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EFFECT OF LOPPING INTENSITY ON TREE GROWTH AND STAND PRODUCTIVITY IN TROPICAL FORESTS

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BHAT, D.M., RAVINDRANATH, N.H. & GADGIL, M. 1995. Effect of lopping intensity on tree growth and stand productivity in tropical forests. Effects of various intensities of lopping on the growth of trees, production of leafy biomass (leaves + shoots) and grass biomass production were investigated in the forests of the Western Ghats, India. Frequent complete lopping of trees resulted in a rapid drain of stored reserves leading to reduction in growth of tree girth and production of leafy biomass. Relatively greater increase in girth at the breast height of trees that were subjected to partial lopping, i.e. less than 50% intensity, was considered to be mainly the result of stimulation of remaining leaves to higher rates of photosynthesis. Opening of canopy increased the grass production in lopped quadrats. In two species, *Aporosa lindleyana* and *Terminalia paniculata*, the growth rate of girth and the yearly production of leafy biomass showed positive correlation up to 75% lopping intensity indicating that these two species can withstand lopping to some extent. For managing the forests and trees on an ecologically sustainable basis, the desired option recommended is to restrict lopping to less than 50% of the crown portion. Intensive long term studies, however, are required to suggest management practices.

Key words: Growth - leafy biomass - lopping - production - Western Ghats

BHAT, D.M., RAVINDRANATH, N.H. & GADGIL, M. 1995. Kesan keamatan pemangkasan ke atas pertumbuhan pokok dan produktiviti dirian di hutan-hutan tropika. Kesan-kesan berbagai jenis keamatan pemangkasan ke atas pertumbuhan pokok-pokok, pengeluaran biojisim daun (daun + pucuk) dan pengeluaran biojisim rumput telah diselidiki di dalam hutan-hutan di Ghats Barat India. Pemangkasan lengkap yang kerap dijalankan ke atas pokok menghasilkan susutan yang pesat keatas simpanan menyebabkan pengurangan di dalam pertumbuhan lilit pokok dan pengeluaran biojisim daun. Pertambahan yang lebih besar bagi lilit pada aras dada pokok yang dipangkas sebahagian daripadanya, iaitu lebih daripada 50% keamatan, telah didapati menjadi penyebab bagi stimulasi dedaun yang masih tinggal untuk kadar fotosintesis yang lebih tinggi. Pembukaan sudur meningkatkan pengeluaran rumput pada kuadrat yang dipangkas. Di dalam dua spesies, *Aporosa lindleyana* dan *Terminalia paniculata*, kadar pertumbuhan lilitan dan pengeluaran tahunan biojisim daun menunjukkan korelasi positif sehingga 75% keamatan pemangkasan. Ini menandakan bahawa kedua-dua spesies ini dapat menerima pemangkasan sehingga pada takat tertentu. Untuk menguruskan hutan dan pokok-pokok atas dasar pelestarian ekologi, pilihan yang disyorkan ialah dengan menghadkan pemangkasan kepada kurang daripada 50% bahagian silara. Bagaimanapun, kajian jangka panjang secara intensif diperlukan untuk amalan pengurusan.

Introduction

Knowledge of adaptations of plants to physical and biotic damages will assist in sustainable management of individual plant species as well as plant community such as a forest. While many papers are available on the impact of herbivores feeding on plant growth rate (Crawley 1983), artificial defoliation on stand yield (Harper 1977), folivory on plant reproduction (Marquis 1992), and pruning on foliage production (Kotwal 1981, Nik Muhamad & Paudyal 1992), there are some reports on the effects of lopping on growth of trees and stand productivity (Gorrie 1937, Bhimaya *et al.* 1964, Ganguli *et al.* 1964, Poulsen 1983, Roy & Debroy 1983, Sharma *et al.* 1991). In the tropics trees are lopped for twigs as fuel, and leaves and tender shoots as fodder (Mellink 1989). In the Western Ghats of India, a portion of the forest area is dedicated to the practice of lopping tree leaves for manure. At present the crown portions of the trees are completely lopped very frequently to meet the leaf manure needs. There is a need to understand the sustainability of the current harvest system and to suggest sustainable lopping levels. These can be achieved by understanding the effect of lopping intensity on tree growth and productivity of leaf biomass and twig litters. It is also important to study the sustainable leaf harvest levels of twigs of various tree species.

This study investigated the effect of different lopping intensities on growth of trees and productivity of leaf biomass of different tropical tree species.

Materials and methods

Study site

This study was conducted in a hilly (600 m above sea level) high rainfall (about 250 cm y^{-1}) tract in Sirsi area of Uttara Kannada district (13°55' to 15°31'N; 74°9' to 75°10'E) of the Western Ghats of Peninsular India. In Uttara Kannada a vast forest tract (>500 km^2) has been assigned as leaf manure forest (LMF) to betel nut (*Areca catechu*) orchard owners to derive usufructs like grass, green manure, dry and fallen leaves, etc. The allotment of forest land to the orchard owners ranges from 4 to 9 ha per hectare of orchard and the overall ratio of LMF to orchard in the district is 7.28:1 ha (Prasad 1984). Orchards are situated in valleys and the adjoining forested hill tracts (LMF) are locally known as "Soppina Betta". To meet the need of fuelwood and manure, orchard owners lop trees in winter and the frequency of lopping varies from once in a year to once in every three years. Because of the preference for a few tree species, in the majority of LMFs, deciduous species dominate and the species diversity is low (Bhat *et al.* 1984, Mani 1984). As a result of the prevailing management practices, forest stand structure and species composition of the LMFs have changed and their productivities reduced (Tippeswamy & Shanmukappa 1961, Reddy *et al.* 1986, Bhat 1990).

Methods

For this study a LMF that has not been lopped for the last several years was chosen. The investigated area was split into five quadrats measuring 0.5 ha (50 × 100 m) in area. Of these five quadrats, four were chosen for trials of different intensities of loppings and one quadrat was treated as control. All the trees with girth at breast height (GBH at height of 132 cm) larger than 40 cm were identified and marked with metal tags in each quadrat. A black strip was painted at the breast height on all the trees. All marked trees were lopped by a fixed intensity in each quadrat. Crown height, defined as the distance from lowest live branch to the tip of the crown, was measured and divided into four equal length parts. Lopping trials were made as follows:

Quadrat I - 100% lopping, i.e. all the branches of a tree were lopped
Quadrat II - 75% lopping, i.e. a three-fourth portion of crown bottom of a tree was harvested.
Quadrat III - 50% lopping, i.e. a half of the crown bottom portion of a tree was harvested.
Quadrat IV - 25% of lopping, i.e. a quarter of crown bottom portion of a tree was harvested.
Quadrat V - 0% lopping.

Lopping of trees started in February 1987 and was repeated in the subsequent four years. All leafy branches were removed in the first year and only new shoots were lopped from the second year. Fresh weight of the green matter (twigs + leaves) of all lopped branches was recorded in the field. Standing grass biomass was harvested and weighed from each quadrat (50 × 100 m) before the lopping operation (i.e. in December - January). Samples of lopped materials and grass were oven dried to obtain the dry weight. GBH of all the marked trees was measured annually by metal tape in all the plots at the fixed point.

In the analysis of the effect of lopping intensity on productivity of leafy shoots, the first year harvest data (1987) were ignored. GBH was assumed as a parameter of tree growth for analyzing the effect of different intensity of lopping on tree growth. Production of leafy biomass of all trees subjected to a treatment was taken into account. Analysis of effect of lopping on individual species was limited to those with five or more trees in each treatment. Stem of a branched tree with > 40 cm GBH was treated as an individual in computing the growth rate of girth.

Results

Effects of lopping intensities on GBH growth

Table 1 shows the number of individuals per treatment for each species. The mean maximum increment of GBH in four years (1988-91) was found in the 50% lopped plot and the mean minimum increment in the 100% lopped plot (Table 2). Negative growth in GBH was observed in the 100% lopped plot and little growth occurred at the 75% lopping intensity during 1988-91. In the other trials increment of GBH during 1988-1991 ranged from 1.36 to 1.95 cm. Except in the 50% lopping intensity trial, reduction in growth rate was observed inter-annually in all treatments including the control. Test for treatment effect on increments of GBH showed significant difference at 1% level [F-test, F (551,4) = 7.37]. In comparing increments of GBH, the lopping intensity treatments can be ranked as follows;

50% > 0% > 25% > 75% > 100% lopping

Table 1. List of species and number of individuals in different lopping intensity trial plots and in the control

	No of individuals in a treatment				In control
	100% lopping	75% lopping	50% lopping	25% lopping	0% lopping
Alseodaphne semicarpifolia	7	4	1	4	9
Aporosa lindleyana	32	25	37	23	31
Bassia latifolia	0	1	3	7	9
Buchanania lanzan	1	12	1	6	33
Caralia integerrima	0	0	1	0	0
Careya arboria	1	7	2	3	47
Eugenia jambolana	9	6	19	8	14
Eugenia umbellata	4	0	0	1	1
Mimusops elengii	1	1	0	0	0
Olia dioica	3	0	1	2	1
Plectronia sp.	0	0	1	0	1
Pterocarpus marsupium	1	0	1	0	8
Terminalia chebula	0	1	1	0	11
Terminalia paniculata	23	14	13	13	41
Terminalia tomentosa	7	1	0	2	38
Total	89	72	81	69	244

Table 2. Effect of different intensity of lopping on GBH of trees (mean ± SE)

Year of observation	Mean girth (in cm) in a treatment				Mean girth (in cm) in control
	100% lopping	75% lopping	50% lopping	25% lopping	0% lopping
1987	75.23 ± 3.68	65.39 ± 3.67	68.21 ± 3.78	73.25 ± 4.29	48.11 ± 1.83
1988	76.53 ± 3.73	67.56 ± 3.75	69.76 ± 3.83	75.10 ± 4.30	49.68 ± 1.88
1989	76.42 ± 3.69	68.09 ± 3.72	70.83 ± 3.84	76.46 ± 4.32	48.36 ± 1.84
1990	77.45 ± 3.68	68.53 ± 3.73	71.59 ± 3.88	76.97 ± 4.27	51.12 ± 1.73
1991	75.96 ± 3.69	67.80 ± 3.68	71.71 ± 3.97	76.46 ± 4.31	51.66 ± 1.83
Net change from 1987 to 1991	0.73	2.42	3.52	3.21	3.37
1988 to 1991	-0.57	0.24	1.95	1.36	1.90

Effect of lopping intensities on biomass production

Leaf biomass harvested every year in the four treatments is given in Table 3. Production of leaf biomass decreased year by year in all treatments, especially in the later years. Among the four lopping treatments, except 100% lopping, the quantity of harvested biomass differed significantly from year to year. In 100% lopping treatment, yearly leaf harvest did not differ significantly for the first three years, but in the other treatments the biomass harvested every year differed significantly (RBD, $F_{T\,0.05(3,9)} = 154.26$; $F_{B\,0.05(3,9)} = 4.3$).

Table 3. Leaf biomass harvested in different lopping treatments during different years

Year of observation	Total leaf biomass in a treatment (t ha^{-1})			
	100% lopping	75% lopping	50% lopping	25% lopping
1988	0.92	0.14	0.13	0.13
1989	0.81	0.15	0.07	0.02
1990	0.77	0.10	0.05	0.01
1991	0.58	0.04	0.04	0.001
Mean	0.77	0.11	0.07	0.02

Standing grass biomass in the treated as well as control quadrats varied during the period 1989 - 1991 (Table 4). The grass biomass production in all quadrats in the second and third year was less than that in the first year. This could be due to factors such as sparse rainfalls or dry spell during the rainy season, other than the lopping treatments. However, maximum standing grass biomass was obtained in 100% lopping quadrat and minimum in 0% lopping quadrat. ANOVA for standing grass biomass in different lopping intensities showed significant difference [F-test (CRD) $F_{T0.05(4,10)} = 4.29$]. With increased opening of canopy by intensified lopping of the crown, light availability to herb layer was facilitated leading to increased grass production in the lopped plots compared to the control.

Table 4. Standing grass biomass in different lopping trial quadrats during December/January

Year of observation	Total grass biomass in lopping quadrats (t ha^{-1})				Control
	100% lopping	75% lopping	50% lopping	25% lopping	0% lopping
1989	0.92	0.83	0.97	0.95	0.58
1990	0.64	0.68	0.60	0.42	0.31
1991	0.77	0.68	0.60	0.53	0.35
Mean standing grass biomass	0.77	0.73	0.72	0.63	0.41

Effect of lopping intensities on GBH growth and leaf biomass production of tree species

The relationship between GBH growth and leaf biomass production at different levels of lopping for a few tree species is shown in Table 5. Correlation coefficient between leaf biomass production and girth increment was positive in *Aporosa lindleyana* and *Terminalia paniculata*. But in *Eugenia jambolana* negative correlation (r_s = - 0.15) was observed in 25% lopping intensity, no correlation at 100% lopping and high positive correlations (r_s = 0.8) at 75% and 50% lopping intensities.

Table 5. Correlation coefficient (r_s) between growth rate of GBH and leaf biomass production in three species

Species	Number of observations	r_s between growth rate of GBH and leaf biomass production			
		100% lopping	75% lopping	50% lopping	25% lopping
Aporosa lindleyana	4	0.8	0.8	0.8	0.8
Eugenia jambolana	4	0.0	0.8	0.8	- 0.15
Terminalia paniculata	4	0.6	1.0	0.8	0.8

Discussion

Plants have developed several mechanisms to restore lost organs. These include restoration of photosynthetic rates by mobilizing the stored nutrients in leaves, by increasing the photosynthetic rates of newly produced leaves or by photosynthesis in green trunk (Oyama & Mendeza 1990). Removal of leaves and whole shoots stimulate the development of dormant buds into shoots and increase branchings (Harper 1977, Poulsen 1983, Foley & Barnard 1984). As the trunk of lopped tree gets enough sunlight as a result of removal of crown in 100% lopping intensity trial, the majority of the buds on the bole become active and start growing into shoots using the stored reserves. Reduction in growth of GBH of trees that were subjected to 100% and 75% lopping intensity trials may be attributed to the use of stored food reserves in the trunk for the regrowth of shoots all over the trunk. Reduction in diameter growth has been reported as a consequence of lopping and regrowth of shoots (Srivatsava 1978), pruning (Kotwal 1981, Nik Muhamad & Paudyal 1992), frequency of physical damage (Clark & Clark 1991), and change in temperature and light (Longman & Jenik 1987). The observed inter-annual reduction and variation in growth of GBH in all the lopping intensity trials as well as in the control may be in response to the change in the external physical environment. Loss of water through the increased cut surface area in trees of the lopped quadrats may also contribute to the change in girth. However, the extent of such an effect needs to be quantified. Mean girth grew positively in the plots with

25% and 50% lopping intensities. Removal of shaded, aged and senescent leaves checks the drain of energy produced by active leaves leading to net gain in biomass and GBH. But partial defoliation of trees has been reported to increase the efficiency of the remaining leaves (Sweet & Wareing 1966). Lopping of shaded leaves of lower branches in 50% lopping intensity trial might have stimulated higher rate of photosynthesis in the remaining leaves. This could be one of the reasons for the relatively high growth of GBH observed in the 50% lopping trial.

The quantity of leafy biomass (new shoots) harvested during the first three years in the 100% lopping did not differ significantly, but in the fourth year it decreased drastically. It indicates that trees can withstand persistent defoliation temporarily or for a few years. It is necessary to investigate how long trees can endure persistent defoliation. Trees continue to restore or refoliate by mobilization of stored reserves which constitute a rapid drain of stored reserves (Begon & Mortimer 1981). Response of a species depends upon magnitude, frequency and type of disturbance. The extent of loss of crown part (foliage & shoots) and the growth of diameter have been reported to be correlated (Clark & Clark 1991). For Scots pine trees, Langstrom and Hellqvist (1991) have reported that unilateral pruning all along the bole reduced tree growth and stem pruning from below caused greater reduction of the tree growth. Jameson (1963) has shown that pruning of crown up to 38% in *Pseudotsuga menziesii* and 75% in *Juglans regia* did not reduce tree growth. Kotwal (1981) has reported stunted growth of trees and reduction in leaf and twig production in *Diospyros melanoxylon* stand that was subjected to total pruning. Significant reduction in diameter growth was reported by Nik Muhammad and Paudyal (1992) in *Acacia mangium* plantation when the crown removal was more than 40%. It has also been reported that the lopping of *Bauhinia purpurea* trees at six months interval had a significant impact on the production of foliage (Roy & Debroy 1983). The positive correlation between girth increment and removal of leaf biomass (new shoots) observed in *Aporosa lindleyana* and *Terminalia paniculata* indicates that the growth of stem is not affected by the lopping intensities during the initial years. Thus these species can withstand lopping to some extent.

As a consequence of opening of canopy, the grass production was higher in the lopped quadrats than in the no lopping quadrat. Many studies (Singh *et al.* 1980, Torres 1986, Bhat & Gadgil 1987, Prasad *et al.* 1987) have reported that grass production is mainly dependent on the tree density and canopy closure. Though the total biomass may be large in 100% lopping intensity in the initial few years, for ecologically sound and sustainable use, 50% lopping is desirable in the stands investigated. However, further studies are needed to understand the effect of lopping intensity on other ecological charactristics of trees such as regeneration, root growth, and phenology.

Conclusion

Frequent complete loppings of trees results in a rapid drain of stored reserves leading to reduction in tree growth. A partial lopping of less than 50% stimulates the remaining leaves to a higher rate of photosynthesis which leads to increase in girth of trees. Although the trees can tolerate the complete loss of leaves and shoots for a few years, they cannot be subjected to such an intensive treatment beyond a certain period. There would be some time lag for the emergence of lopping effect on growth of trees. Opening of canopy increases the above-ground grass production. For managing the forests and trees on ecologically sound and sustainable basis in the high rainfall hilly tracts like Utara Kannada district, the desirable option is to restrict the lopping intensities to a maximum level of 50% of the crown portion of individual trees.

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