Detritus, Water Volume, and pH in Epiphytic Bromeliads' Central Tank

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Abstract:

Tropical plants are known for their highly efficient nutrient cycles; some of the best examples of this are epiphytic bromeliads. Epiphytic bromeliads rely solely on precipitation and leaf detritus for nutrients; such as nitrogen and phosphorous. However, little is known about the impact of detritus and water volume on the central tank chemistry in these bromeliads. Using pH as a bioindicator, this study examined this relation in epiphytic bromeliads along the Continental Divide in Monteverde, Puntarenas, Costa Rica. The collected data showed no statistical significance in pH when compared by four categories: (1)Detritus Dry Weight, (2)Total Water Volume, (3)Ratio of Dry to Wet Detritus Weight and (4)Ratio of Dry Detritus Weight to Total Water. Detritus was also ranked qualitatively on a scale from one to five based on decomposition level. The pH of these groups was compared by Kruskal-Wallis test and found not to be significant. Differences in pH imply either synergistic effect between two or more of these groups or influence from physiological characteristics of the bromeliad itself.

Key words: bromeliad, detritus, epiphyte, pH, water volume

Resumen

Los plantas tropicales son conocidas por sus eficientes ciclos de nutrientes; algunos de los mayores ejemplos son las bromelias epifítas. Las bromelias epifitas cuentan con la precipitación y los detritos solamente de hojas como nutrientes; tales como nitrógeno y fósforo. Sin embargo poco se conoce sobre el impacto de los detritros y volumen de agua en la química del tanque dentro de estas bromelias. Al usar pH como un indicador biológico, este estudio examinó la relación entre bromelias epifitas en la division continental en Monteverde, Puntarenas, Costa Rica. Los datos recogidos no mostraron una diferencia siginificativa en pH cuando se compararon cuatro categorías: (1)Peso Seco del Detrito, (2) Todo Volumen de Agua, (3) Relación de Detrito Seco a Mojado y (4) Relación del Peso Seco de Detrito con todo el Volumen de Agua. Los detritos fueron clasificados cualitativamente en una escala de uno a cinco basado también en el grado de descomposición. El pH de los grupos fue comparado con la prueba de Kruskal-Wallis y no se encontró ninguna diferencia significativa. Las diferencias en pH implican ya sea un efecto sinérgico entre dos o más de estas grupos o una influencia de características fisiológicas de la bromelia en sí misma.

Introduction

Epiphytic Bromeliads are often called '"aerial marshes"', but unlike terrestrial water bodies which get nutrients from silt and soil, these plants must rely solely on nutrients from detritus, specifically decaying leaf material, to survive.[1] Epiphytic bromeliads are a highly specialized group of vascular plants from the Bromeliaceae family. They are important in Neotropical forests in nitrogen and phosphorous cycles, as well as increasing biomass and providing unique habitats. By growing leaves in a tight, overlapping rosette pattern bromeliads form a central tank for nutrient and water collection. Their morphology also allows them to grow on trees and branches with no contact to the ground. Since epiphytic bromeliads do not absorb nutrients from their substrate, they are highly dependent on detritus and precipitation trapped in their central tank for sustenance.[2]

Figure 1: Example of epiphytic bromeliad.[3] Bromeliad depends solely on water and nutrients stored in its central tank for survival. Breakdown of detritus is the source of nutrients for central tank.

Detritus, as well as the bacteria, fungi, and protozoa that consume it, live in the bromeliad's central tank and make up the basic trophic level of bromeliad habitats.[4,5] These organisms perform anaerobic and aerobic respiration, and release CO_2 as a byproduct of detritus decomposition.[6] Dissolved carbon dioxide reacts with water to form dissociated carbonic acid (Fig. 1). This reaction can lower the pH of the water. The actions of the biota present in the central tank therefore affect the chemistry of the water present in the central tank.[7]

Research has been done on the microfuana of epiphytic bromeliads and on how detritus affects terrestrial bromeliads.[7,9,10,11,12] However, little is known about effects of detritus on the chemistry in the central tanks of epiphytic bromeliads. The focus of this experiment is to test whether detritus and water volume amounts influence epiphytic bromeliad tank environment. This study uses the pH of the water in the central tank as a bioindicator of respiration and decomposition. This research is important in identifying and exploring the nutrient cycling processes of the unique habitats formed by epiphytic bromeliads.

$$CO_2 + H_2O \leftrightarrow H^+ + HCO_3^-$$

Figure 2: Reaction of aqueous dissolved carbon dioxide to dissociated carbonic acid. pKa=6.35.[7]

Methods

Sampling Site

This study was conducted in the Monteverde Cloud Forest, in Puntarenas, Costa Rica along the Continental Divide near Cerro Amigos and the Monteverde Biological Station property (Fig. 2). All samples were taken on the Pacific slope (10° 19' N, 84° 47-8' W) during the wet season, (July 23rd-31st 2012) at an altitude of 1845 asl. The site is classified as lower montane wet forest by the Holdridge life zones; with an average yearly rainfall of 3.5 meters.

Bromeliad Selection

Individuals were sampled only along the Pacific slope of the continental divide. This insured similar exposure to conditions such as wind, precipitation, and sunlight. The Continental Divide was selected because strong winds keep trees shorter, making them easier to work with. Within the selected area, there was variability in the microhabitats where the epiphytes grew. For this experiment a strict set of criteria were imposed on possible samples. This was done to minimize any confounding variables that might impact the study. Only specimens found at eye level or below in areas of at least partial shade during the day were sampled. Any specimens found in light patches or on downed trees not overshadowed were avoided. There were no restrictions placed on species, genus, or morphospecies of bromeliads used. Only bromeliads with a tank diameter of 4 cm were sampled (Fig. 3). There was also no specification of the substrate on which the individual grew.

Sampling Procedure

Once a bromeliad had been selected, detritus was remove and bagged. Latex gloves were worn to protect the material removed. After any major debris was removed, a pipette was used to siphon off any water in the central tank and surrounding rosette. This liquid was then transferred to a water tight container. The pH of the solution was measured using a portable pH meter. The vial was then labeled with the sample number and pH reading. Any further detritus was collected from the specimen. The leaves' crevices were probed with a finger and any available material was removed. The sample was then examined for extent of detritus decay. A qualitative scale was used to rank the detritus from one to five, with a one corresponding to solid detritus, a five corresponding to complete decomposition, and a three being about fifty-fifty (Fig. 4). The amount of detritus was not considered, only the level of decomposition.

Detritus and Water Weighing

Detritus and water samples were kept refrigerated overnight in the lab. The samples were then removed from storage and their individual bags. The detritus was compacted by hand in the bag and any excess water was removed through applied pressure. The matter was removed by hand and placed in a paper towel of a standardized weight (1.45 g). The inside of the bag was then cleaned to remove any additional debris. The paper towel and detritus were weighed using a standard scale. The detritus was placed in a hot box at 66°C for twenty four hours. The detritus was removed and weighed again. This revealed the dry weight of the detritus and the weight of the water that had been sequestered in the decomposition process. Sequestered water was assumed to be the difference between wet weight minus dry weight. After this, the detritus was discarded.

Water samples were centrifuged to remove suspended debris. The free water was transferred to a container, weighed and discarded.

Results

Detritus and water volume amounts were found to have no significant impact on epiphytic bromeliad tank water. Five parameters were investigated in this study: (1) Dry Weight, (2) Total Water Volume, (3) Ratio of Dry to Wet Detritus Weight, (4) Ratio of Dry Weight to Total Water and (5) Detritus Decomposition Level. The first four sets were log transformed to create normal distributions. This allowed for regression comparisons with pH, which was found to be normally distributed already.

The regression between pH and log Dry Weight (ANOVA F=2.020, p>.05, DF=34) showed no statistical significance. Dry weight did have the greatest influence on pH (correlation coefficient=0.24) but was still not significantly different than zero. A coefficient between 0.1 and 0.3 is considered to be a small relationship between the variables.[13] The three parameters (Total Water Volume, Ratio of Dry to Wet Detritus Weight and Ratio of Dry Weight to Total Water) also fit this trend, but had lower correlation coefficients (0.13, 0.09, and 0.06). All four showed wide spreading (Fig. 6), and all four have low F statistics (Table 1).

The pH was investigated at different Detritus Decomposition Levels. The samples were grouped by decomposition level (1, 2, 3 and 4+) (Fig. 7). Categories 4 and 5 were

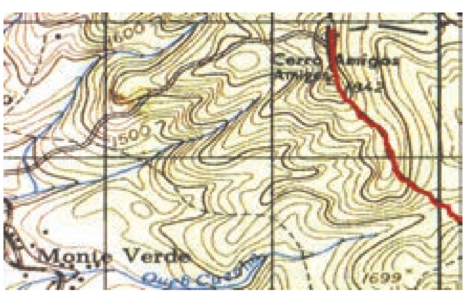

Figure 3: Topographic map of Monteverde, Puntarenas, Costa Rica. Red line indicates Pacific slope of Cerro Amigos.

Figure 4: Example of epiphytic bromeliad sampled. Specimen grew on main trunk of a tree along the Continental Divide in Monteverde, Costa Rica. Habitat conditions included strong winds, precipitation from clouds and being shaded for part of the day.

Figure 5: Detritus removed from a sample epiphytic bromeliad. A qualitative scale was used to classify each sample by decomposition level. From one to five the scale progressed from solid matter to complete decay. This sample was ranked a three out of five.

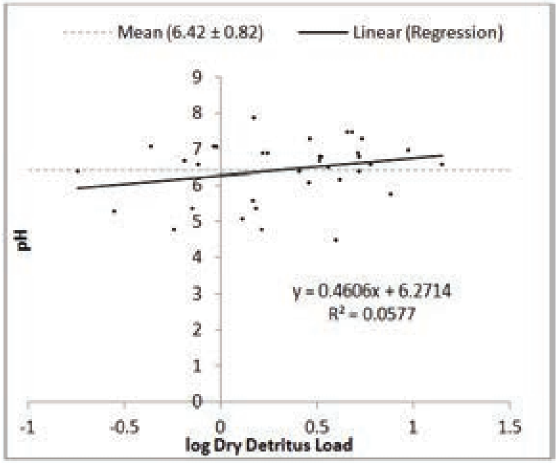

Figure 6: The effect of detritus load (mean weight 0.46 ± 0.32) on water pH in the central tank formed by the leaf rosette of epiphytic bromeliads. Samples were taken along the continental divide in Monteverde, Puntarenas, Costa Rica. pH ranged from 4.8-7.9 with a mean of 6.42 ± 0.82. A non-statistically significant positive correlation is present in graphs depicting pH as a function of the log transformed data of Total Water Volume, Ratio of Dry to Wet Detritus Weight and Ratio of Dry Weight to Total Water (0.12 ± 0.33, -0.59 ± 0.77 and 1.9 ± 2.6 respectively.

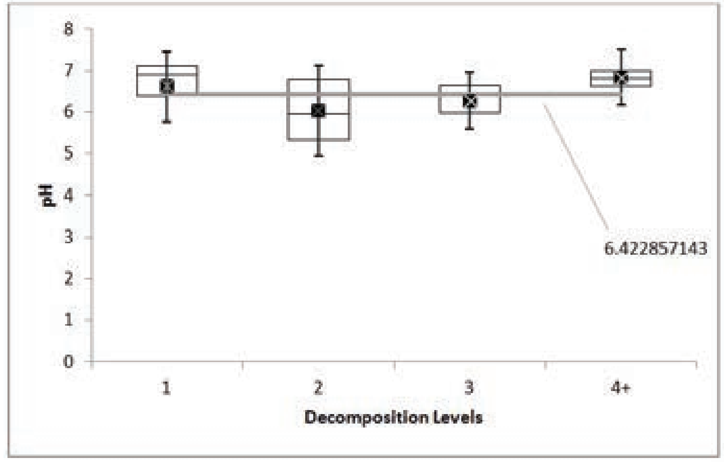

Figure 7: Box and Whisker plots of pH and detritus decomposition level. Level 4+ is a combination of samples with highest decomposition levels. Whiskers represent one standard deviation from the mean. Level 4+ had the most basic average pH of 6.83 ± 0.41. The lower levels (1, 2, 3) all have slightly more acidic pH averages (6.62 ± 0.84, 6.03 ± 1.09, 6.27 ± 0.67). The overall mean pH was 6.42. Samples were taken along the continental divide in Monteverde, Puntarenas, Costa Rica.

combined to 4+ to meet minimum sample size to run a non-parametric test. The Kruskal-Wallis test returned no statistical difference in mean pH between the groupings ($\chi 2=5.08$, $p>.05$, DF=3).

Discussion

These investigations showed no statistically significant relationship between detritus amount, decomposition level, and the central tank's pH for epiphytic bromeliads. This implies that the pH is not solely dependent on either the decomposition or on the amount of leaf material in the central tank. This finding is supported by research done by Benzing *et al.* in which terrestrial bromeliads were found to create stable microhabitats with little variation based on external factors.[7] It was also thought that because bromeliads are exposed to varying precipitation levels, the central tank pH would simply be a function of dilution. To test this, pH was compared to Total Water Volume and was found to have no statistical significance. This indicates that pH depends on more factors than precipitation input.

It was hypothesized that the decomposition level of matter in the bromeliad would influence the central tank's water pH. As heterotrophs consume the detritus for respiration, they release CO_2.[5] It was thought that this byproduct would lower pH as carbon dioxide reacts with water. Higher decayed matter was assumed to have been present in individuals longer and that more of its carbon would have been reduced and released as CO_2. This should result in a lower pH of the aquatic environment. Data from this showed that litter decomposition level had no statistical effect on pH.

Table 1: Test statistics from the four linear regression correlation tests. All four had low F statistics and high p values. Only dry detritus weight had a small correlation with pH value; all others had coefficients that signified no impact.

Regression of pH by	F statistic	p value	dF (Model,Error)	R^2 value	Correlation Coefficient
Dry Detritus Weight	2.020	>.05	1,33	0.057	0.24
Total Water Volume	.1315	>.05	1,33	0.004	0.06
Ratio of Dry to Wet Detritus Weight	.5384	>.05	1,33	0.019	0.13
Ratio of Dry Weight to Total Water	.5382	>.05	1,33	0.10	0.09

The more degraded leaf matter corresponded to more basic water (Fig. 7). Level 1 detritus, which corresponds to no decomposition in the matter, had an average pH close to that of measured rainwater pH (6.42) in Monteverde.[14] Then for Level 2, the water had the lowest pH. The water became more basic in Level 3 and Level 4+ had the most basic pH. This could be due to an initial surge of degradation thus releasing carbon dioxide from the material. In a study of terrestrial bromeliads, the microhabitat was characterized as dominated by respiration consumers.[11] This appears to hold true, at least at low decomposition levels, for the epiphytes in the family. After the initial break down, there seems to be a period of stabilization. This effect could come from the host bromeliad itself in an attempt to keep a favorable central tank environment.[11] This could signify that the bromeliad processes are most efficient at a specific pH, and that the plant has pathways to maintain this equilibrium.[15]

The investigation of the relationship between pH parameters of detritus and water volume revealed no significant results. Neither the detritus nor the water volume seemed to affect the habitat of the bromeliads. The amount of dry detritus had the biggest impact on pH. Biologically this implies that the amount of available material for degradation does play some role in the chemistry of the central tank water, even if it is a minor one. However, since there was some noticeable difference in pH for all four comparisons, maybe there is a synergistic effect between two or more of these categories. This opens up the possibility of research that investigates the relationship between epiphytic bromeliads, habitat, and tank water.

Epiphytic Bromeliads offer a unique research opportunity. Their evolution has turned them into little microcosms of life. More research needs to be done to better fully understand how these plants are able to survive, and thrive, under conditions that seem inhospitable.

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