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# Biological responses of *Platystele microtatantha* and *Specklinia aristata* (Orchidaceae) to climate change in Monteverde, Costa Rica

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## ABSTRACT

The lifting of the cloud bank due to climate change in the Monteverde cloud forest has already caused discernible effects on the dry season mist regime. Epiphytes, including the most prevalent family of epiphytes, Orchidaceae, may serve as a useful indicator group of climate change. This study sought to fill the gap in knowledge about orchidaceous epiphytes and climate change by testing the response of the pleurothallid orchids *Platystele microtatantha* and *Specklinia aristata* to supplemental mist treatments simulating 1970s mist frequencies. Two sites were studied: *P. microtatantha* growing on an orchid frame and *P. microtatantha* and *S. aristata* individuals growing on tree trunks in a pasture. The frame *P. microtatantha* experienced an increase in leaf number for the supplemental mist treatment. The frame *P. microtatantha* and the *S. aristata* experienced significant increases in leaf thickness for the supplemental mist treatment. The pasture *P. microtatantha* individuals showed a trend significant to the  $p = 0.0540$  level of higher fruitset frequency in the supplemental treatment. Both the *S. aristata* and the pasture *P. microtatantha* showed a significant correlation between total leaf number and inflorescence and flower number. These results indicate that the mist regime affected epiphytic orchids and these plants could possibly be used as climate change indicator species.

## RESUMEN

La elevación del banco de nubes debido al cambio global del clima ha causado ya efectos perceptibles sobre el régimen de la niebla de la estación seca en el bosque nuboso de Monteverde. Las epífitas pueden servir como grupo útil del indicador de cambio del clima. Sin embargo, no se ha realizado ningunos estudios del cambio del clima en la familia más frecuente de epífitas, Orchidaceae. Este estudio intentó llenar ese hueco por probando la respuesta de la *Platystele microtatantha* y de la *Specklinia aristata* de las orquídeas pleurothallida a los tratamientos suplementales de la niebla relicating frecuencias de la niebla de los años setentas. Dos sitios fueron estudiados: *P. microtatantha* que crece en un marco de la orquídea y un *P. microtatantha* y *S. aristata* que crece en troncos del árbol en un pasto. La *P. microtatantha* del marco experimentó un aumento en el número de la hoja para el tratamiento suplemental de la niebla. La *P. microtatantha* y la *S. aristata* experimentó aumentos significativos en el grueso de la hoja para el tratamiento suplemental de la niebla. La *P. microtatantha* del pasto demostró una tendencia significativa a nivel de  $p = 0.0540$  una frecuencia más alta del fruitset en el convite suplemental. Ambo la *S. aristata* y la *P. microtatantha* del pasto

demostró una correlación significativa entre el número total de las hojas y el número de las inflorescencias y de las flores. Estos resultados indican que las epífitas de orquídeas afectadas régimen de la niebla y estas plantas podrían ser utilizadas posiblemente como especie del indicador del cambio del clima.

## **INTRODUCTION**

Recently, human activities have altered both regional and global climate patterns, producing already discernible effects on biological communities and species (Foster 2001, Walther et al. 2002). In neotropical cloud forests, climate change critically affects the biological community through alteration of the mist regime (Foster 2001, Nadkarni and Solano 2002, Pounds et al. 1999). This alteration may occur from the changes to the climate on a global scale, including increasing sea surface temperatures and the average .6°C increase in worldwide temperature (Pounds et al. 1999, Walther et al. 2002), or from changes on a regional scale, such as the alteration in regional precipitation patterns due to broad deforestation (Lawton et al. 2001). One of the most important forms of climate change for montane cloud forests, such as in Monteverde, Costa Rica, is the altitudinal lifting of the cloud bank (Foster 2001, Nadkarni and Solano 2002, Pounds et al. 1999). This lifting is associated with rising sea surface temperatures affecting the adiabatic lapse rate on mountains (Pounds et al. 1999). Reduced evapotranspiration after deforestation in tropical lowlands which decreases the moisture of the air flowing up mountains and therefore increases the elevation at which clouds form may also contribute (Layton et al. 2001). In any case, the lifting of the cloud bank has already altered the mist regime in the cloud forests of Monteverde, which have been experiencing an increase in the frequency of mist-free days during the dry season as well as the frequency of consecutive mist-free days during the dry season since the 1970s (Foster 2001, Nadkarni and Solano 2002, Pounds et al. 1999).

In cloud forests experiencing wet and dry seasons, as in Monteverde, mist is the sole form of dry season precipitation, and changes in mist occurrence can have far-reaching effects on the plant species reliant on this relatively constant moisture for survival (Dressier 1981, Walter 1983). Cloud forest epiphytes are particularly sensitive to mist regime changes as they are small, and therefore possess a high surface area to volume ratio and increased susceptibility to water loss (Zotz and Hietz 2001). They also grow independently from the soil substrate, and therefore are without access to the groundwater, decreasing accessible moisture reserves for tissue water (Helbsing et al. 2000). Because of these factors, the environmental tolerances of epiphytes are very narrow (Benzig 1998). Therefore, they are more vulnerable and respond more quickly to climate changes than terrestrial flora (Benzig 1998, Foster 2001, Helbsing et al 2000, Nadkarni and Solano 2002). Because these epiphytes are so absolutely dependent on atmospheric moisture for their fitness, they present a potentially powerful indicator group of even subtle climatic changes. Though their sensitivity has not been broadly examined, Nadkarni and Solano (2001) found that four species of epiphytes transplanted from high-altitude, high-mist conditions to lower altitudes with less mist responded with higher leafless and increased mortality.

Epiphytes in the family Orchidaceae represent by far the most prevalent and diverse group of epiphytes in both form and function (Benzig 1998, Dressler 1981, Dressler 1993, Gentry and Dodson 1987, Walter 1983) and, like other epiphytes, are exceptionally reliant on mist (Gentry and Dodson 1987). To counter desiccation, these plants have adopted several water-conserving strategies, including modifications in their roots, stems and leaves and, in some species, the ability to open stomata at night and photosynthesize using Crassulacean acid metabolism (CAM). Many types of epiphytic orchids possess pseudobulbs, swollen stem organs that store water and nutrients. Orchids lacking pseudobulbs, such as those in the subtribe Pleurothallidinae, show thickened leaf cuticles and succulent leaves capable of water storage (Dressler 1981, Dressler 1993, Walter 1983). Though research has shown an epiphytic (Nadkarni and Solano 2002) and broad vertebrate (Pounds et al. 1999) response to climate change in the Monteverde cloud forest, a study on this most prevalent family of epiphytes had yet to be performed. This study sought to fill this gap in knowledge of climate change ecology.

Dressler (1993) suggests that branch tip epiphytic orchids may be even more vulnerable to alterations in the mist regime because of their extremely small size—even for epiphytes—and lack of developed water storage organs such as pseudobulbs. *Platystele microtatantha* and *Speklinia aristata*, branch tip species in the subtribe Pleurothallidinae, which can be commonly found in the cloud forest of Monteverde, are therefore particularly suitable candidates for the study of a potential biological response to climate change.

This study consisted of two experiments performed in the dry season, the first involving *P. microtatantha* only, the second including both *P. microtatantha* and *S. aristata*. The first experiment tested the response of *P. microtatantha* on a frame in a forest light gap to present dry season ambient climate conditions versus a supplemental mist treatment simulating the mist frequencies of the 1970s from February 26 to May 11, 2003. I hypothesized that individuals receiving the supplemental mist treatment would show increased fitness through higher survival and growth rates and leaves that are more succulent than those individuals under ambient conditions. The second experiment tested the response of both *P. microtatantha* and *S. aristata* in a common field setting in a pasture to ambient climate conditions and the supplemental mist treatment from April 12 to May 11, 2003. I hypothesized that the field individuals receiving the supplemental mist treatment would also show increased fitness through thickened leaves and a higher flowering and fruitset rate. Because larger plant size generally increases reproductive fitness (Silvertown and Doust 1993), I also hypothesized that larger plants, i.e. those individuals with a higher number of leaves, would show a higher flowering and fruiting frequency.

## **MATERIALS AND METHODS**

I conducted this study at the Estación Biológica Monteverde in Monteverde, Puntarenas, Costa Rica at 1545 m towards the end of dry season from April 12, 2003 to May 11, 2003. I performed the first experiment on *P. microtatantha* individuals growing on a frame in a light gap

in the forest, the second on *P. microtatantha* and *S. aristata* plants growing on trees in a pasture.

## Frame

The first experiment took place in a forest light gap, replicating light and wind conditions that *P. microtatantha* would experience in its natural setting. Forty-six *P. microtatantha* individuals were collected approximately one year prior to the beginning of this study from a single host tree, *Meliosma vernicosa* (Sabiaceae) and remain on their original branches. The branches were placed on a frame in the light gap at this time such that the orchids have experienced fairly homogenous wind and light conditions between individuals since then. Since February 25, 2003, half of the individuals received a control treatment of present ambient climate conditions, while the other half received the supplemental treatment to replicate the mist frequencies of the 1970s. I took over the experiment on April 11, 2003 and continued these two groups, altering the supplemental mist frequency to replicate 1970s April and May conditions. (The 1970s mist frequency for this period was daily mist, expect for one mist-free triplet of days, one mist-free pair of days, and three mist-free single days.) The treatment group received supplemental mist twice daily, from 0700-0730 hours and from 1600-1630 hours. It did not mist when sufficient moisture was present, judged to be equal to or greater than five millimeters of mist or rain precipitation.

From February 25 to April 11, 2003, the number of leaves per plant was recorded every fifteen days, as well as the thickness of the longest leaf of each individual. Mortality was recorded as it occurred. I recorded the final leaf number per plant and leaf thickness data May 11, 2003, and used a one-way analysis of variance (ANOVA) to test for differences between the ambient control group and the supplemental mist treatment group for leaf thickness change and leaf number change. There was insufficient plant mortality to test statistically.

## Pasture

I conducted the second experiment on *P. microtatantha* (on one pasture tree) and *S. aristata* individuals (on two trees) growing on three tree trunks in a pasture. I marked eighty individuals on each tree, forty of each treatment, again consisting of ambient climate conditions and the supplemental mist treatment. Again, it misted twice daily, from 0730 to 0900 hours and 1430 to 1600 hours, and did not mist when sufficient precipitation was present. To decrease the effects of mist differences between North and South facing portions of the two *S. aristata* trunks and facilitate containing the mist within treatment portions, I divided each trunk into eight vertical strips with ten individuals each, alternating control and treatment individuals. To equilibrate the *P. microtatantha* tree, which consisted of five trunks, I divided each trunk in half along the North-South line and chose eight individuals in each half, again alternating treatments.

I recorded initial leaf thickness and inflorescence and flower count April 12, 2003, and collected inflorescence, flower and fruitset April 26 and May 3. I recorded the final inflorescence, flower and fruitset, leaf thickness and total leaf number May 11, 2003.

For the *P. microtatantha* tree, I performed a one-way ANOVA to evaluate leaf thickness,

and analyses of covariance (ANCOVAs) to test between treatments for inflorescence, flower, and fruit count with leaf number as the covariate. To evaluate fruitset frequency between treatments, I performed a  $\chi^2$  test on a two-way contingency table on. For the *S. aristata* trees, I performed a two-way ANOVA to analyze leaf thickness between trees and treatments and performed all other statistics as above. Again, there was insufficient mortality to evaluate statistically.

## RESULTS

### Frame

One individual out of 23 from each treatment died over the study period. There was a significant difference in leaf number change between treatments ( $F = 8.374$ ,  $p = 0.0060$ ), with the ambient, control group losing more than four times as many leaves as the supplemental mist treatment gained ( $-2.18 \pm 0.74$  and  $0.50 \pm .055$ , respectively, Fig. 1). These were substantial changes, as initial leaf number averaged a mere  $8.01 \pm 0.773$  over both treatments. Leaf thickness also differed significantly ( $F = 8.472$ ,  $p = 0.0057$ ). The control group gained an average of  $0.13 \pm 0.03$  mm in leaf thickness, while the supplemental mist group gained nearly twice that ( $0.25 \pm 0.03$  mm, Fig. 2).

### Pasture

#### *Platystele microtatantha*

One individual out of 40 control plants died, while three individuals out of 40 supplemental mist treatment plants died. Leaf thickness between treatments showed no significant difference for this group ( $F = 0.314$ ,  $p = 0.5769$ ). In fact, both treatments showed an average decline in leaf thickness (ambient =  $-0.07 \pm 0.01$  mm, supplemental =  $-0.09 \pm 0.02$  mm, Fig. 3). A difference in fruitset significant to the  $p = 0.0540$  level was shown in the fruitset frequency between treatments, with a  $\chi^2$  value of 3.713 for two degrees of freedom. The number of flowers setting fruits (7 in ambient versus 17 in supplemental, Fig. 4) rather than the number of flowers that did not set fruit drove this difference.

There was no significant difference between treatments for inflorescence, flower and fruit number ( $F = 0.041$ ,  $p = 0.8395$ ;  $F = 0.031$ ,  $p = 0.8598$ ;  $F = 0.241$ ,  $p = 0.6252$ , respectively). However, there was again a significant correlation between the number of leaves an individual plant possessed and the inflorescences and flowers it produced ( $F = 13.866$ ,  $p = 0.0004$ ;  $F = 0.6.633$ ,  $p = 0.0121$  respectively, Fig. 5), though this correlation was again not significantly present in the fruitset ( $F = 2.936$ ,  $p = 0.0909$ ).

#### *Speklinia aristata*

Neither treatment experienced mortality. Leaf thickness differed significantly between treatments across both trees ( $F = 83.139$ ,  $p < 0.0001$ ). Thicknesses also differed significantly between trees ( $F = 8.721$ ,  $p = 0.0036$ ). The control group of *S. aristata* tree two gained more than twice as much leaf thickness as the control group of tree one (tree one =  $0.09 \pm 0.03$  mm gained, tree two =  $0.19 \pm 0.03$  mm gained), while the supplemental mist groups of each tree

gained a more similar amount (tree one =  $0.37 \pm 0.03$  mm gained, tree two =  $0.44 \pm 0.03$  mm gained, Fig. 6).

The frequency of flowers setting fruit showed no significant difference between treatments ( $\chi^2 = 0.335$ ,  $p = 0.5629$ , Fig. 4). However, only a total of seven fruits were produced, all of which were first recorded on May 3 or May 11. Furthermore, the number of inflorescences, flowers and fruits did not display a significant difference between treatments ( $F = 0.397$ ,  $p = 0.5294$ ;  $F = 0.759$ ,  $p = 0.3851$ ;  $F = 0.486$ ,  $p = 0.4866$ , respectively). However, the number of inflorescences and flowers did show a significant correlation with the total number of leaves in a plant ( $F = 6.207$ ,  $p = 0.0138$ ;  $F = 4.610$ ,  $p = 0.0333$ , respectively, Fig. 7), though the number of fruits did not ( $F = 0.020$ ,  $p = 0.8821$ ).

## DISCUSSION

The rapid response exhibited by the plants in my study elucidates the precarious conditions of epiphytes critically dependent on dry season mist for survival. That these plants displayed a significant pattern of increasing fitness in 73 days for the frame and 28 days for the pasture is remarkable, and indicates that the current decreased mist frequency is already having an effect on these epiphytes. This study also demonstrated that orchidaceous epiphytes may serve as indicators of climate change for cloud forests.

Differences in leaf thickness are strongly indicative of differential plant fitness as higher succulence demonstrates no need to draw on moisture stored in tissues (Zotz and Hietz 2001). The significant difference in leaf thickness exhibited by the frame *P. microtatantha* and the *S. aristata* individuals illustrates an increase in water storage and therefore decreased water stress. The difference found between *S. aristata* trees probably occurred because tree two was shadier and less isolated than tree one. That the pasture *P. microtatantha* did not demonstrate a significant difference in leaf thickness, while the frame individuals did, was perhaps due to the shorter supplemental mist treatment in the pasture, and that the pasture tree was more isolated in the relatively bare field than the frame in the denser forest light gap.

However, the pasture *P. microtatantha* was perhaps also allocating moisture resources to producing fruits, possibly to avoid the pulse of insect fruit predators that occurs at the start of the rainy season (Coley and Barone 1996, Shaik et al. 1993). That the pasture *P. microtatantha* showed a significant  $\chi^2$  difference in fruitset frequency while the *S. aristata* did not may have reflected this differential resource allocation. However, significant fruitset may not have occurred in the *S. aristata* simply because of the length of the treatment period was insufficient. Out of 160 of these individuals, only seven produced fruits, and only in the last week of the study period. Perhaps because these plants are larger than *P. microtatantha*, they require a longer period of supplemental mist to produce fruits.

The lack of significant ANOVAs for number of inflorescences, flowers, and fruits between treatments for both pasture species could be explained by insufficient length of time of the supplemental mist treatment. Generally, plants tend to allocate resources to survival before reproduction (Helbsing et al. 2000). Perhaps leaf succulence is therefore a priority over flowering and fruiting, with the lack of succulence in the pasture *P. microtatantha* accounted for

by the alternative priority of herbivore avoidance.

Total leaf number showed significant difference in the frame, with the ambient control group losing more than a quarter of their total leaf number, while the supplemental mist group gained half a leaf. This is certainly an indication of a difference in fitness between individuals that received supplemental mist and those that did not. Furthermore, total leaf number tightly correlated with the number of inflorescences and flowers produced over both pasture species. (The lack of significance in fruitset probably resulted from the small sample size.) This probably occurred because, as Silvertown and Doust (1993) asserted, larger plants have more resources to draw on to produce reproductive structures.

Synthesizing data over all species and sites, it can be inferred that higher mist entails higher number of leaves per plant, which entails higher inflorescence and flower production, which, with added mist, leads to a higher frequency of fruitset. In short, this study exhibits that mist is vital for diverse aspects of epiphytic orchid fitness.

The results of this study are valuable for the continued study of climate change at Monteverde. It is clear that, as surmised by Benzig (1998), Foster (2001), and Nadkarni and Solano (2002), epiphytes present a strong potential indicator species of climate change. In this experiment, fitness differences occurred in remarkably short periods of time, signifying that climate change is already having a discernible effect on these plants. Furthermore, this study has shown that the most substantial family of epiphytes, Orchidaceae, to be affected by climate changes in Monteverde. Given the current consequence of climate change and resulting mist changes in Monteverde and other cloud forests, and the likely increase in importance of climate change in the future, indicator species of climate change would be an incredibly useful tool to record and confirm this phenomenon. Since the alteration of the mist regime is such a pressing issue in the Monteverde cloud forest, I recommend that epiphytic research should place a new priority on studying these organisms in relation to climate change, monitoring their response to changes in the mist regime and further potential as indicator species.

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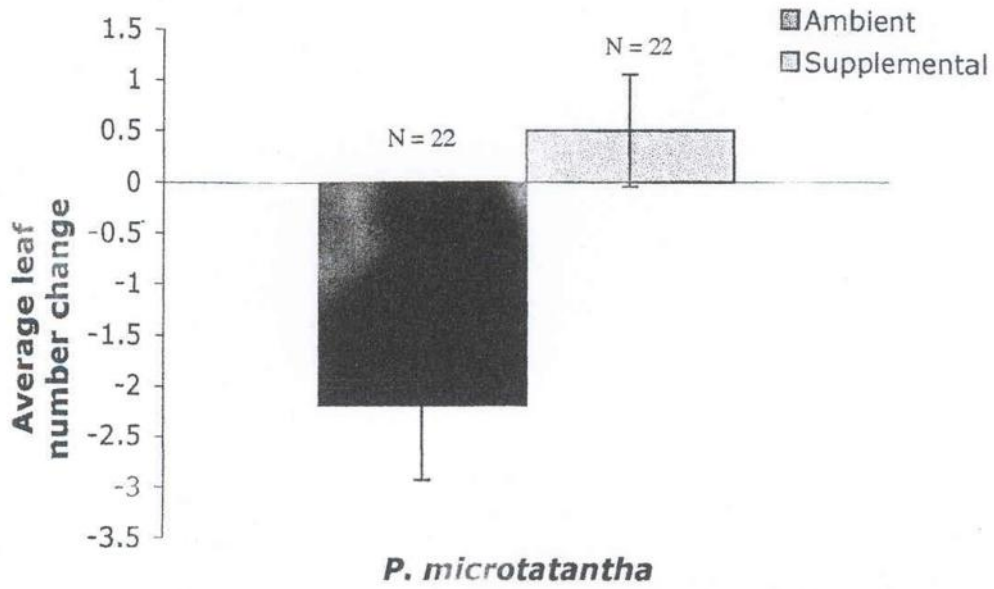


FIGURE 1. Average ( $\pm 1$  SE) leaf number change between treatments for *P. microtantha* individuals growing on the frame.

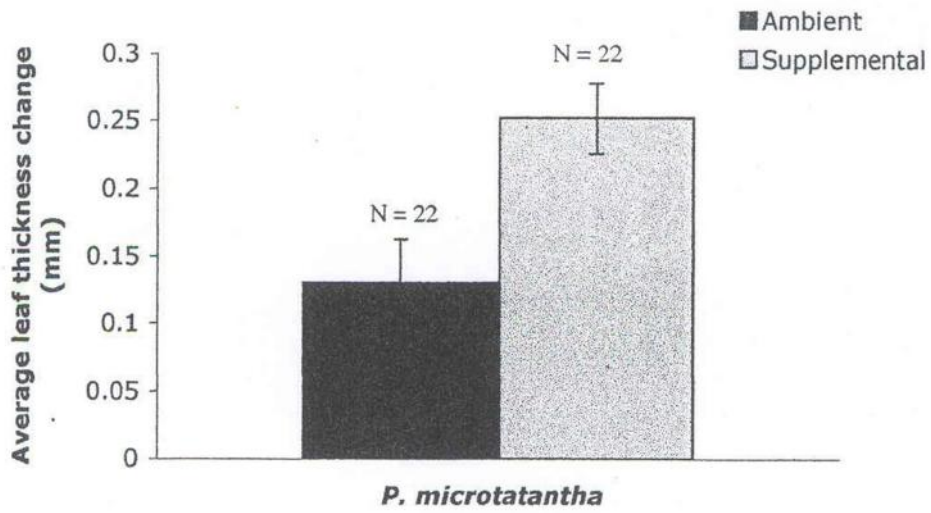


FIGURE 2. Average ( $\pm 1$  SE) leaf thickness change between treatments for *P. microtantha* individuals growing on the frame.

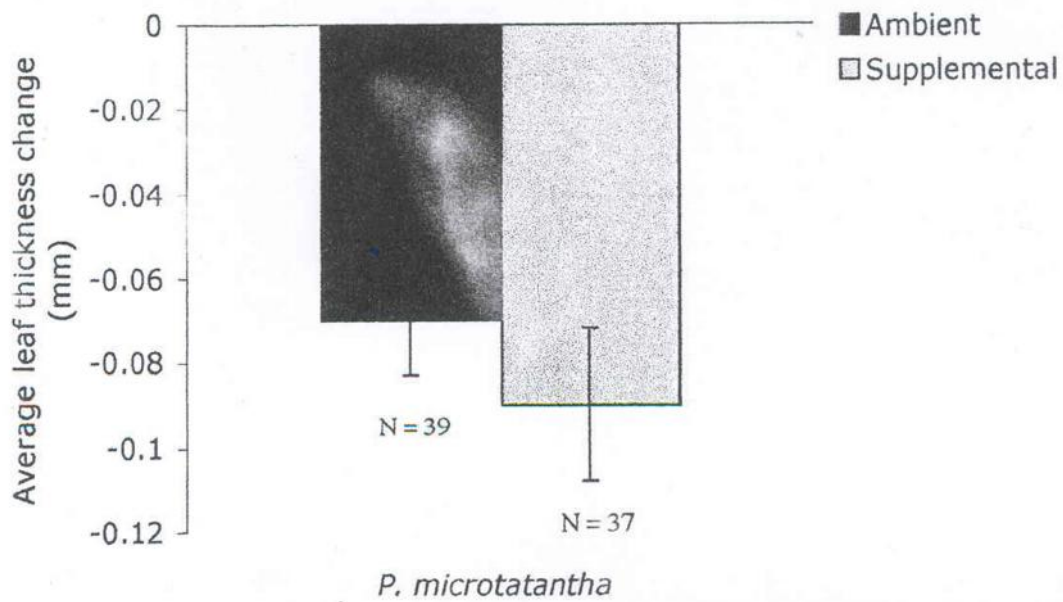


FIGURE 3. Average ( $\pm$  1 SE) leaf thickness change between treatments for *P. microtatantha* individuals growing in the pasture.

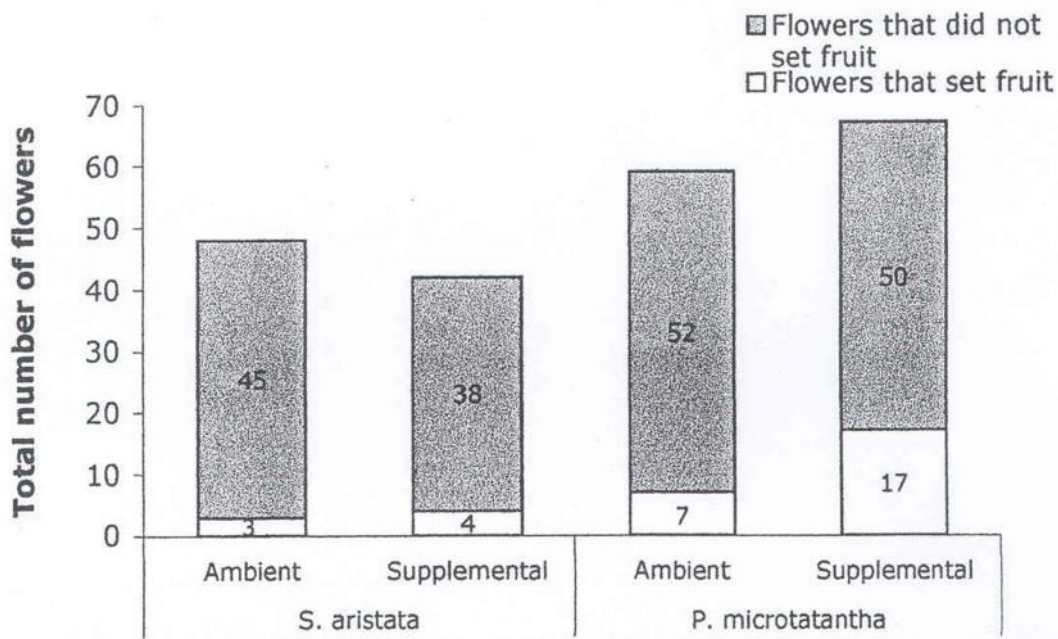


FIGURE 4. Ratio of flower number to number of fruits produced between treatments for both pasture species. Data for both *S. aristata* groups are combined.

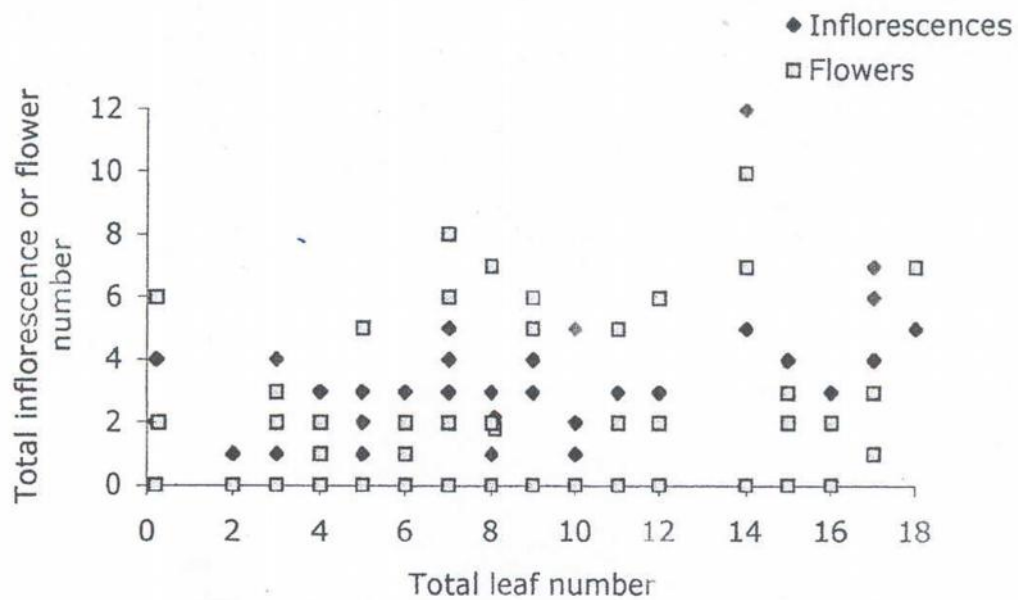


FIGURE 5. Total leaf number per individual versus total inflorescences and total flowers for the *P. microtatantha* individuals growing in the pasture.

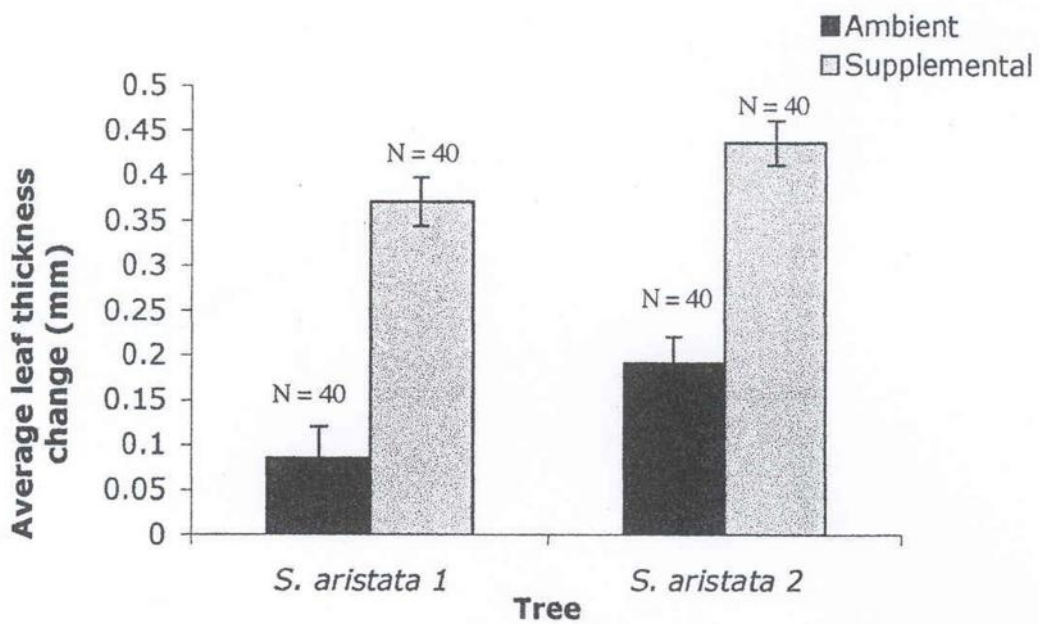


FIGURE 6. Average ( $\pm$  1 SE) leaf thickness change between treatments for the two *S. aristata* groups growing on trees in the pasture.

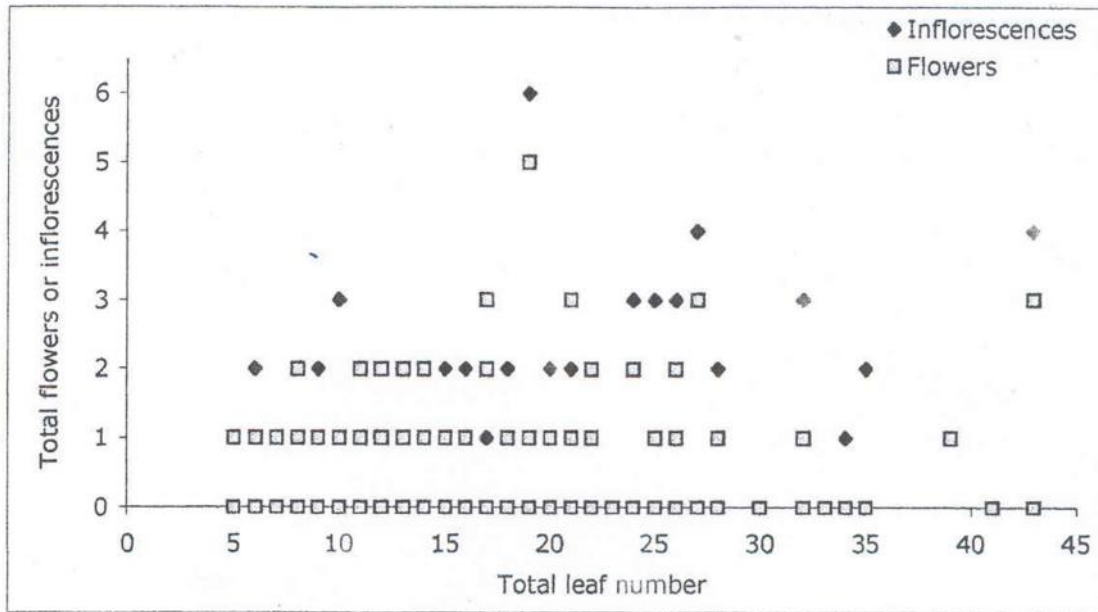


FIGURE 7. Total leaf number per individual versus total inflorescences and total flowers for the *S. aristata* individuals.