Final Report – Cornell Field Course BioEE 660

January 2005

Course Instructors:

Dr. Jed P. Sparks, Assistant Professor

Dr. Drew Harvell, Professor

Dr. Nelson Hairston, Professor

Course sponsored by:

Cornell University and the Kohala Center

Mailing Address:

Dr. Jed P. Sparks
Department of Ecology and Evolutionary Biology
Cornell University
Ithaca, NY 14853

Telephone Number 607-254-427 **FAX** 607-255-8088

E-mail address jps66@cornell.edu

Overview of Course

This course is a graduate-level field research course with the goal of educating beginning graduate students in the methodologies of modern ecological research. It is also motivated by a desire of the instructors to introduce the next generation of scientists to the ecosystems of Hawaii. The course is divided into three parts: terrestrial forest ecology, marine ecology, and the study of freshwater ecosystems. This report will be limited to the terrestrial ecology part of the course.

Students participating in this course (Cornell course number – BIOEE 660 Field Studies in Ecology and Evolutionary Biology) design and implement an experiment asking some question about the ecology of Hawaiian ecosystems. During the course in 2005, the students examined the variation in leaf morphology, photosynthetic performance, and nutrient dynamics in 'Ohi'a lehua *(Metrosideros polymorpha)* over elevation and substrate variation on the Island of Hawaii. The study involved the sampling of leaves for morphological, chemical, and isotopic analyses along an elevation gradient in the Hilo, Upper Waiakea, and Mauna Loa State Forest Reserves adjacent to Saddle Road and the Mauna Loa Observatory Access Road. At each site, leaves were collected and photosynthetic parameters were measured using non-destructive cuvette systems (LiCor 6400 portable gas exchange system).

Study sites

Six sites were used for the study in 2005. Four located within the Hilo, Waiakea, and Mauna Loa SFRs (listed below) and two located on private property near the city of Hilo. The SFR sites used were:

Site A: 1855 flow at 3800' along Saddle Road, Hilo SFR.
Site B: 1855 flow at 5400' along Saddle Road, Upper Waiakea SFR.
Site C: 1855 flow at 8000' along Mauna Loa Observatory Access Rd, Mauna Loa SFR.
Site D: 1881 flow at 8000' along Mauna Loa Observatory Access Rd, Mauna Loa SFR.

Methods used

Ten leaves from ten trees were sampled from each site. Leaves were excised using a razor blade and the utmost care was taken to minimize impact on individual trees. Photosynthetic measurements were made by placing intact leaves into a cuvette system (LiCor 6400, LiCor Inc.). Collected leaf samples were measured and dried in Hawaii and then mailed to Cornell University. Once back at Cornell, leaves were analyzed for nitrogen content, stable isotope ratio (both for carbon and nitrogen) and further examined for morphological variation.

Results and Discussion

Morphological information

Leaves of 'Ohi'a lehua (*Metrosideros polymorpha*) exhibited significant variation across the range of elevational sites examined. Individual leaves decreased in total area as elevation increased. From Hilo to Mona Loa average leaf area decreased by > 40%. In addition, leaves became significantly thicker across the elevation gradient (400% increase between 500 and 8000 ft.). Pubescence (i.e., the degree of hairiness) increased significantly with elevation. No pubescent individuals were observed below 3000 ft. elevation. Between 3000 and 4000 ft. elevation a mixture of pubescent and glabrous (hairless) individuals were observed. Above 4000 ft., most leaves observed were pubescent and pubescence (both density and length of hairs) increased with elevation.

The change in leaf morphology observed in 'Ohi'a lehua is a pattern often observed over elevational transects. Leaves, on average, tend to become smaller and thicker and pubescence, if present, increases with elevation. The evolutionary pressure driving this variation has been debated and several driving factors that vary with elevation have been suggested: increases in UV radiation, decreases in temperature, changes in the partial pressure of carbon dioxide, changes in precipitation. Regardless of the driving force, changes in leaf morphology have significant implications for the photosynthetic performance of plants. The broad elevational distribution of 'Ohi'a lehua and our ability to monitor individuals along a similar substrate (a single lava flow) allows to directly assess the influence of leaf morphology on photosynthetic performance.

Isotopic information

The carbon isotope ratio of leaf material increased from -29‰ to -25‰ in Ohia lehua and from -31‰ to –28‰ in vaccinium over elevation (Fig. 1). The carbon-isotopic composition of foliage is a reflection of the integrated ratio of the leaf internal to external carbon dioxide concentration (c_i/c_a) experienced by the leaf over its lifetime. Therefore, the $\delta^{13}C$ value contains useful information concerning the photosynthetic process. In the case described here, the leaf value moves in the positive direction as elevation increases. This means c_i and c_a diverge from each other at higher elevations. Two separate processes could account for this divergence. First, the total amount of leaf carboxylation enzymes could increase with elevation (i.e., plants at higher elevation draw down c_i more efficiently). Second, the diffusional pathway of carbon dioxide into the leaf is longer at higher elevations (i.e., leaf thickness and the effect of pubescence on the leaf boundary layer decreases the rate of carbon dioxide diffusion into the leaf).

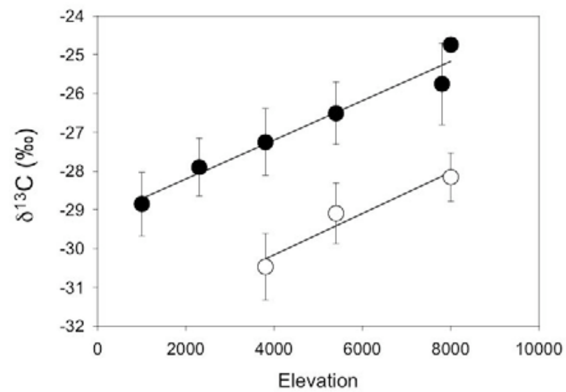

Figure 1. Carbon isotope ratio of leaf material of Ohia lehua (closed circles) and vaccinium (open circles) over elevation on the windward side of Hawaii.

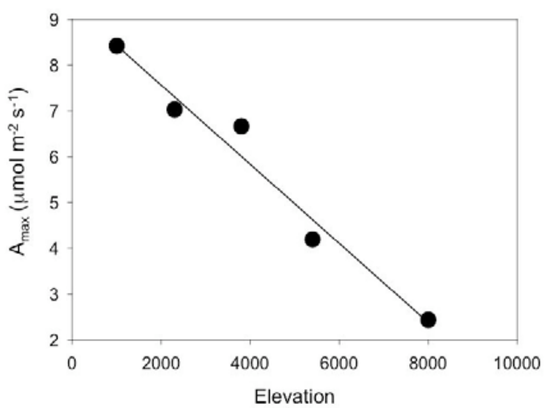

Figure 2. Maximum photosynthetic rate in Ohia measured at saturating light conditions (1400 µmol m^{-2} s^{-1}) over elevation. Each datapoint is a mean of 10 leaves.

Leaf nitrogen

Leaf nitrogen remained relatively constant within each species over elevation (data not shown). Leaf nitrogen can be used to estimate the amount of the primary carboxylating enzyme (RuBP carboxylase) found per unit of leaf area as it is the primary source of nitrogen in a plant leaf. Within Ohia lehua and vaccinium this appears to be relatively constant with elevation.

Plant gas exchange measurements

Maximum photosynthetic rates at saturating light conditions significantly declined with elevation in Ohia (Fig. 2). Given the similar nitrogen contents observed in leaves across elevation (see above), a decline in maximal photosynthetic rate is likely due to some change in morphology that increases the pathway resistance for carbon dioxide diffusion into the leaf.

A method for estimating the diffusional resistance for carbon dioxide into the leaf is to vary the leaf external carbon dioxide concentration and simultaneously measure the photosynthetic rate and c_i. This is referred to as an A-c_i curve. The initial slope of the relationship between the internal carbon dioxide concentration and the photosynthetic rate is proportional to the supply of carbon dioxide to the dark reactions of photosynthesis. This slope is often expressed as a single value V_{cmax}. V_{cmax} is the carbon dioxide concentration (measured in μmol CO_2 per mol of air) where photosynthesis is no longer limited by the diffusion rate of CO_2. For Ohia growing along an elevational gradient in Hawaii, V_{cmax} significantly increased with elevation (Fig. 3).

The increase of V_{cmax} over elevation suggests the rate of carbon dioxide diffusion is slower in Ohia leaves from higher elevation. This observation is consistent with the morphological characteristics of leaves from higher elevation sites. Thicker leaves would have a longer diffusional pathway for carbon dioxide. Additionally, pubescence would increase the thickness of the boundary layer surrounding the leaf further lengthening the carbon dioxide diffusion pathway.

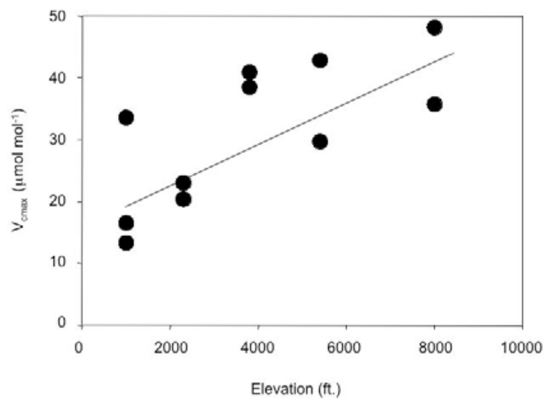

Figure 3. V_{cmax} (see text) in Ohia over elevation. Each point is the mean of three trees.

The work reported here demonstrates that leaf morphology varies significantly with elevation in Ohia lehua on the Big Island of Hawaii and that this variation has implications for the productivity of individuals growing at high elevation.

This work did not address why Ohia lehua exhibits different leaf morphologies depending on the elevation of the growth environment. In future offerings of BioEE 660 we suggest an examination of the resistance to UV radiation and temperature buffering across the leaf morphologies exhibited in Ohia lehua.