LIANA LOADS, MECHANICAL DESIGN AND SAFETY FACTOR OF TREE SPECIES IN FRAGMENTS OF THE TROPICAL SEMIDECIDUOUS FOREST

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INTRODUCTION

The vertical light gradient is one of the most important environmental heterogeneity axes in tropical rainforests. Most of the above - incident sun radiation is intercepted by successive leaf layers along canopy - forest floor route and, for this reason treelets, shrubs and saplings in the forest understorey have to cope with low light availability to be able to survive, and eventually, growth to maturity (Poorter *et al.,* 2003). The light interception by trees is in large extent related to their architecture. Tree architecture refers to the overall plant shape and the spatial position of its components, such as crown depth, branch patterns, phyllotaxis and geometry of foliage. Thus, the architecture of a tree species may represent different strategies employed to get larger amount light (Aiba & Kohyama 1996). Investment in height growth allows trees either optimally to intercept light and competitively to shadow neighbors. Nevertheless, the investment to elevate leaves to forest canopy should be concomitant with a proportional increase in trunk diameter, in order to prevent the mechanical risk of breaking due to self weight and wind incidence. Hence, along tree ontogeny there is a trade - off between growth in height and increase in trunk diameter (Niklas 1994). One way to assess this trade - off is through investigating the allometric relationship between trunk diameter and height. The mechanical stability of trees can be evaluated by the stability safety factor (FS), which is the ratio between the buckling height and the observed height. It indicate the safety margin necessary to trees withstanding the stress of dynamic load such as wind, rain and falling debris. Coexisting tree species with similar DBH (trunk diameter at breast height) can greatly vary in height, and the ratio height:diameter is termed slenderness. Trees with a great slenderness have a high probability of snapping (Putz *et al.,* 1983). Thus, slenderness can reflect tree architecture and the proportion of the investment in height versus trunk diameter growth.

Lianas can influence tree growth and mortality rates by weighting down host tree crowns and increasing mechanical strain (torque) on the stem and roots (Putz 1984). Therefore, taking into account the same tree species, it would be expected that trees free of lianas show differences in allometry when compared to tree infested by lianas.

OBJECTIVES

We expect, considering the same tree species, that liana - free trees to have an allometry (safety factor and slenderness) that is different from that of trees with liana loads. Our objective is to investigate this expectation by comparing the relation of the safety factor with slenderness between trees with 51 - 100% of crown infestation and liana - free trees of 15 species in ten fragments of the Seasonal Semideciduous Forest.

MATERIAL AND METHODS

Field Collections

Trees were sampled in ten forest fragments within or just outside the perimeter of the Environmental Protection Area (EPA) of Campinas municipality, São Paulo state, southeastern Brazil (22º45' - 23º00' S, 47º00' - 47º12'W). The mean rainfall is ca.1409 mm.year - 1 distributed in a rainy season from October to February (spring - summer) and a dry season from March to September (autumn - winter, Mello *et al.,* 1994, Santos *et al.,* 2007). The climate is Köppen's Cwag' hot temperate with summer rains and mild dry winter. The prevalent soil is Red - Yellow Argisol (Alfisol), and the topography ranges from slightly through strongly hilly to mountainous (Oliveira *et al.,* 1999, Santos *et al.,* 2007).

Processing of the collected material

The data were collected by Santos (2003), who applied 500 units of the point - quarter sampling method in each fragment to sample trees with DBH $\geq$ 5 cm and visually to estimate crown infestation by lianas in 25% interval classes. From that survey, we selected fifteen tree species with 10 or more individuals in two classes of liana loads: 0% of crown infestation by liana and 51 - 100% of crown infestation. The class 51 - 100% of crown infestation was the sum of the trees in the classes 51 - 75% and 76 - 100%. On the one hand, lianas can cause damage to the crown of the host tree and reduce the tree total height; and on the other hand, trees with lianas in their crown can increase trunk diameter so as to reduce mechanical stress. To distinguish between these two possible effects of liana loads, we adopted two procedures. First, we compared tree slenderness considering the reference height of 7 m. We chose this reference height because we observed that the same species, such as *Urera baccifera*, could grow either as a tree or a shrub with no more than 7 m in height. Second, we compared the relationship of the safety factor with slenderness between trees with and without lianas. We calculated the safety factor (SF = D_{obs}/D_{min}) as the ratio of the observed diameter (D_{obs}) to the critic buckling diameter (D_{min}). The critic buckling diameter was calculate by the formula $D_{min} = 0{,}109\ H^{1{,}5}$ (MacMahon 1973) where H is the reference height (in our study, 7 m). The observed diameter (Dobs) at the height of 7 m was calculated through species - specific diameter/height allometric equations, considering the original data of measured height and diameter. For each species the slenderness (H/D) were calculated as the ratio between 7 (the reference height) and the diameter (D_{obs}) at 7 m height. The observed height (H) of each tree was calculated as H = H_{arv} - 1.3 m, where H_{arv} is the tree total height and 1.3 m is the level above ground where the diameter was measured.

Data processing

We applied least square linear regression to evaluate the relationship of the safety factor with slenderness between trees with and without lianas, where the safety factor was the response variable and the slenderness the factor variable. To test for significant difference between the linear regressions of trees with and without lianas we performed covariance analysis ANCOVA with $P < 0.05$ (Sokal & Rholf 1995). We verified whether trees with and without lianas differ in relation to safety factor and slenderness using test t (Sokal & Rholf 1995), where each tree species was one sample unit. All statistical analysis were made in the SYSTAT 11 (Willinkinson 2001) and ANCOVA 33 (Flavio A. M. Santos).

RESULTS AND DISCUSSION

In average, trees with lianas had greater slenderness (1.55 m.cm^{-1}) than trees without lianas (0.95 m*cm^{-1}, t = 2.40, df = 28, P = 0.023). In trees without lianas the safety factor ranged from 3.19 to 7.52 and in infested trees, from 2.97 to 6.02. The average safety factor was smaller in infested trees (4.25) than in liana - free trees (5.09, t = - 2.38, df = 28, P = 0.024). At the same reference height of 7 m, trees with lianas had a smaller trunk diameter (6.43 cm) than trees without lianas (7.25 cm, t = 2.38, df = 28. P = 0.024).

As expected, in the linear regression the safety factor diminished as slenderness increased for both trees with and without lianas (without lianas $R^2 = 0.91$, $P < 0{,}001$; with lianas $R^2 = 0.96$, $P < 0.001$), but the coefficient of inclination b was significantly different (ANCOVA, F_s (1, 26) = 7.76; P = 0.01).

The negative relationship between safety factor and slenderness indicated that larger the slenderness, lower the security margin of a tree to withstanding dynamic loads. In addiction, we found that infested trees had greater reduction in the safety factor at the same value of slenderness contrasted to trees without lianas. Trees with larger slenderness have more chance of snapping (Putz *et al.,* 1983). For nine out of the fifteen investigated species in this study, liana - infested trees had lower safety factor. Thus, at least for those nine species, our results indicated that liana - infested trees are more likely to have a mechanical failure.

According to Putz (1984), lianas can increase mortality rate of host trees. Our results suggested that one possible explanation for that is the lower mechanical stability showed by infested trees. Therefore, the increase in mortality rates of infested trees may not be a direct effect of lianas, but a result of the interaction between the higher vulnerability of infested trees and the incidence of disturbance factors such as wind and falling debris.

CONCLUSION

Trees with lianas had larger slenderness than trees without lianas. At the same height trees infested by lianas had lower stem diameter than non - infested trees, possibly because trees infested by lianas have lower growth rate than trees without lianas.

The relationship between safety factor and slenderness were negatively correlated both for liana - infested trees and non - infested trees. However, liana - infested trees had higher value of slenderness at the same value of safety factor. In sum, our results indicated that liana - infested trees are more prone to mechanical failure due to smaller mechanical stability, thus becoming more vulnerable to stress imposed by wind and falling debris.

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