Lechuguilla *(Agave lecheguilla)*; an Important Commercial Fiber Plant and a Source of Income to the Arid Land Farmers of Mexico

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Abstract

Agave lecheguilla is a valuable fiber plant grown naturally in arid lands of Mexico for extraction of fiber. The paper gives a short account of the plant, its distribution, methods of extraction of fiber by the arid land farmers and its processing methods. It is a good source of economy for the arid land farmers,

1. Introduction

Lechuguilla (*Agave lecheguilla*) is one of the nonforestry commercial species in arid and semiarid regions of Mexico used to obtain "ixtle" (fiber) through a shredding process. However, lechuguilla-shredding is a low profitable activity for shredders. They can manually shred 1.87 kg of dry fiber per hour, which in the market has a price from 8 to 11 pesos (about $1.00 US dollar). Using machines for shredding the amount obtained ranges from 15 to 18 kg of dry fiber per hour (Mayorga-Hernández et al., 2004). The technical name of the lechuguilla is *Agave lechuguilla* Torrey. It belongs to the family *Amarilidaceae*. The fiber of lechuguilla has been in use since 1741. Archeological evidence shows that it may have been for thousands of years (Cepeda, 1949). In excavation in the Cavern of the Fright, in the center of Coahuila state, Mexico, a great quantity of sandals and mats made from lechuguilla and yucca fiber plants were found (Taylor, 1966). The Spaniards exploit the fiber in northern Mexico in the 16th century. They found that hunters and gatherers of the "Chichimecas" tribe made arrows from the floral axis of the plant and bowstrings from the fibers (Sheldon, 1980). It reveals that the fiber of lechuguilla has been in use since the prehistoric era as an economically and socially important resource for arid land farmers. At present, it is an important source of primary income for the inhabitants of "ixtlera" region, besides their secondary activities such as the rearing of small ruminants (sheep and goat), cattle and birds, and sale of snake meat owing to the facts that the rainfed and subsistence agriculture in arid Mexico is highly affected by unfavorable climatic conditions.

The fiber is extracted from the leaves, and is classified as hard fibers; the fibers possess high strength, durability, good luster and good. The fiber is primarily used in the textile industry for the manufacture of sacks, threads, bags, mats, brushes or polishing materials. It has a great demand in the national and international market and is exported to other countries of Latin America, Europe, and Asia. The plants are also used as livestock feed if the environmental conditions are poor for the growth of basic and forage crops. It contains a high potential of saponins and possesses medicinal properties against the disease commonly known as 'Tina'.

Since the plant is a valuable resource of the arid and semi-arid zones of Mexico, it should be investigated for other possible uses.

Agave lechuguilla belongs to the agaves group. It is robust and resistant to adverse climatic conditions, and it prospers in regions of scarce precipitation, where the basic food crops can not thrive.

2. Distribution

The plant grows in longitudes between 99°05' and 105°45'W and latitudes between 21°59' and 31°40'N. Lechuguilla plants improve soil structure in the arid zone, by reducing soil erosion. Lechuguilla grows in colonies in sandy soil and it is found to grow on steep hills quite adpressed to rock giving a greenish vegetation, thereby reducing soil erosion. Mostly they grow on heaps of pebbles and produce extend profuse superficial roots to a long distance thereby absorbing quickly scanty showers in arid regions

3. Ecological Conditions

Lechuguilla requires precipitation of 200 to 500 mm annually. Rain generally occurs very irregularly and short torrents, the most of which evaporates due to prevailing high temperature in the arid environments. The temperature in the lechuguilla growing regions vary from 0 to 12°C in spring or, in summer rises upto to 45°C. The plant generally grows in calcareous soils with a shallow sedimentary formation with accumulation of stony pebbles in the arid zones of north-eastern Mexico. One can find lechuguilla in abundance in the mountain ranges as well as in the plain lands in well-drained soil. The plant grows at lower parts of mountain and valleys between mountain ranges. It also grows in a sandy or loamy soil and in soils of igneous origin.

Lechuguilla grows in association with different species varying again in different localities. The predominant species are *Larrea tridentata*, *Porliera angustifolia*, *Jatropha dioica* and *Fourqueria sphendism*. Plant densities varied from 26 to 400 per 100 m^{-2} in different localities depending largely on soil type, slope, and the abundance of pebbles. Plant population decreased with an increase in the flat valley in a loamy soil. Lechuguilla did grow luxuriantly in a colony in shallow soil with an accumulation of stony pebbles. However, it is predominant in a sandy soil with poor organic matter and pH of 6.5 to 8.5 (Maiti et al., 1990). There is significant difference in the morphological characters among different localities, indicating that ecological conditions have a great influence on the fiber productivity and quality. It was found that the middle and external leaves yield more fiber (Villarreal et al. (1991).

The plant is found from 200 to 2000 m asl. They adapts well to soils with depth from 10 cm to 1 m, with 20 to 85% of stones. The pH ranges between 6.5 and 8.4, with organic and nitrogen contents varying from 1 to 15%, and 0.1 to 0.5%, respectively. The lechuguilla is found abundantly in the plains and also on hillsides or mountain slopes. The growth of the plant in mountainous lands with very marked slopes tends to be erect, probably with a higher fiber content.

Lechuguilla is associated with vegetation characterized by a great diversity of perennial species, with succulent, long, and thick leaves, or thorny species in the ecosystems such as *Larrea tridentate*, *Yucca* spp., *Parthenium argentatum*, *Opuntia* sp., *Dasylirion sp.* and *Acacia spp.*

4. Morphology

Lechuguilla shows a great variability in plant densities and morphology under different edaphic conditions and the degree of surface inclination. It grows in rocky soils, with a population density decreasing with a decrease in pebbles. Morphological types vary in leaf orientation, leaf form, leaf dimensions, marginal spines, and pigmentation (Maiti and Garza de la Riba, 1992). The central young cone called "cogollos", at the center of the plant, and the leaves expanded and leaned in variable angles at maturity.

An inflorescence stalk develops from the center of the "cogollo" which reaches a height of 2 to 3 m. The flowers are yellow color and form an axillary group in the form of racemes in the axillary in position of the floral axis . The flower has very short period of life.

The plants form a rosette of leaf canopy with the spreading external leaves and a central conical cylinder "cogollo" in young leaves of the center of the canopy. The root system is fine which extends outward over a long distance in the superficial layer of the soil and with the tillers or sprouts originate from the root stocks that propagate vegetatively to give rise to a cluster of lechuguilla seedlings around the parent stalk (Figure 1).

The plant possesses 25 to 50 leaves on the surface of the soil and consists of one stem. Their color is clear green to dark. Each leaf terminates at the leaf apex in a sharp strong, deep black thorn. The margins of the leaf have hook-shaped thorns. The external leaves are strong and spread apart. It takes about 6 years to produce the 2 to 3 m high inflorescence axis with a diameter of 4 cm. It bears yellowing flowers that soon dry up. The flowers are protected with greenish res bracts. The perianth calyx is divided in six calyx lobes. The fruit is a capsule containing the seeds of a dark coffee color. Each flower possesses six stamens with versatile and bilobed anthers. It has only one pistil of circular form and is superior. The plant reproduces by seeds, but generally by vegetative buds arising from the underground rhizomes or stolons (Sheldon, 1980).

5. Anatomy

The fibers are present in leaf mesophyll in the form of fiber filaments from the base of the leaf up to the leaf tip forming apical spine.

From a transverse section of the leaf at the base, middle and top portions of the central, middle and central leaves, it was observed that the fiber cells in the fiber bundles showed a gradual increase in the degree of lignifications from the base at the apex (Diagram 1).. The fiber cells at the base are thin-walled with a broad lumen, but at the middle and apex of the same leaf, they showed higher degree of lignifications with narrow lumen. The fiber bundles were at a much younger stage of development in the leaves of "cogollo" compared with the middle and external leaves, which were highly lignified. The fiber strands of the leaf from the base extend vertically and converge gradually along the growing leaf through the mesophyll tissue until they united in the leaf apex to form the strong spine in all the leaves. The filaments near the leaf margins were short and did not reach the apex.

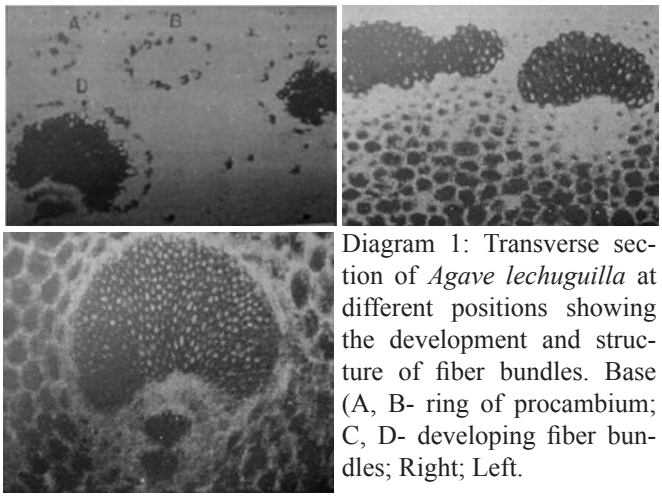


Diagram 1: Transverse section of *Agave lechuguilla* at different positions showing the development and structure of fiber bundles. Base (A, B- ring of procambium; C, D- developing fiber bundles; Right; Left.

6. Exploitation

Sheldon (1980) indicates that lechuguilla can be exploited more fully in its areas of distribution.

The fiber is usually obtained from the "cogollo", the youngest part of the lechuguilla plant; the survival of the plant under exploitation depends on the time and frequency of removal of the "cogollo". An excessive removal of "cogollos" could lead to the death and disappearance of the lechuguilla colony. Dry land farmers start to remove the "cogollo" from the sixth year of growth. The plant could live for 15 to 20 years (Patoni, 1927; cited by Sheldon, 1980). However, it is necessary to undertake research on the utility of the mature leaves, since their fibers are stronger and more desirable; it is a natural resource not yet explored. Fiber obtained from the mature leaves is observed to be highly lignified. It was observed that the fibers extracted from the mature leaves were very thick and of poor quality, but chemical treatment could increase their resistance and force.

Lechuguilla harvesters travel long distance across mountains to gather the "cogollo". The members of the whole family work hard to extract the fibers for earning revenues. A machine to extract fibers from young and mature leaves could improve exploitation of this important natural resource. Also, the marketing system must be improved.

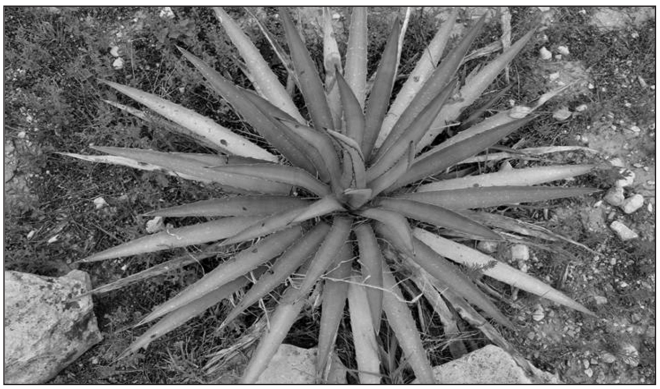
Lechuguilla fiber is of high quality and has a strong demand in the national and international market. Its efficient exploitation is limited by the following factors:

a. Production is irregular because of abundant precipitation; the peasants prefer to devote their time to raifed agriculture, which is more profitable.
b. Variations into prices affect the socioeconomic conditions of harvesters "ixtleros".
c. Middlemen.
d. The crop grows far from the residence of the farmers.
e. The process of manual extraction is inadequate and crude.

7. Harvest and Extraction

Fiber has been extracted by a traditional method. Lechuguilla farmers select the plants of a good size. The "cogollos" are manually harvested starting from the sixth year (Sheldon, 1980). Mechanical methods to harvest and extract fiber are not available to the small farmers. Once the "cogollo" is harvested, the lechuguilla farmers separate the leaves and discard the youngest leaves, which possess very little fiber. Then the marginal thorns are eliminated to facilitate the extraction. Later, the leaf is smashed with local extracting tool consisting of one knife of 40 cm long and a flat wooden piece. The apical of the leaf is held with one hand, and with the other hand the basal end is placed flat on a wooden plank and is pressed and smashed with the knife. The parenchymatous tissue or pulp of the leaf is thus separated. The procedure is repeated on both sides of the leaf, and the fibers are completely separated from the leaf pulp (Figure 2). The fibers are then spread on the floor, or roof for sun drying. The waste tissue serves as livestock feed, although it could also be used in the fabrication of paper. The mechanical method of extraction has been used since 1980. The decorticating machine consists of a rotating cylinder with sharp teeth connected to a motor. The farmers feed the leaves into the machine, which extracts the fiber and eliminates the pulp at the same time (Figure 3). This extracting machine should be made available to the farmers. The main disadvantage of shredding machines is a deficient cleaning, as the fiber is stained and with a high amount of residues stack on it, which affects adversely its price in the market. Fiber of lechuguilla is classified during the purchase-selling process, as quality depends mainly on cleanness, coloration and longitude. In some instances there are losses because when the cylinder turns, pulls the fiber and tangles it or expels the fiber through the discharge outlet (Mayorga-Hernández et al., 2004).

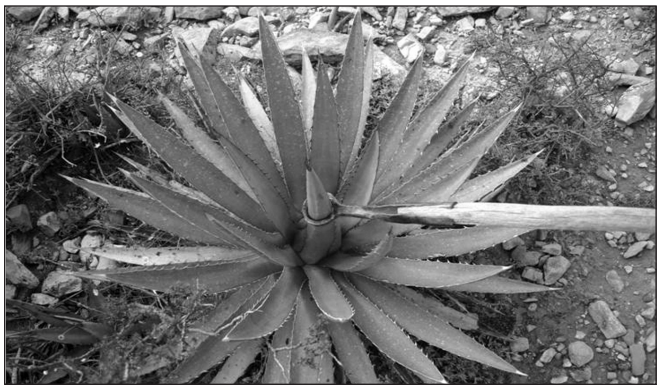
Agave lecheguilla plants growing under semi-arid conditions



Agave lecheguilla plant forms a rosette of leaf canopy spreading external leaves

Agave lecheguilla inflorescence

Selecting *Agave lecheguilla plants* for fiber extraction



Selection and harvest of central young leaves; central conical cylinder known as "Cogollo" for fiber extraction using a local tool known as "lechugero"

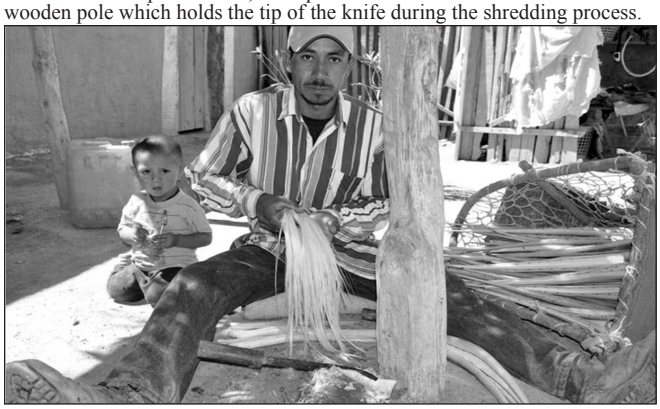
Showing the removal of "Cogollo" from the "lechuguero" by hand

Transport of removed "Cogollos" by gatherer using a man made canister or basket hold in his back

Manual shredding of removed *A. lecheguilla* young leaves from "Cogollo" to extract fiber by using traditional tools

Use of an unsharpened knife, a flat piece of wood known as “banco” and a wooden pole which holds the tip of the knife during the shredding process.

The parenchymatous leaf residue known as “Guiche” left after fiber extraction



Extracted *A. lecheguilla* fiber from “Cogollo”.

Selecting *Agave lecheguilla plants* for fiber extraction

Drying of *A. lecheguilla* fiber

Manual display of dried fiber

Unravel of *Agave lecheguilla* fiber

Disentangle of *Agave lecheguilla* fiber

Showing of unraveled *Agave lecheguilla* fiber

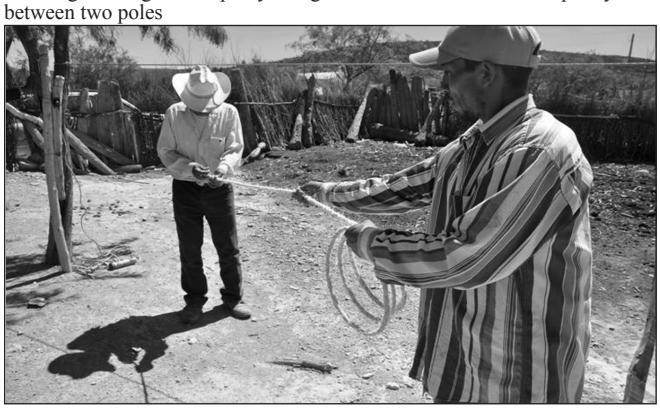
Rolling unraveled *Agave lecheguilla* fiber to begin the thread of a rope

Threading the rope in the initial stage

Showing threaded rope

Twisting of the grown rope by using a local man made wooden pulley held between two poles

Tighten up of finished and twisted threaded rope



Stretching and rolling the rope

Rope made from *Agave lecheguilla* fiber

Two additional methods was proposed by a scientist for the exploitation and collection of lechuguilla: (1) without cutting the plant and carrying the external leaves, and 2) collecting all the leaves of the plant.

8. Quality, Application and Industrialization of Fiber

The quality of lechuguilla depends on water absorption, density, and diameter. In these terms, it is superior to other vegetable fibers which have lower resistance. The lechuguilla fiber has a great demand on the fabrication of scrubbing machines in the world market owing to the high bending modulus. The strong mature fibers are cut into small bundles, treated with black resin, and sold to foreign market for use in machine scrubbing. The long central fibers show higher values of elongation and tension than the peripheral short fibers. However, the fiber from the external leaves may be used for rustic purposes such as brooms, scrubbing machines (Maiti and Garza de la Riba, 1992).

9. Machine Processing of Fiber

The fiber is processed in a machine that separates out impurities and dusts, arranges the fiber in parallel, and cuts fibers into uniform sizes.

A study has been carried out to evaluate the fiber quality obtained from lechuguilla leaves by manual and mechanical procedures. Results showed no significant differences ($p>0.05$) between both extraction procedures for fineness (linear density), resistance to the tension force, maximum elongation and mechanical damage. However, there were significant differences ($p\leq0.05$) for color of fiber due to the amount of residue remaining on the fiber obtained from the machine.

10. Conclusion

Considering the great potential and the varied ecological conditions in which it is found, it is important to determine which ecosystems produce higher quality fiber. There is a great need to improve the methods of exploitation and introduce adequate mechanical instruments for the harvest and extraction of fiber without damaging it. Very little scientific information is available on the variability in fiber productivity, structure, and quality.

Lechuguilla varies in morphological types and abundance under different edaphic conditions. Fiber cells in lechuguila originate at the base of the developing leaf from procambial cells surrounding in undifferentiated mesophyll. Gradually, these procambial cells develop into fiber cells and are transformed into fiber bundles with xylem and phloem on the concave side of the bundle.

Fibers from species of *Agave* (*A. sisalana* and *A. cantala*) could be substituted for those of *A. lechuguila* in machine scrubbing brushes, provided they are treated with resin (Maiti, 1973).

The uses of the plant and its fibers can be diversified; shampoo can be made from the fleshy root, insecticides can be made from leaf residues and insulating can be made for roofs, cots and paper. Research is needed to discover uses for the fibers obtained from the mature leaves. An effective method of propagation from seeds or tissue culture could save and conserve the valuable plant. Lechuguilla seeds germinate easily and can be used for propagation. The small lechuguilla farmers need to be educated in the conservation and efficient exploitation of the plant and its products.

The following plates show a panoramic view of lechuguilla vegetation, harvesting of leaves, manual fiber extraction procedures, and man-made fiber threading in the semi-arid regions of northern Mexico.

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