Sri Lanka. Bars indicate the standard error of the mean. Letters qualitatively indicate significant differences (a>b>c) among treatments for each species according to Duncan's multiple range test (P<0.05).