BIOLOGICAL CHARACTERISTICS AND NUTRITIVE VALUE OF ABORTED FLOWERS OF THE CARDÓN (*PACHYCEREUS PRINGLEI*, CACTACEAE) IN BAJA CALIFORNIA SUR, MEXICO.

JOSE LUIS LÉON DE LA LUZ,
REYMUNDO DOMÍNGUEZ-CADENA,
& ALFONSO MEDEL-NARVÁEZ.
Centro de Investigaciones Biológicas del Noroeste (CIBNOR)
Apdo. Postal 128, La Paz, B. C. S. 23000, Mexico
E-mail: jlleon@cibnor.mx

Summary: The cardón (*Pachycereus pringlei*, Cactaceae) is one of the dominant plants on most of the arid peninsula of Baja California. A significant percent of the floral buds and female flowers fall from the branches, supposedly a consequence of tissue cavitation from insect larvae infestation. The yield of aborted floral buds from a single cactus may amount to one to two kilograms. These flowers are sought by cattle, which gain weight when the flowers are consumed in large amounts. This paper documents the importance of these aborted floral buds as forage and it presents a comparison of nutrient content with other desert plants used as forage. The carbohydrate content of aborted buds is higher than in leguminous-tree foliage. Although the forage value of the aborted floral buds for cattle is high, we do not recommend intensive use of this resource because of the potential impact on the persistence of cardón in its native environments.
Key words: Baja California, flowers, *Pachycereus pringlei*, range forage.

Introduction

The cardón, *Pachycereus pringlei* S. Wats. (Cactaceae), is one of the few ubiquitous plants of arid Baja California, Mexico (excluding the Mediterranean and upland sub-tropical biotic provinces in the northwest and the southernmost mountains of the peninsula). The cardón is probably the most massive species in the cactus family.

Cardons have a wide distribution over most of the peninsula, including all the islands in the Gulf of California, but some populations are also found along the northwest coast of mainland Mexico, in the state of Sonora. The cardón often occurs in dense stands on alluvial plains called "cardonales" (cardón forests). In some areas—such as mountain slopes—they are sparsely distributed.

An average mature cardón reaches a height of 8-9 m, but some populations harbor exceptional individuals as tall as 18 m. The number of arms (branches) per individual (from few to 20 or more) is variable throughout the entire range, depending on the population, and is probably related to both genetic and environmental factors (Bashan et al., 2001). Moran (1968) estimated the age of the largest individuals at 150 to 200 years, and sexual maturity is reached after 70-80 years.

Cardón flowers, unlike those of most cacti, are not perfect. Different populations may have dioecious, gynodioecious, or trioecious flowers. There may be some individuals with sterile flowers (Fleming et al., 1994, 1996, 1998). In all cases, flowers generate up to 3 ml of nectar during their 14-15 hour span of anthesis (8:30 p.m. to 11:00 a.m.). An important feature is the high drop-rate of floral buds in early development (an occurrence also reported for other cacti); these drop-rates are variable and reach close to 100% of the floral buds of individual plants (León de la Luz et al., 1995) (Fig. 1B). In the cardón this is attributed to several causes, including abnormal development and disturbance by large perching birds, but we believe that the primary cause is infestation of the pericarpel tube by insect larvae (unknown species of flies and moths, León de la Luz, unpubl. data) and subsequent tissue cavitation (Fig. 2). After anthesis, all the male flowers drop, but hermaphrodite and female flower drop-rates are variable depending on the extent of larval cavitation.

Interviews with cattle ranchers provide corroboration for our observation that aborted flowers serve as a valuable forage resource from April to June, a season when pasture and shrub foliage is practically absent. Cattle consume all the dropped buds and flowers surrounding a mature cardón, an amount up to 2 kg. Ranchers believe that this seasonal forage enables cattle to survive the season and gain weight. They justifiably presume that dropped flower buds are highly nutritious. Where cattle are excluded, dropped flowers remain for months before dis-

Figure 1. **A.** Cardón branch with several stages of flowers from buds to immature fruits. **B.** Aborted floral buds beneath a mature cardón. **C.** Stages of aborted floral buds.

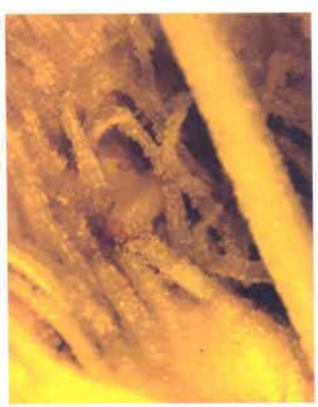

Figure 2. Dipterous larva inside a flower.

integrating by natural processes. Cattle do not consume ripe cardón fruit because they possess an inedible, spinescent cover.

This paper documents the importance of aborted buds and flowers as a vital dry-season food resource for cattle. Exploitation of the buds has implications for the conservation of cardón stands, which represent a nearly free, seasonal food supply for range cattle, compared to the urgent need for commercial feed, a significant expense for poor ranchers of the peninsular rangelands.

Materials and Methods

Our study site is a biological preserve located a few kilometers west of La Paz, Baja Califor-

Table 1. Analysis of mature cardón plants in a biological preserve near La Paz, Baja California Sur (Mexico) in 1991. Number of dropped floral buds and flowers were assigned to one of the three stages of development: flower buds (*fl1*), flowers (*fl2*), or advanced flowers (*fl3*)

Number of branches	Plants	Height mean	(m) sd	Developmental stage *fl1*	*fl2*	*fl3*
1 (1-10 arms)	39	3.42	± 0.97	993	429	126
2 (11-20 arms)	25	4.71	±1.83	1753	321	59
3 (21-30 arms)	12	4.96	±1.46	964	502	281
4 (31-40 arms)	9	5.76	±2.24	62	22	17
5 (+41 arms)	6	6.07	±1.18	83	30	28
Total	91			3855*	1304*	511*

* χ^2 0.05, 8 = 415, P >> 0.05.

nia Sur, Mexico (24°06′N, 110°24′W). Cattle foraging has been excluded for more than 15 years. This site is located on an extensive alluvial plain largely composed of loamy soils. Cardón reproductive phenology ranges from late March to early August. Flowers appear from late April to late June, and mature fruit are seen from early June to early August.

We followed the reproductive events of 91 mature cardons. Each plant was measured from the soil surface to the tip of the highest branch and the number of all branches and reproductive branches was recorded. The number of floral buds generated during the reproductive season (March–August, 1991) was recorded for each plant, as well as the percentage of flowers that developed into fruit. Dropped floral buds and flowers were assigned to one of three stages of development: flower buds (*fl1*), flowers (*fl2*), and advanced flowers (*fl3*). Floral buds ranged in size from 1 to 6 cm and flowers from 6 to 7.5 cm.

During the peak of the reproductive season of 2000 (early June), we analyzed the energy and nutrition content of 20 floral buds collected under three conditions: collected on the plant, fallen on the same day, and fallen for more than one day (up to 5 days on the ground). Samples in each group were ground and homogenized, and a portion of the prepared sample was used for analysis, with three replications for each condition. Moisture, protein, lipid, ash, and crude fiber content were determined according to AOAC (1984) standard methods. Carbohydrate content (NFE, nitrogen-free extract) was determined by subtracting the percentage of protein, lipid, ash, and crude fiber content from 100% (dry-weight basis). Metabolizable energy was determined in an adiabatic calorimeter with a 1 g pellet of ground material.

Results

(a) Aborted floral bud pattern

In our study area, the population density of cardons taller than 3 m (estimated minimal height for reproductive individuals, based on direct observations) ranged between 38 and 54 individuals per hectare. Our 91 reproductive individuals ranged from 3.70 to 8.15 m. The number of arms varied from 0 to 52 and reproductive arms composed at least 87% of all the branches of mature individuals. There was a greater dropping of buds in the earliest developmental class (*fl*1 = 68%, *fl*2 = 23%, and *fl*3 = 9%). In general terms, a low correlation was found between dropped floral buds and the height of the cardón (r^2 = 0.36, t = 4.2, p < 0.05) or number of arms (r^2 = 0.27, t = 6.6, p < 0.05). Therefore, we see no predictive value between these variables. Table 1 shows the results for the 91 monitored plants in relation to the stage of the dropped floral buds (*fl*1, *fl*2, *fl*3). A χ^2 test compared the number of events at each stage, where the *Ho* states the homogeneity among these three, which was rejected ($\chi^2_{0.05, 8}$ = 415, P >> 0.05).

(b) Nutritive value

Table 2 shows the results for the nutrient content of dropped cardón flower buds. A nonparametric Kruskal-Wallis single-factor analysis of variance by ranks was performed under the following hypothesis: *Ho*: the values for the nutritional quality in all three aborted bud stages are the same; *Ha*: there are differences among the stages. The analysis shows only that a difference in moisture among dropped-bud stages is statistically significant, declining as time passes since the falling. For the other variables, there are no statistically significant differences.

Table 2. Nutritional analysis (%) of aborted cardón floral buds. The data show the mean for three replicates. The lower row shows results of a statistical test for the significance among conditions

Aborted bud condition	Moisture %	Protein %	Lipids %	Ash %	Fiber %	Carbohydrates %	Energy Kcal gr-1
on plant	76.31	10.98	4.04	7.57	5.61	71.88	3945.1
< 1 day on ground	46.18	9.33	5.20	7.62	14.07	63.77	3876.9
1 to 5 days on ground	9.48	9.02	3.97	7.71	24.42	54.85	4006.1
Kruskal-Wallis test	*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Where *ns*: non-significant; * significant 0.05 < P < 0.02

Table 3 compares cardón buds with other important species in the cardonal community. These species are common in this arid environment and are highly desirable as cattle forage. The material analyzed included leaves of trees and stem parenchyma of cacti (Vega-Villasante et al., 1997). Legume trees of the genera *Cercidium*, *Lysiloma*, and *Prosopis* have the highest protein content, but dropped cardón buds have a higher protein content than the stem-parenchyma of other cacti (*Opuntia* and *Ferocactus*) and *Cyrtocarpa* (a highly valued forage tree). The carbohydrate content of cardons was considerably higher than in leaves of the analyzed trees, largely because of the nectar residue in the cardón buds. All cacti have low lipid levels.

Discussion and Conclusions

Our results provide useful data on the cardón as a valuable forage resource. We emphasize that the consumption of these annual transitory floral buds does not have a detrimental affect on the vegetative biomass of individual plants. Conversely, harvesting of green cactus biomass, which has been traditionally used by cattle ranchers during the harshest season—choya, *Opuntia cholla*; biznaga, *Ferocactus* spp.; and cardón branches—depresses the fitness of each plant, and there is no evidence of the value of such biomass as a nutritious forage.

Although the nutritive content of cardón floral buds is of medium level compared to the leaves of some legumes, assimilation of nutrients depends on several factors, including digestibility. Also, nutrition depends on fiber content and the cellulose-to-lignin ratio. Shrub leaves, grasses, and forbs (forage plants other than grasses) have a high ratio of cellulose to lignin, and they provide excellent nutritional value when available (Holecheck 1984). The fiber content in dropped cardón floral buds is similar to the contents found in leguminous trees, suggesting high digestibility.

All the sexual variants in cardón buds and flowers (male, female, and hermaphroditic individuals) are equally good nectar producers. We believe that all have the same nutritive value for cattle and local fauna.

Based on our field observations, dropped floral buds vary from tens to hundreds per individual each season. Because age, size, and the number of branches per plant seem to be poorly correlated with development and drop rate of immature and mature flowers, we have no strong basis for estimating the potential yield based on individual characteristics in a given year. Yet, it is important to consider that reproductive phenology is related to factors in the environment, such as the level of rainfall in preceding years (Rathcke & Lacey, 1985; Keeley, 1987), and probably to other factors as well.

Although data are not available, we are certain that the availability of dropped buds depends on two conditions: total bud production per plant and the fall-off rates. In turn, the second factor seems to depend on other conditions, such as the reproductive activity of one or more unknown fly and moth species that lay eggs at an early stage of bud development, emerging a short time later as larvae. Fly larvae infest the pericarpelar tube of young buds, weakening the tissues that connect the flower to the stem. It is not known what environmental factors control the insect population. Rates of egg laying (apparently an event with a stochastic component) could explain the lack of correlation reported here between plant size and the number of aborted buds.

Our recommendation is that floral buds should be considered a restricted supplementary food, limited only to fallen buds. We do not recommend inducing floral bud-dropping or harvesting of intact buds. Like many large and dominant plants in other ecosystems, replacement and persistance of wild populations of cardón depend in great measure on the annual low levels of recruitment of new or younger individuals, which in turn depends on flower production, pollination, and limited opportunities

Table 3. Following the same variables analyzed as Table 2 (except energy). Nutritional comparison of plants (%) commonly associated in the cardonal community and also used as forage. Analyzed tissue of cacti are stem parenchyma and leaves for the other plants (data from Vega-Villasante et al., 1997)

	Moisture	Protein	Lipids	Ash	Fiber	Carbohydrates
Opuntia cholla	80.4	3.8	2.2	5.1	7.2	81.53
Ferocactus sp.	91.7	8.2	5.8	1.6	1.1	83.04
Cercidium microphyllum	44.3	19.4	4.8	21.4	23.1	31.00
Lysiloma candida	62.7	15.6	5.5	10.1	15.1	53.57
Cyrtocarpa edulis	69.6	9.7	8.6	5.2	10.6	66.29
Prosopis articulata	24.0	28.9	7.7	14.4	35.0	13.89

for fruit-setting, seed dispersion, and germination. For the cardón, an important component of the mature Baja Californian plant communities, these issues are still poorly understood.

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