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Estimating fiber for lechuguilla (*Agave lecheguilla* Torr., Agavaceae), a traditional non-timber forest product in Mexico

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ABSTRACT

Lechuguilla (*Agave lecheguilla*) plants are amongst non-timber forest products that are an important source of income for the inhabitants of the arid and semiarid regions of Mexico. There are however, no management programs to promote and protect this resource. In the present study a reliable, non-destructive and easy-to-follow method to estimate yield of lechuguilla fiber in wild populations was developed. A table for estimation of dry fiber production per plant was generated selecting height of cogollo multiplied by its diameter as the independent variable, using a quadratic polynomial regression equation. Using this table in the field would allow a quick and reliable estimation of lechuguilla fiber yield in natural populations.

1. Introduction

Gathering of non-timber forest products is one of the main activities of the inhabitants of the arid and semiarid regions of Mexico, either for home use or sale (Aguirre, 1983). Lechuguilla (*Agave lecheguilla* Torr.) is amongst these materials; its fiber has been used since 8000 years ago (Sheldon, 1980) and it is currently a significant component in the economy of about 20,000 gatherers and their families (Reyes-Agüero et al., 2000) even though it is sold at very low prices. On average, a lechuguilla gatherer ('ixtlero') can collect 1.87 kg of dry fiber per hour, with a selling price of US$ 0.90–1.00 (Mayorga-Hernández et al., 2004).

Lechuguilla is a very common plant in the Chihuahuan Desert, covering large areas of the arid and semiarid lands of northern Mexico and the southern United States (Nobel and Quero, 1986). Lechuguilla fiber is used in metal polishing brushes, furniture and car seat filling, carpets and cleaning brushes (Berlanga et al., 1992; Flores and Perales, 1989; Rzedowski, 1964), as construction material in combination with thermoplastic resins (Belmares et al., 1979; Nieto, 1983) and has recently been suggested as a concrete reinforcement (Juárez et al., 2004).

In spite of the numerous current and potential uses of this species, there is a lack of management to promote and protect the resource. This situation limits the possibilities for new markets and better prices, since there are no data to establish agreements with potential buyers or to ensure sustainable use. Local producers have commented on failure to close contracts with potential international buyers due to the lack of reliable information on fiber yield. As for any species, management of lechuguilla requires knowledge of the existing resource, the yields per plant and per unit area, and the annual productivity in order to estimate productivity rates, extraction volume and frequency.

There are theoretical contradictions on the sustainability of the current use of wild lechuguilla, some authors point out that populations of lechuguilla have been decreasing due to over-exploitation to obtain fiber, and other authors consider that harvest of lechuguilla is sustainable as it has existed since Colonial times and the resource is not considered at risk (Pando-Moreno et al., 2004). Estimation of fiber available for harvesting and its regeneration rate still remain a challenge. Zapien (1980) reported an average of 18,100 lechuguilla plants ha^{-1} for four localities in the state of Coahuila, in northern Mexico, with an average production of dry fiber of 3.11 g $plant^{-1}$, range 1.98–6.86 g $plant^{-1}$, 1, but did not develop a model for assessing fiber production in other localities.

Other works (Zárate et al., 1991; Pando-Moreno et al., 2004) have focused on developing mathematical models to estimate biomass of the plant central cone where new leaves are folded (the 'cogollo'), since this is the part most commonly harvested for manual fiber extraction. Variables tested in these models have been direct plant measurements (height, diameter, number of leaves) as well as their derived areas or volumes of applicable geometric forms. Thus, Zárate et al. (1991) analyzed four

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regression models (lineal, potential, exponential and logarithmic) and found the potential regression model to be the most adequate functional form ($r^2 = 0.761$) using a conical cogollo volume as the independent variable against biomass of the cogollo. Similarly, Pando-Moreno et al. (2004) after testing several variables (height of plant, volume of plant (taken as a half sphere), volume of the cogollo (considered as a cone shape), height of the cogollo, diameter of the cogollo, and height multiplied by diameter of the cogollo) reported cogollo volume as the independent variable with the highest correlation coefficient ($r = 0.9098$) against cogollo biomass.

Blando-Navarrete and Baca (2001) are amongst the few who have modeled fiber production per plant. They found a linear regression coefficient ($r^2 = 0.761$) between direct measurements of the plant and fiber production, unfortunately, the best predictor variables (i.e. plant cover area and number of useable leaves) are time-consuming and difficult to measure.

In the present study a reliable, non-destructive and easy-to-follow method of estimating lechuguilla fiber yield in wild populations was developed using a broad spectrum of phenotypes and environments. This method should be implemented in plans for harvesting lechuguilla in northeastern Mexico, by government agencies, and more importantly by land owners who are ideal candidates for applying sustainable management practices (Sheil and Boissiere, 2006).

2. Methods

2.1. Study areas

Four study areas were selected within the states of Coahuila and Tamaulipas in northeastern Mexico. These areas were: (1) ejido La Independencia, municipality of Jaumave, Tamaulipas (23°33′37″N, 99°22′57″W; elevation 789 m); (2) ejido Estación Marte, municipality of General Cepeda, Coahuila (25°45′49″N, 101°45′38″W; elevation 1177 m); (3) Research Center La Sauceda (25°50′49″N, 101°22′12″W; elevation 1121 m) and (4) ejido Estación Paredón (25°56′48″N, 100°59′18″W; elevation 728 m); the last two in the municipality of Ramos Arizpe, Coahuila.

The study areas in Coahuila have an arid, dry to desert climate (in Köppen classification BWh(w); INEGI, 1986a). In Tamaulipas the study areas have a semiarid climate ($BS_1h(w)$; INEGI, 1986b). Soil types were: Yermosol in Estación Marte and Paredón; Xerosol in La Sauceda Research Center, and Litosol in Jaumave (CONABIO, 2008).

Land tenure is mainly communal ('ejidos'), except for La Sauceda which is an experimental area of a government research agency. Communal lands are open access areas where grazing and extraction of fuel wood and some plants is a regular practice.

Estación Marte has an average maximum temperature of 32 °C and average minimum of 7 °C, and an average annual rainfall of 318 mm. The area is mostly flat, with rosetophyllous desert scrub as the dominant vegetation type, although microphyllous scrubland is present in small patches. Dominant species in the area are: 'lechuguilla', 'gobernadora' *Larrea tridentata* (Coville), 'ocotillo' *Fouquieria splendens* Engelm., 'guapilla' *Hechtia texensis* S. Watson, 'candelilla' *Euphorbia antisyphilitica* J. Meyrán, and 'nopal cegador' *Opuntia microdasys* (Lehm.) Lehm. ex Pfeifer.

Species composition in Paredon is similar to Estación Marte, differing only in height and abundance of the species. In this area, rosetophyllous species are located on slopes and stony soils. Here, the abundance of lechuguilla, candelilla, and guapilla is very high. Average maximum temperature is 33 °C, average minimum 7 °C and the average annual rainfall is 293 mm.

In La Sauceda Research Center, average maximum temperature is 31 °C, average minimum is 8 °C, and average annual rainfall of 293 mm. The following species are common: gobernadora, lechuguilla, 'hojasén' *Flourensia cernua* DC, candelilla, 'nopal rastrero' *O. rastrera* F.A.C. Weber, 'pitaya de agosto' *Echinocereus conglomeratus* C.F. Först, 'palma samandoca' *Yucca carnerosana* (Trel.) McKelvey, and 'bisnaga roja' *Ferocactus pringlei* (J.M. Coult) Britton & Rose.

In Jaumave, lechuguilla is associated with nopal rastrero, 'guajillo' *Acacia berlandieri* Benthos, 'palma china' *Yucca filifera* Chabaud, gobernadora, and nopal rastrero. Other annual species, such as 'oreganillo' *Lippia berlandieri* Schauer and 'hierba del venado' *Turnera difussa* Willd. ex Schult. are also present. Average maximum temperature is 27 °C, average minimum is 15.8 °C, and average annual rainfall of 515 mm.

2.2. Sampling and data analysis

Evaluation sites within localities were selected from directions of ixtleros of where they usually gather lechuguilla plants. A total of 95 lechuguilla plants were sampled: 20 plants from Estacion Marte and 25 from each of the other 3 localities. Selected plants were all chosen from different clusters and covered the broadest possible range of heights, above the 25 cm, which is minimum size allowed for collection according to the Mexican environmental regulations (SEMARNAT, 1996).

Several variables of the plants were measured before harvest to be used as the independent variables in the analysis: cogollo height and diameter, plant height and diameter, and number of leaves. Mean and dispersion values of these variables for each locality are shown in Table 1.

The cogollos of the plants were then collected to extract and quantify the amount of fiber per plant. Local inhabitants extracted the fiber using traditional methods and fiber was then dried in the field to a constant weight. Variance analysis and Tukey's test were made to compare dry weight of fiber per plant between localities.

Stepwise regression was carried out for each locality and for the whole set of data to determine the variable or combination of variables (cogollo height × cogollo diameter (cm^2), plant height × cogollo diameter (cm^2), and cogollo volume (cm^3) (assumed conical) that best predicted fiber air-dry weight, our dependent variable.

Table 1
Lechuguilla statistical values from four localities in NE Mexico

Variables	Estacion Marte ($n = 20$)			Jaumave ($n = 25$)			Paredón ($n = 25$)			Sauceda ($n = 25$)		
	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.	Min.	Max.	Mean ± S.D.
Independent variables												
Plant height	32.00	52.00	41.20 ± 6.23	31.00	97.00	59.84 ± 18.66	25.00	71.00	53.84 ± 10.31	35.00	70.00	52.28 ± 9.55
Cogollo height	25.00	44.00	34.50 ± 5.92	25.00	73.00	48.80 ± 14.95	35.00	60.00	47.56 ± 7.80	32.00	58.00	46.16 ± 7.47
Cogollo diameter	1.20	3.20	2.52 ± 0.57	1.60	5.70	3.57 ± 1.20	2.30	5.25	3.98 ± 0.78	2.10	4.20	2.86 ± 0.53
Number of leaves	10.00	20.00	14.80 ± 2.95	4.00	33.00	16.64 ± 8.62	11.00	37.00	22.32 ± 5.79	5.00	27.00	15.72 ± 4.80
Dependent variable												
Dry fiber weight	1.00	22.00	9.60 ± 5.40	2.68	65.14	26.26 ± 19.21	6.50	53.00	24.36 ± 12.48	3.20	29.30	11.86 ± 7.15