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Mauto (*Lysiloma divaricatum*, Fabaceae) Allometry as an Indicator of Cattle Grazing Pressure in a Tropical Dry Forest in Northwestern Mexico

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Abstract

Mauto (*Lysiloma divaricatum* (Jacq.) J. F. Macbr.; Fabaceae) is a thornless, arborescent legume that is abundant in tropical dry forests in northwestern Mexico. To test whether mauto allometry may be used as an indicator of cattle grazing pressure, we compared plant height, canopy cover, and basal trunk diameter between an area where cattle had been excluded for 12 years with an area under continuous heavy cattle grazing. Mauto plants that had mostly avoided grazing grew to 12 m in height, with an average basal trunk diameter of 11 cm. Under intense grazing, many plants appeared as a bonsai, that is, as small pruned trees with a relatively thick trunk. Such differences were expressed in the linearized (log-log) slopes of the height–diameter and cover–diameter allometric relationships, which varied significantly between the grazed and ungrazed areas. Basal trunk diameter increased faster per unit increase in plant height and canopy cover in the grazed area than in the ungrazed area. Therefore, these morphological or allometric relationships of mauto could be useful for quickly assessing cattle grazing pressure in tropical dry forests.

Resumen

El mauto (*Lysiloma divaricatum* (Jacq.) J. F. Macbr.; Fabaceae) es una planta leguminosa arborescente y sin espinas que es abundante en bosques deciduos tropicales del noroeste de México. Con el objetivo de probar si la alometría del mauto puede ser usada como indicador de la intensidad del pastoreo por ganado, comparamos la altura de la planta, cobertura del dosel y diámetro basal del tronco entre un área en donde el ganado había sido excluído durante 12 años y un área en donde el pastoreo había sido constante y severo. Los árboles sin ramoneo pueden crecer hasta 12 m de altura y mostraron un diámetro basal promedio de 11 cm. Las plantas sujetas a intenso ramoneo adquieren forma de bonsai, o sea, arbolitos podados con troncos relativamente gruesos. Tales diferencias se vieron reflejadas en las pendientes de las relaciones linearizadas (log-log) entre altura y diámetro y entre cobertura y diámetro, que fueron significativamente diferentes entre ambas áreas de estudio. El diámetro basal del tronco se incrementó más rápidamente por unidad de incremento de altura y de cobertura en las plantas del área pastoreada que en las del área no recientemente pastoreada. Por lo tanto, estas relaciones morfológicas o alométricas del mauto podrían ser usadas para determinar rápidamente la intensidad del pastoreo por ganado en bosques deciduos tropicales.

Key Words: forest grazing, Baja California Sur, Sierra La Laguna Biosphere Reserve

Nomenclature: Wiggins (1980) and Roy Gereau (Missouri Botanical Garden)

INTRODUCTION

Niklas (1994) defines allometry as the study of size-correlated variations in organic form and process. In its general usage, allometry has 2 meanings: 1) the growth of a part of an organism in relation to the growth of the whole organism or some other part of it and 2) the study of the consequences of size on organic form and process. Allometric relationships have been studied for a broad spectrum of species in order to find patterns and models (Niklas 1993). Additionally, allometry has been studied in order to assess the effect of human activities and browsing impact on the morphology of plants. For example, Stirling et al. (1998) analyzed the effects of different concentrations of CO_2 and temperature on allometric growth patterns of 5 annual plants. Escós et al. (1997) studied the impact of grazing by sheep and goats on the variation in the allometric relationships between plant parts on a Mediterranean shrub (*Anthyllis cytisoides*), concluding that these relationships provide a sensitive indicator of the impact of grazing. Grace and Fownes (1998) found that browsing altered allometric relationships in *Acacia koa*. These contributions are relevant to understanding the impact of human-related disturbances on plant allometry, but studies are scarce, particularly in dry tropical forests.

This study determines the usefulness of plant allometry as an indicator of the impact of cattle grazing. We used mauto (*Lysiloma divaricatum* (Jacq.) J. F. Macbr.), a dominant, thorn-

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Figure 1. Tropical dry forest study area in the Sierra La Laguna Biosphere Reserve, State of Baja California Sur, Mexico.

less, leguminous dry tropical forest tree in the mountainous Sierra La Laguna Biosphere Reserve in the southernmost part of the Baja California Peninsula, Mexico. If undisturbed by large grazers, this tree of the legume family can reach 15 m, usually displays an umbrella-shaped crown with an average crown height of 5 m and a canopy cover around 15 m^2, and has a single trunk with an average basal diameter of 10 cm, and the lower branches sprout from the trunk at 1.5 to 3 m aboveground (Shreve and Wiggins 1964; Breceda et al., unpublished data 2005).

Specifically, we compared the size and morphology of mauto exposed to cattle grazing with these characteristics in areas where cattle had been excluded for 12 years. The morphological variables measured were height, crown cover, and basal diameter of the trunk. Additionally, crown shape was recorded. We predicted that cattle grazing would significantly affect the allometry of mauto.

STUDY AREA AND METHODS

Study Area

This study was conducted in the Sierra La Laguna Biosphere Reserve, located in the southernmost part of the Baja California Peninsula, Mexico. The study site is in La Zorra Canyon (23°30′0″ N, 109°49′36″W), at about 490 m elevation (Fig. 1). Mean annual temperature is 23.5°C in this area. January has a mean temperature of 16.9°C, and July has a mean temperature of 29.8°C. Annual rainfall is 303 mm, with late summer being the main rainy season, followed by 8 dry months (García 1973; Coria 1988). The soil is a eutric regosol with sandy texture, low organic matter content, and shallow depth resulting from steep sloping parent rock (Maya 1991) and erosion from infrequent but severe tropical storms. Slopes are typically about 30%, with a northwest–southeast ridge and drainage orientation. At this altitude, the predominant vegetation is a tropical dry forest, which grows under strong seasonal rainfall and is characterized by the loss of leaves and understory during the dry months. According to León de la Luz (1999), the tropical dry forest of the Sierra La Laguna contains 520 species within 312 genera and 92 families. Most plant species in this community are annuals, perennial herbs, and shrubs. The structurally and compositionally important families are Fabaceae, Gramineae, Euphorbiaceae, Compositae, and Cactaceae (Breceda 1994). Shrubs and trees with the greatest vegetation cover are *Jatropha cinerea* (C. G. Ortega) Muell.-Arg, *J. vernicosa* Brandegee, *Lysiloma divaricatum* (Jacq.) J. F. Macbr, and *Tecoma stans* (L.) Juss. The most important herbs and annuals are *Bouteloua* spp., *Cnidoscolus angustidens* Torr., and *Carlowrightia californica* Brandegee (Breceda 1994). This reserve has significant biological, environmental, social, and economic importance. It contains 92 endemic plant and animal species (Arriaga 1994), is the main source of water in the region, and is the resource base that sustains numerous small settlements devoted to extensive cattle ranching. About 7 250 cattle graze in the reserve, and the estimated stocking density is 19 ha/AUY (per animal-unit year) in the buffer zone, where grazing is permitted (Breceda et al. 2005). Overgrazing is suggested because the national rangeland office recommends a stocking rate of 25–35 ha/AUY for similar areas (Martínez-Balboa 1981). Cattle forage in pastures and on leaves, stems, and fruit of numerous shrubs and trees. For this tropical dry forest, there are 40 plant species serving as the most important livestock feeding resources, including herbs, vines, shrubs, and trees (Arriaga and Breceda 1999).

Table 1. Descriptive statistics for morphological variables of mauto in protected and grazed areas.

Area	Variable[1]	N	Mean	Standard error	Range
Protected	H	577	161 cm	141 cm	1–1 700 cm
	C	577	17 452 cm^2	65 209 cm^2	4–942 480 cm^2
	D	577	2 cm	3 cm	0.1–45 cm
Grazed	H	433	64 cm	168 cm	1–1 700 cm
	C	433	24 538 cm^2	112 300 cm^2	4–942 480 cm^2
	D	433	3 cm	9 cm	0.1–45 cm

[1]H = height, C = crown cover, and D = basal trunk diameter.

Experimental Design

In September 1999, 2 adjacent 1.5-ha areas were delineated. Cattle had been excluded from 1 area during the previous 12 years, and the other area had been continuously grazed. The 2 areas have similar temperature, soil texture, parent rock, slope, physical appearance, and aspect. In order to obtain a random sample of mauto plants in each condition, we measured all plants growing in 15 randomly selected 10- × 10-m quadrants in each area. All mauto plants were identified, and their height (cm), crown cover (cm^2), and basal diameter (cm) were measured. Crown cover was estimated with the ellipse formula: $C = 0.25\pi\ (D_1)\ (D_2)$, where D_1 is the largest crown diameter and D_2 is the diameter perpendicular to D_1. Basal diameter was measured with vernier and tape measure, crown diameters were measured with fiberglass tapes, and plant height was measured with a telescoping measuring rod. A total of

577 trees were measured in the protected area, and 433 trees were measured in the grazed area.

Statistical Analyses

To analyze and compare allometric relationships between plant height, crown cover, and basal trunk diameter in the 2 areas, reduced major axis regressions (RMA, a type II regression technique), and Pearson correlation coefficients (r) were calculated. To facilitate the analyses, the relationships between variables were first linearized using logarithms to the base 10, such as $\log Y = \log a + b \log X$, where X and Y are morphological variables. Calculations were performed in Excel 97 for Windows and Statgraphics 1.4 for Windows. RMA analysis is preferred over least-squares regression analysis when both variables are assumed to have an associated error term and there is no independent variable (La Barbera 1986; Rich et al. 1986; Bertram 1989; Niklas 1994).

RESULTS

Descriptive statistics of plant height, crown cover, and basal trunk diameter for the two conditions are shown in Table 1. Allometric relationships between height and crown cover was statistically similar between the grazed and ungrazed areas, as indicated by the overlap of 95% confidence intervals for the slopes (Table 2). However, relationships between height and basal diameter and between crown cover and basal diameter were different between protected and grazed areas, indicated by the lack of overlap of corresponding confidence intervals (Table 2). These results show that mauto trees in the grazed area have a greater basal diameter than in the ungrazed area for plants with the same height and crown cover.

Table 2. Reduced major axis (RMA) regression between morphological variables and 95% confidence intervals for slopes.

Area	Relation (Y, X)[1]	Model (RMA)	r	95% confidence intervals for slope	
				Lower	Upper
Protected	C vs H	$\log Y = -0.38 + 1.92 \log X$	0.935	1.86	1.98
($N = 577$)	D vs H	$\log Y = -1.20 + 0.71 \log X$	0.769	0.66	0.76
	D vs C	$\log Y = -1.06 + 0.37 \log X$	0.807	0.35	0.38
Grazed	C vs H	$\log Y = -0.09 + 1.94 \log X$	0.935	1.87	2.01
($N = 433$)	D vs H	$\log Y = -1.15 + 0.86 \log X$	0.835	0.81	0.91
	D vs C	$\log Y = -1.11 + 0.44 \log X$	0.864	0.42	0.46

[1]H = height, C = crown cover, and D = basal trunk diameter.

In the grazed area, about 14% of the mauto plants showed a "bonsai" morphology (Fig. 2A), with basal diameter proportionately increasing faster than height and crown cover. Mauto growing in the protected area for 12 years typically developed several branches from a short basal trunk, giving them the appearance of a shrub. This is different from mauto trees that apparently avoided browsing over a much longer time period. These trees can reach 12 m aboveground and possess a single, rather slim trunk (Fig. 2B).

Figure 2. A, Mauto showing the bonsai effect in area subject to grazing. **B,** Mature mauto showing normal form.

DISCUSSION AND CONCLUSIONS

Cattle grazing affected allometric relationships between height and basal diameter and between crown cover and basal diameter of mauto in the tropical dry forest in the La Laguna mountain range. Cattle normally browse leaves but not stems (V. Ortiz, personal observation), which leads to the basal trunk diameter of grazed trees developing at a relatively faster rate than height and crown cover compared to areas where mauto is protected from cattle grazing. It is noteworthy that some mauto escaped browsing, growing to normal heights in places inaccessible to cattle, such as sites surrounded by dense growth of thorny shrubs.

The results allow us to conclude that certain allometric relationships can be employed as criteria to identify grazing impact, as indicated by other authors. Escós et al. (1997) combined allometric measures (between branch diameter and branch order and internode length and node order) and development instability (exaggerated intraindividual variance in repeated morphological traits and patterns) as indicators of the impact of grazing on the architecture of plants. They concluded that moderate grazing by sheep and goats on *Anthyllis cytisoides* promotes growth and enhances stability of vegetative structure. Escós et al. (2000) also found a relationship between grazing pressure and slope exposure through a developmental stability analysis of complexity of branching and productivity and concluded that differences between grazed and protected plants were most evident in more mesic areas. Alados et al. (1998) used the statistical noise in allometric relations as an indicator of developmental instability to assess the impact of grazing on common plant species in the arid intermountain west of the United States and concluded that grazing pressure imposed by presumably coadapted wild herbivores enhances developmental stability in species habituated to moderate grazing.

In spite of other investigators using developmental instability as an estimator of grazing impact and our use of the RMA regression model, we conclude that allometric relationships are a useful tool for identifying grazing impact on plant form. We found that "bonsai" mauto is an indicator of active grazing and that "shrubby" mauto is an indicator of relatively recent protection from grazing. Such effects should be studied in terms of the ecology of the plant community as a whole because mauto has the largest canopy cover and is the most important tree species in this community (Breceda 1994). Crown and leaf debris provide nutrition and shade, lessen evaporation, and ameliorate temperatures, thus creating a "nursery" condition for seeds, seedlings, and young individuals of other species to successfully develop (Arriaga et al 1993). Our findings of the effects of cattle grazing on allometric forms should be applicable in other tropical dry forests since this species ranges across mainland Mexico and northern Central America.

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