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Species Richness and Cover of Orchids and Bromeliads on an Active Volcano

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Abstract. Orchid and bromeliad species richness and cover were examined in 14 plots at 100-m intervals at 200–1500 m elevation along a 1957 flow of aa lava (blocky lava with a high silica content) on Concepción volcano in Nicaragua. Seventeen orchid species and four bromeliad species were recorded, using a point intercept method. Orchid and bromeliad species richness peaked between 600 and 1000 m and accounted for 50% or more of the species encountered. Orchid and bromeliad cover were greatest at 600–800 m and accounted for more than 50% of the vegetation cover. In particular, *Sobralia* spp. and *Vriesea pedicellata* accounted for the majority of vegetation cover at 700 and 800 m. Orchid and bromeliad species richness and cover were positively correlated with percent lichen cover and negatively correlated with herbaceous plant height. High temperature and low precipitation regimes apparently limit orchid and bromeliad distributions at low elevations, and competition with taller plants may limit their distribution at high elevations. Canopy orchids and bromeliads may play a key role in primary succession on active volcanoes in the tropics.

Key words: bromeliads, orchids, lava flows, primary succession, species richness, volcanoes

Introduction

Primary succession following volcanic eruptions has been studied less than any other form of plant succession because of the inaccessibility of most volcanoes and the ephemeral nature of these communities (Del Moral 1993, Krebs 1994). Volcanic disturbance has occurred repeatedly in the tropics, where volcanoes and volcanic ranges can be dominant features of the landscape; but little floristic or structural evidence of primary succession remains after 100 years, because tropical climates promote rapid plant succession (Beard 1976, Whittaker & Bush 1993). Models of succession following volcanic disturbance show floristic composition changing from bare rock to nonvascular plants followed by grasses and herbs, then pioneer shrubs and trees (Del Moral & Wood 1993, Krebs 1994). In the tropics, orchid and bromeliad species have been noted as important plants during different stages of succession on volcanoes in Cameroon, Papua New Guinea, Indonesia, and the West Indies (Taylor 1957, Keay 1958, Howard 1962, Whittaker & Bush 1993). Little quantitative data exist on orchid or bromeliad species richness or cover on active volcanoes. This study examined the species richness and cover of orchids and bromeliads on a 1957 flow of aa lava (blocky lava with a high silica content) at 200–1500 m elevation in Nicaragua. In particular, I examined factors associated with orchid and bromeliad species richness and cover along an elevational gradient.

Study Site and Methods

This study was conducted in 1996–1997 on the Concepción volcano (1610 m) on the island of Ometepe, located in Lake Nicaragua, Nicaragua. Concepción is a stratovolcano with a long history of continual volcanic activity. The last major flow occurred in 1957, when aa lava flowed from the crater down the north side of the volcano to 200 m elevation. According to the Holdridge classification system (Holdridge 1962), climax vegetation on the Concepción volcano should be tropical dry forest (31–400 m), tropical moist forest (400–800 m), premontane wet forest (800–1400 m), and premontane rain forest (1400–1650 m).

Fourteen permanent plots, 5 × 20 m, were established at 100-m intervals in the center of the 1957 lava flow at 200–1500 m (Figure 1). A point intercept method was used to quantify species richness and cover within each plot (Bonham 1989). Six 20-m transects were established 1 m apart within each plot. Point intercept scores were recorded every 0.5 m along each transect for a total of 246 intercept points in each plot. Broad classifications of mosses, lichens, detritus, and bare-ground were recorded for nonvascular plants encountered at the intercept points. Most vascular plants were identified to species (Dressler 1993, Stevens et al. 2001). Species in the orchid genus *Sobralia* were combined because of vegetative similarities among three species that generally bloom for one day. Voucher specimens were deposited in herbaria at UCLA and Universidad Centroamericana.

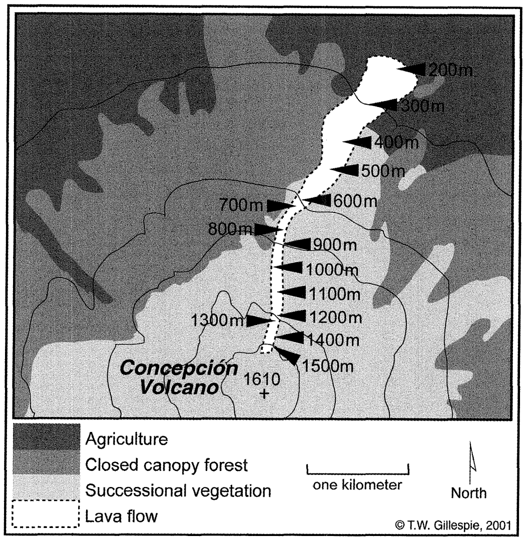

FIGURE 1. Location of 14 plots on a 1957 aa lava flow on the Concepción volcano in Nicaragua, 1996–1997.

Growth forms of species encountered in plots were classified following Whittaker and Bush (1993), in which all species were categorized as woody (shrubs or trees) or herbaceous (non-woody plants). Mean herbaceous and woody plant heights were recorded for the 10 individuals nearest to the center of each plot. All species were measured vertically from the base of the stem to the highest point of the plant, including the inflorescence. A Spearman rank correlation was used to identify variables associated with orchid and bromeliad species richness and cover.

RESULTS

Species Richness and Cover

Using the point intercept method, 59 species were recorded in 14 plots at 200–1500 m. Total species richness increased with elevation, reaching a peak between 1000 and 1100 m and then declining to 1500 m (TABLE 1). Seventeen orchid species and four bromeliad species were recorded, using the point intercept method. Orchid species richness was highest at 700 m, while bromeliad species richness peaked at 800 m. Orchids and bromeliads accounted for approximately half the species encountered between 600 and 1000 m. Vegetation cover increased linearly with elevation to 1200 m and then declined toward the volcano rim. Orchid cover was highest at 900 m, while bromeliad cover peaked at 700 m. Between 700 and 800 m, orchids and bromeliads accounted for more than 40% cover in the plot and more than 50% of the vegetation cover for vascular plants. Images of vegetation and flora along the lava flow are available on the Web at www.geog.ucla.edu/volcanoes/volcanoes.html.

The bromeliads *Pitcairnia imbricata* and *Vriesea pedicellata* both occurred continuously between 500 and 1000 m, with their highest cover values at 700 m (TABLE 2). Above 800 m, *Werauhia* had the greatest cover. The orchids, *Sobralia* spp., *Scaphyglottis graminifolia,* and *Epidendrum radicans*, occurred in four or more elevational plots and accounted for the majority of the orchid cover on the lava flow. Nine species of bromeliads and orchids were recorded in one elevational plot and accounted for less than 3% of the vegetation cover.

TABLE 1. Distribution of orchid and bromeliad species richness and cover on a 1957 aa lava flow.

Elevation (m)	Species richness	Species		Cover (%)		
		Orchid	Bromeliad	Vegetation	Orchid	Bromeliad
200	4	1	0	23	<1	0
300	3	0	0	26	0	0
400	8	2	0	28	4	0
500	16	1	3	34	8	4
600	14	5	2	46	14	12
700	16	6	2	72	22	27
800	14	5	4	74	23	20
900	14	4	3	86	25	11
1000	18	4	3	94	18	7
1100	20	3	1	98	3	2
1200	10	0	0	99	0	0
1300	8	0	0	98	0	0
1400	6	0	0	94	0	0
1500	4	0	0	63	0	0

TABLE 2. Percent cover of bromeliad and orchid species along an elevational gradient in meters.

Species	Elevation (m)													
	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
Bromeliads														
Pitcairnia imbricata (Brongn.) Regel				<1	4	8	5	2	2					
Vriesea pedicellata (Mez & Wercklé) L.B. Sm. & Pittend.				2	9	18	14	3	2					
Werauhia sp. (G168)							<1	6	3	2				
Tillandsia anceps G. Lodd.							<1							
Orchids														
Bletia purpurea (Lam.) DC.	<1					<1								
Sobralia spp.			3		4	14	17	14	8	<1				
Scaphyglottis graminifolia (Ruiz & Pavón) Poepp. & Endl.			1	7	5	<1								
Epidendrum radicans Pavón					2	6	5	4	4					
Jacquiniella globosa (Jacq.) Schltr.					<1									
Scaphyglottis prolifera Cogn.					2									
Platystele sp. (G143)						<1								
Encyclia fragrans (Sw.) Lemée						<1								
Elleanthus caricoides Nash.							<1							
Encyclia vespa (Vell.) Dressl.							<1							
Hexadesmia fasciculata Brongn.							<1							
Epidendrum rigidum Jacq.								4	<1					
Elleanthus discolor (Rchb. f. & Warsz.) Rchb. f.								3						
Elleanthus cynarocephalus (Rchb. f.) Rchb. f.									5	2				
Pleurothallis sp. (G169)										<1				
Other vascular plant cover	23	26	24	24	19	23	31	49	69	94	99	96	94	63

Correlates of Species Richness and Cover

A significant correlation occurred among orchid and bromeliad species richness and cover and total species richness (TABLE 3). A significant correlation also occurred among orchid and bromeliad species richness and cover and percent lichen cover; but percent moss, detritus, and bare rock did not correlate. A strong negative correlation occurred among herbaceous plant height and orchid and bromeliad species richness and cover. Orchid and bromeliad species richness or cover was not associated with woody plant height or herb and woody plant cover.

DISCUSSION

Distribution of Orchids and Bromeliads on Concepción Volcano

Orchids and bromeliads were most prolific between 600 and 1000 m. The aa lava flow between these elevations covers more than 50 ha, and orchids and bromeliads were abundant throughout the area. The point intercept method, however, missed a number of orchid and bromeliad species within the plots, and a greater number of orchid and bromeliad species occurred on the lava flow between plots. High moisture regimes and open areas create favorable conditions for lichens on aa lava flows, which in turn appear to provide an ideal habitat for a number of species that normally occur as epiphytes in cloud forests at 500–1100 m (Atwood 1984).

Lower orchid and bromeliad species richness and cover below 400 m appeared to result from environmental stress and a small species pool. Temperatures on barren and dark aa lava flows in the tropical dry forest life zones are higher than on any other land cover type in Central America, and mid-day temperatures of exposed lava can result in mild burns (C. Farris pers. obs.). These extreme temperatures and the seasonal nature of precipitation permit only mosses and the weedy fern, *Nephrolepis multiflora* (Roxb.) Jarrett ex Morton, to occur in shaded

TABLE 3. Spearman rank correlation between orchid and bromeliad species richness and cover.

Characteristics	Species richness		Cover	
	Orchid	Bromeliad	Orchid	Bromeliad
Total species richness	0.684*	0.758*	0.666*	0.733*
Total vegetation cover	−0.052	0.106	−0.061	0.073
Elevation	−0.327	−0.137	−0.321	−0.162
Moss cover (%)	0.424	0.127	0.37	0.216
Lichen cover (%)	0.605**	0.578**	0.645**	0.622**
Detritus cover (%)	0.208	0.405	0.395	0.304
Bare rock	0.077	−0.123	0.079	−0.097
Herb cover	0.194	0.234	0.214	0.34
Woody cover	−0.005	0.177	−0.009	0.12
Herb height	−0.796*	−0.694*	−0.807*	−0.796*
Woody height	0.156	0.325	0.152	0.273

* $P < 0.01$, ** $P < 0.05$.

pockets of the lava flow during the dry season. In addition, tropical dry forests in Central America have significantly fewer orchid and bromeliad species than do cloud forests and lowland rain forests; thus fewer species would be expected than in wetter forest types (Janzen & Liesner 1980, Gentry & Dodson 1987). The decline of orchid and bromeliad communities with an increase in elevation is the result of successional processes and competition from taller plants. A number of hemi-epiphytic shrubs and taller herbaceous plants in the Gunneraceae, Asteraceae, and Ericaceae families outcompete the shorter orchids and bromeliads at above 1000 m (Gillespie & Prigge 1997).

Life History Characteristics

Almost all orchid and bromeliad species encountered on the lava flow were classified as having an epiphytic habit (Howard 1974, Stevens et al. 2001). *Pitcairnia imbricata, Vriesea pedicellata, Bletia purpurea, Epidendrum radicans,* and *Sobralia* spp. were the only species recorded as being both epiphytic and terrestrial; the remaining species were recorded as epiphytic. Only one *Pleurothallis* species was recorded growing epiphytically or on another plant in the plots; the remaining orchid and bromeliad species were attached directly to the substrate. These species, which generally begin their life cycles in the canopy, appear to be able to use the blocky aa lava flows as surrogates for tree branches. Almost all orchids and bromeliads from this study, with the exception of *B. purpurea,* occur in both cloud forests and lowland rain forests (Atwood 1984, Stevens et al. 2001). All of the orchids and bromeliads encountered, with the exception of *V. pedicellata,* have ranges outside of Central America. Most of the species extend into South America, and two species (*B. purpurea* and *E. rigidum*) range into Florida (Correll 1950, Stevens et al. 2001). This suggests that these communities are composed of widespread species. Many of these species also occur in road cuts in Central America. Three vegetatively similar *Sobralia* species, *S.* cf. *macrantha* Lindl., *S. powellii* Schltr., and *S. helleri* Hawkes, were recorded in plots with flowers; and *S.* cf. *macrantha* was the most common.

Orchids and Bromeliads on Active Volcanoes in the Tropics

Few quantitative studies have been made on orchids or bromeliads on active volcanoes in the tropics, but a number of researchers have noted their importance. Keay (1958) compiled a list of plants covering more than 2 ha on a 1922 lava flow in Cameroon. He found orchids to be the second largest family after Moraceae but acknowledged that many herbs were missed. Whittaker et al. (1989) compiled data on plant colonization of the Krakatoa Islands and reported a number of heliophilous terrestrial orchids, such as *Arundina graminifolia* (D. Don) Hochr., *Phaius tankervilliae* (W. Ait) Bl., and *Spathoglottis plicata* Bl., which had colonized the islands 11 years after the 1887 eruption. Most of these orchids were open-habitat specialists that went locally extinct after forest closure. A similar pattern has been noted for bromeliads on the island of St. Vincent in the Lesser Antilles. *Pitcairnia* species (*P. angustifolia* Aiton and *P. sulphurea* Andrews) covered large areas at the top of the volcano; and, barring another eruption, this area will become elfin forest (Beard 1976). No mention has been made, however, of orchid species on this volcano.

It is difficult to determine if high orchid and bromeliad cover also occurs on other volcanoes in Central America, or if this is a phenomenon unique to the Concepción volcano. These ephemeral communities can occur only on active stratovolcanoes with recent (<50 years) aa lava flow in the tropical moist or wet life zones. The abundance of orchids and bromeliads is unlikely to be as great on the smoother pahoehoe (ropy) lava or in drier areas (Eggler 1971). These communities may occur in sections of the Arenal volcano in Costa Rica, but I know of no published vegetation work that has been conducted on that volcano.

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