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Technical Note: Cattle as a dispersal agent of *Acaena elongata* (Rosaceae) in the cordillera of Mérida, Venezuela

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Abstract

In the tropical Andean environments little is known about the relationship between weed dispersal and disturbances caused by cattle. We propose that abundance and dispersal of the Venezuelan Andean weed Acaena (*Acaena elongata* L.) is associated with the widespread grazing habits of cattle. We studied Acaena presence in areas with different cattle movements and grazing intensities. Acaena density increased with cattle trail density ($r^2 = .98, P < .001$). Infestation patterns suggested dispersal by cattle along trails. Areas with greater cattle movement (0.34 trails/m) possessed the greatest density and highest number of Acaena plants ($P < .001$). This weed has morphological and phenological features adapted to cattle dispersal. Fruits mature during the season when cattle are less selective and travel the greatest distances.

Key Words: dispersal, cattle, *Acaena elongata*, tropical mountains

In high tropical environments little is known about the ecology of plant invasion; however, some of the major problems are related to dispersal mechanisms and their consequences (Smith and Young 1987). One of the most important factors determining the ability of invasion is the method of dispersal used by a plant species (Van Hulst 1987, Hengeveld 1988), especially in disturbed environments (Stebins 1971). Recently, zoochory has received much attention (Howe and Smallwood 1982). However, little is known about dispersal by adhesion (Sorensen 1986).

The Venezuelan Páramos (mountain regions above 3,500 m) is a good example of a tropical Andean environment subject to disturbances by grazing and associated species dispersal. Widespread grazing is concentrated above the agricultural zone, in the Andean "Páramos" (Monasterio 1980). In these regions, the changes in vegetation and the dispersal of weeds could be related to the introduction of cattle. Although these changes have not been recorded, they can be studied indirectly with respect to their current relationship with the introduction of foreign agents. The aim of this research was to investigate one of these changes related to cattle: the abundance and the dispersal of weeds in the Andean zone. For this study we selected Acaena (*Acaena elongata*, L.), a common weed of the Andean mountains. Acaena is predominant in environments with widespread cattle grazing, and has fruits with adaptative features (burrs) that facilitate dispersal by large animals

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Fig. 1. *Acaena elongata* (Rosaceae). Perennial, small shrub of the high tropical Andean mountain. The surface of the fruit is covered with hooks which allows external transportation by the domestic animals.

(Fig. 1). To determine if the abundance and dispersal of this particular weed is related to cattle grazing, we evaluated the following hypotheses: (1) Acaena should be more abundant in those areas most frequented by cattle, and (2) plant distribution should be directly related to the movement patterns of the cattle.

Materials and Methods

Study Area

The study was conducted in the "Páramo" region known as "El Banco" (3,700 m), Cordillera of Mérida, Venezuela (8° 5′ N, 70° 55′ W) (Fig. 2). The climate in this region is cool and humid with a unimodal rainfall pattern from May to October (Monasterio and Reyes 1980). The vegetation is dominated by shrubs including *Espeletia schultzii* and *Hypericum laricifolium*. This pair of shrubs is one of the most important and most widespread associations in the Andean "Páramo" (Monasterio and Reyes 1980). In the study area, the presence of Acaena, a small perennial native shrub of the high tropical Andean mountains, is prominent. Its distribution is from above the treeline to an elevation of 4,000 m, and it is most abundant in shrub communities (Vareschi 1970). The common name (Acaena or Cadillo) refers to the adhesive features of its fruits. Fructification begins during the wet season (May–October) and the fruits are ready to be dispersed during the dry season (January–March), by means of attaching themselves to cattle, horses, and humans.

Methods

Sampling was done in February, March, and April 1991, in a valley where the cattle are moved on a daily basis between agricultural and grazing lands (Fig. 2). The daily and seasonal pasturing patterns allowed us to select regions with varying movements of cattle in a homogeneous area, with regards to orientation, slope, soil, and vegetation. The density of cattle trails was estimated by 20 transects each measuring 30 m, perpendicular to the contour. A measurement was developed by counting the number of trails/meter to indicate the frequency of cattle movement (Walker and Heitschmidt 1986). By virtue of this measurement, the region was divided in 2 areas of 10,000 m^2: 1 with a low density of trails (LDT), and the other with a high density of trails (HDT) (Fig. 2).

In both areas, twenty—9 m^2 quadrats were placed at random. By means of 50 random points in each quadrat, the following was measured: (a) biovolume of shrubs using the method of square points (Mueller-Dombois and Ellember 1974) and (b) absolute and relative cover of Acaena. Additionally, in each quadrat was recorded (i) the total number of individual Acaena plants, (ii) the number of Acaena plants that grew isolated or beneath shrubs, and (iii) in 1 Acaena plant the green/dry biovolume was measured by selecting 10 random points.

In order to evaluate the relationship between cattle movement and Acena presence we chose the area with greater cattle movement (HDT). The number of trails and individual Acaena plants

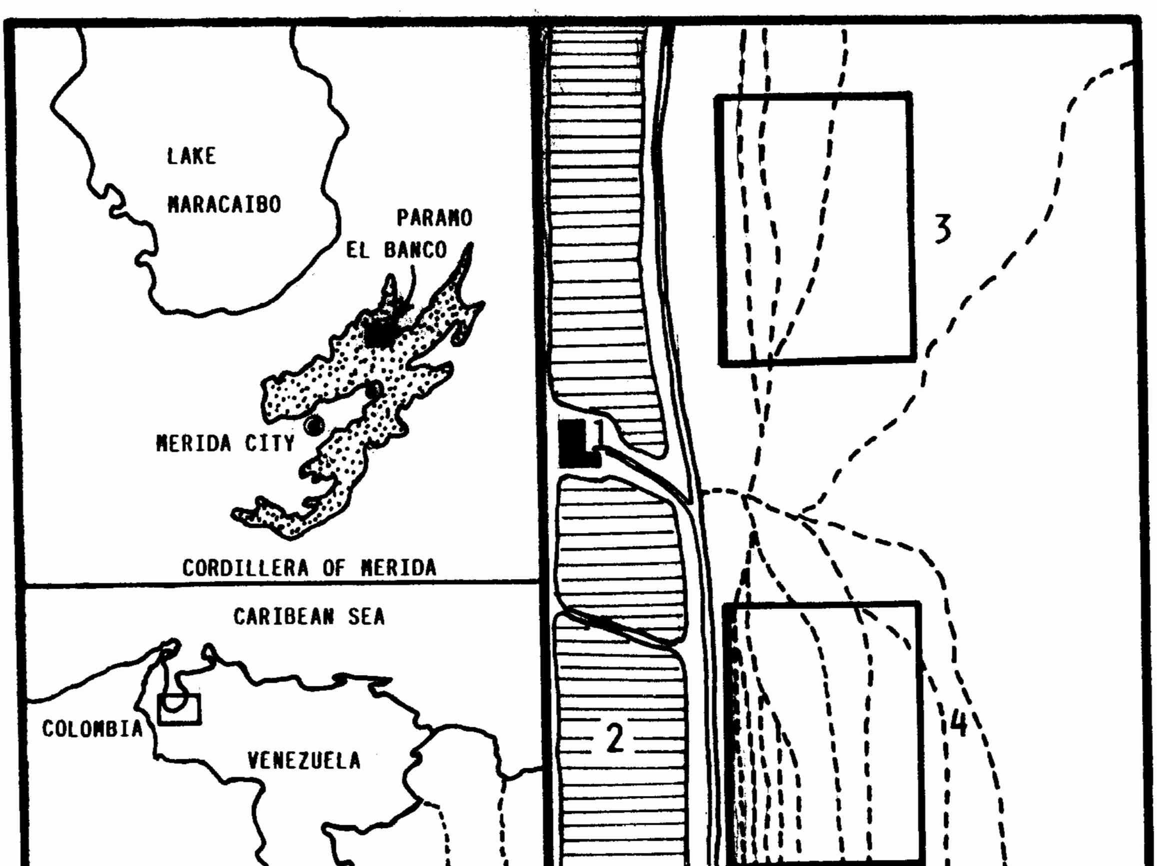

Fig. 2. (a) Páramo "El Banco", study area in the Cordillera of Mérida, Venezuela. (b) Slope of valley where cattle are moved on a daily basis from the farmer house (1) between agricultural (2) and grazing lands. The sampled areas are indicated by quadrats: (3) low trail density and (4) high trail density.

was measured using 6 transects of 10 by 60 m (divided into sections of 10 by 10 m) perpendicular to the slope.

To evaluate the effect of grazing with respect to the presence of Acaena, 2 regions of 1,000 m^2 of high and low grazing intensity were selected. The selection was based on observations of animal movement carried out in 1990, and on interviews with farmers. In each region, 10 quadrats of 1 m^2 were placed at random. In each quadrat, 10 points were taken at random to measure cover and biovolume of the main plant species.

Dispersal of Acaena by the cattle was tested using 300 marked burrs (fruits) equally distributed on the limbs of a cow moved over 2 regions chosen specifically for their markedly different shrub densities. The number of burrs released and the place where they fell was recorded every 25 m.

The number of trails and individual Acaena plants was compared in the 2 areas with different trail density using the Mann-Whitney test. Cover and shrub biovolume data were transformed (arcsin root), verified with the Bartlett test, and data compared using 1 way analysis of variance (Sokal and Rholf 1981). The proportion of Acaena green/dry biovolume (number of contacts), below and above 10 cm, was compared using X^2 test. The distribution of the fruits (burrs) dispersed in the field experiment between regions with higher and lower density of shrubs was compared using the Kolmogorov-Smirnov test (Sokal and Rholf 1981).

Results

The area with greater movement of cattle (0.34 ± 0.05 trails/m) compared with that of lesser movement (0.09 ± 0.03 trails/m) possessed a greater absolute and relative density of cover of Acaena ($P<.001$), and a higher number of individual plants ($P<.001$). However, these 2 areas did not differ in shrub biovolume of other plant species ($P>.05$, Fig. 3). In both areas Acaena grew

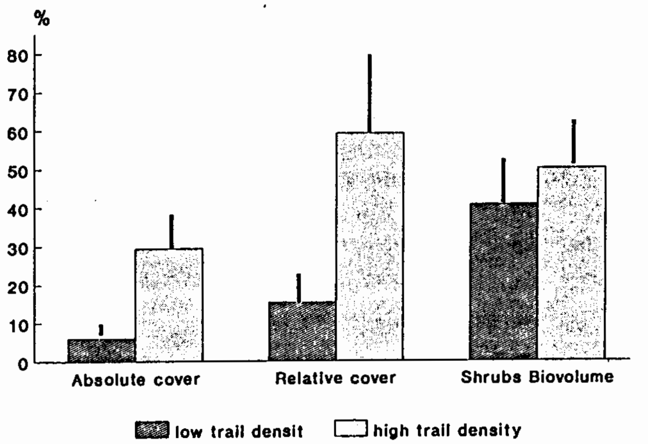

Fig. 3. Absolute and relative cover of *A. elongata* as a function of trail density (F = 88.4 and F = 67 respectively, n = 20, $P<.001$). The shrub biovolume did not differ between both areas (F = 3.9, n = 20, $P>.05$).

more frequently under shrubs than in isolated groupings. However, the areas with different cattle movement did not differ in the proportion of the number of Acaena plants in isolated groupings compared to those under shrubs (isolated/under shrubs) (X^2 = 1.97 $P>.9$).

In the area with greater cattle movement, trail density decreased with the distance from the base of the slope ($r^2 = -.98$ $P<.001$, Fig. 4a), while the density of Acaena increased with trail density ($r^2 = .98$ $P<.001$, Fig. 4b).

The green/dry biovolume ratio for Acaena individuals showed greater dry biovolume below 10 cm and greater green biovolume above 10 cm (X^2 = 162.9 $P<.001$).

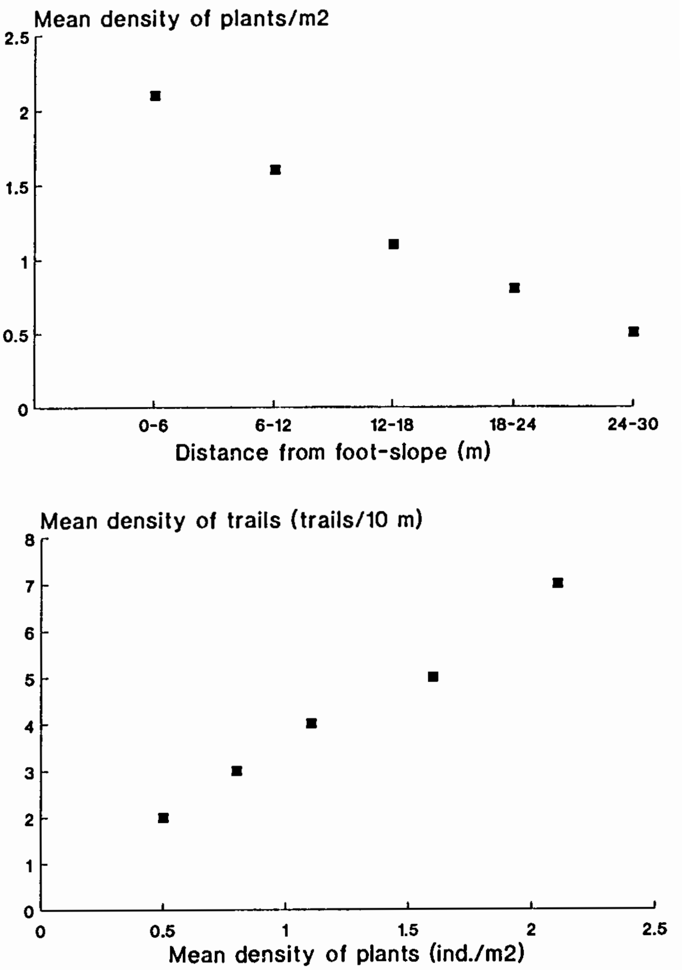

Fig. 4. (a) Mean density of *A. elongata* plants in relation to distance from the foot-slope ($r = -0.99$, n = 6, $P<.01$). (b) Mean density of *A. elongata* plants in relation to trail density ($r = 0.99$, n = 6, $P<.01$). Each point is the mean of 6 replicates.

Cover of Acaena and *Festuca myurus* was greater in areas with high than with low grazing intensity, while the opposite is true for *Stipa mexicana*. The other species do not show significant differences between regions (Table 1).

Table 1. Cover (%) of dominant plant species in regions with different grazing intensities[a].

	high grazing intensity		low grazing intensity		
Species	mean	SD	mean	SD	P
A. elongata	53.1	35.8	0.0	0.0	<.001
Festuca sp.	21.9	20.9	0.0	0.0	<.001
Stipa sp[b]	1.9	4.1	54.2	26.0	<.001
Geranium sp.	2.5	7.9	13.2	27.2	>.05
Rumex sp.	4.3	6.9	0.8	2.6	>.05
Poa sp.[b]	0.0	0.0	6.3	10.6	>.05
Luzula sp.[b]	0.0	0.0	0.6	1.7	>.05
Calamagrostis sp.	1.3	4.2	3.9	9.2	>.05

[a]Data from twenty 1 m^2 quadrats compared with 1 way ANOVA.
[b]Good foragers plant species.

The dispersal experiment counting the number of burrs that fell from a cow indicated that about 70% of the marked burrs fall within the first 175 m. The distribution of the burrs released along the cattle trails in regions with different shrub densities differs

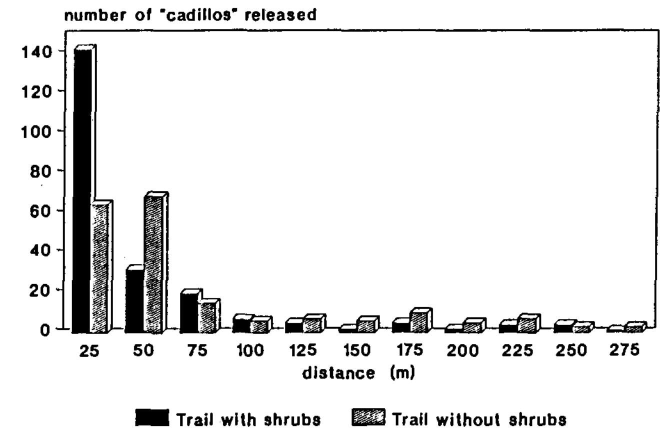

Fig. 5. Distribution of burrs (fruits) released from the limbs of a cow which has moved between 2 areas with different shrub densities. Dispersal distance distributions are different (Kolmogorov-Smirnoff test, D = 0.304, *P*<.001).

significantly (D = 0.304, *P*<.001, Fig. 5).

Discussion

Animals are vehicles for the dispersal of seeds of many species and are considered as important elements in the maintenance of populations (Harper 1977). There is some evidence which relates the activity of cattle to plant invasion. Brown and Archer (1987, 1989) found a higher density of seeds of *Prosopis glandulosa* germinating in areas subject to cattle grazing in Texas (USA). They suggested that the rate of invasion of this species increased substantially after the introduction of domestic animals. Shmida and Ellner (1983) maintained that the external transportation of seeds by cattle contributes to the persistence of annual plant populations in the Mediterranean Chaparral. We suggest that in the Venezuelan "Páramos", cattle play a triple role with respect to weed invasion, as a dispersal agent, generator of disturbances and modifier of the competitive balance by means of preferential grazing.

The surface of the fruit of Acaena is covered by small hooks, a morphological feature of the pericarp which allows external transportation by native herbivores and cattle. This is one of the most common characteristics of plants which are dispersed by adhesion (Sorensen 1986).

During the dry season, fruits are arranged into spikes which are projected towards the outside of the shrub. The maturation of fruits during this season appears to have 2 adaptative advantages: first, the decrease in foliage of other more palatable species enables Acaena (with a high proportion of green biomass on the superior layer) to be more attractive fodder (the foliage is the "fruit"(Janzen 1984)). The burrs then attach onto the bodies of cattle while the plant is eaten. Second, the low availability of foliage during this season results in animals traveling greater distances and results in a broader dispersal of Acaena seeds. The effect of this "double advantage" is a strategy that results in the colonization of new sites at high rates (see Hengeveld 1988).

The higher density of Acaena in areas with many trails suggests that plant dispersal is determined by cattle movement in places more frequently visited (Fig. 3 and 4b). Our field experiment also confirmed that cattle act as dispersal agents. More than 70% of the fruits attached to the animals' legs fell before the first 175 m, and a substantial proportion of fruits may potentially be dispersed to a distance of up to several hundred meters.

The distribution of dispersed burrs also depended on the morphological characteristics of the vegetation. Because of cattle brushing against the shrubs, the rate of fruit fall would be related to shrub density, especially during the first stage of cattle movement (Fig. 5). The distribution and the final destiny of the fruit should therefore be highly determined by the spatial heterogeneity of the environment. If we consider cattle as a "vehicle of transportation" of the fruits, the shrubs would function as "stops" along the dispersal routes where there is a higher probability that the "passenger" burrs get off. The mean distance transited by Acaena fruits would therefore be inversely related to the density of shrubs through which the cattle must travel.

In the 2 areas with different cattle trail density, we compared similar vegetation patterns to determine the proportion of Acaena plants under shrubs/growing in isolation. They do not differ significantly (Table 1). This suggests that the "intensity of movement" factor (indicated by cattle trail density) may be the most important factor for dispersal in this species.

The density of Acaena is greater at the foot of the slopes and is directly related to the density of the trails (Fig. 4a). This is a consequence of the movement of cattle who prefer low graded slopes parallel to the contour lines (Walker and Heitschmidt 1986).

Formation of a trail disturbs soil as it is compacted (Walker and Heitschmidt 1986). We observed that Acaena plants grow more successfully along compacted trails than other species. Due to the effectiveness of their dispersal mechanisms, the species with adhesive fruits or seeds are more common in these disturbed environments (Stebbins 1971).

Grazing data demonstrated a higher density of Acaena in heavily grazed areas (Table 1). This appeared to be a result of cattle movement rather than a decrease of the more palatable species. The majority of these species, exclusive of *Stipa mexicana,* have little presence in both regions. We suggest that the presence of Acaena is more related to intensity of cattle movement than to long-term effects of grazing.

If the expansion of this weed is closely related to cattle activity, its distributional range may be greater today than before the Spanish settlement. Its colonization potential may date back a few hundred years ago as cattle were introduced by the Spanish in the 16th century (Monasterio 1980). Unfortunately, there are no historical records of Acaena nor other weeds in the Venezuelan Andes. Consequently, more research is needed to determine what should be done to reduce the impact of livestock in the tropical Andes.

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