The Native Yucca: a Boon to the Farmers of the Arid North-east Mexico

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Abstract

Growing naturally in the arid and semi-arid zones of Mexico and the United States Yucca serves as an important source of fibers for inhabitants of this region. Besides, its flowers and fruits are also consumed by the local people. Flowers are also used as feed for livestock. However, over-exploitation of this natural resource poses a threat to the desert eco-system and subsistence of inhabitants of arid lands. This paper provides an insight into the distribution, ecology, morphology, reproduction, growth, method of fiber extraction and processing, etc. of Yucca with future areas of research for effective conservation and management of this valuable slow-growing natural resource.

1. Introduction

The genera of *Yucca* are found growing in the arid and semi-arid zones of Mexico and the United States where the harsh environmental conditions are not favorable for the growth of annual crops. It serves as an important source of fibers apart from other economic value. The fibers are strong and of high quality. It acts as a gift of nature to the poor arid-land farmers of these regions. The plants bearing huge pendant edible inflorescence beset with white fragrant flowers add beauty to the nature as well as give shade to the livestock.

The plants grow in the wild and are highly exploited. The fiber producing species is *Yucca carnerosana*, although there exist around 25 more species, among which *Yucca filifera* is important for a great diversity of uses.

The fiber is used largely for dish washing and house construction. The dry leaves and stems are used to prevent soil erosion in the hilly agricultural lands. *Yucca* flowers borne on long pendant inflorescences are covetable vegetable in Mexican kitchen. Therefore, *Yucca* constitutes a source of revenue for the subsistence of farmers of these regions.

In accordance with the classification of Linnaeus, the genus *Yucca* belongs to the family *Liliaceae*. Hutchinson defined a new order: *Agavales* with *Agavaceae* family, which includes genera belonging to both the families, *Liliaceae* and *Amaryllidaceae*. *Yucca carnerosana* is commonly known as ixtle palm or palm 'samandoca' (Marroquin et al., 1981). *Yucca filifera* is known as *Y. australis*, as well as 'zote' (big palm).

2. Distribution

The genus is represented by around 47 species of which 29 grow in arid and semi-arid climates in Mexico with the exception of *Y. elepantpes*, *Y. aloifolia*, and *Y. lacandonica* which grow in the humid zones (Pina, 1980). In America, these plants grow in the north-eastern United States, Mexico, and some regions of Central America (Webber, 1953). In Mexico, this plant grows in the arid and semi-arid states of San Luis Potosí, Zacatecas, Tamaulipas, Coahuila, Nuevo Leon, Durango, Chihuahua, and Baja California. Some studies in the distribution of *Yucca* plants indicate that the potentially economical area in the exploitation comprehend almost 1,000,000 plants of *Yucca* in the arid and semi-arid zones of Mexico.

3. Ecology

Plants grow in hills (hill sides and summits) in soils of depths varying from 8 cm to 1 m; color of the dry soil is coffee dark, pale, grayish or dark gray, ivory dark or reddish dark, black

and red-yellowish. Humid soil could be of a yellowish coffee or reddish coffee color. The pH varies between 6.8 and 8.4; the percentage of organic matter and nitrogen ranges from 1 to 13% and 0 to 1%, respectively.

Plants of the genera *Opuntia*, *Agave*, *Prosopis*, *Larrea*, *Euphorbia*, *Acacia* and *Parthenium* are found in abundance. Plants of the genus *Yucca*, specially *Y. filifera* and *Y. carnerosana*, grow in the arid zones of Mexico characterized by the presence of extreme high and low temperatures and maximum annual precipitation of 400 mm.

4. Morphology

Plants are perennial, in certain cases bushy, and trees. The leaves are ascendant, rigid, fibrous, flat, and convex and have flat, dentate, or fibrous margins; they end and finish in a sharp apex. The inflorescence is an erect or hanging panicle. The flowers are campanulate or globose with five petals, curved and free, sometimes united in the case of the segments. The ovary is superior and trilocular with numerous ovules on axile placentation. The fruit is indehiscent and dehiscent in berry and capsule, respectively; the seed is flat and brilliant or opaque black. It may have a smooth or rough surface.

Cattle browsing affect the reproduction and population structure of *Yucca elata*. Cattle browsing of the inflorescence reduce the reproduction capacity. Browsing also increases branching, probably due to the absence of apical dominance, to increase the procumbent habit of the plant. Cattle browsing has probably led to the local extinction of the *Yucca* moth (*Tegeticula yuccasella*) and local reduction in the bird diversity.

5. Pollination and Reproduction

Generally, all the species of the genus *Yucca* have entomophilous pollination through a lepidoptera of the genera *Promuva tegeicula* or *Yuccela trel*, which develop inside the fruit. The insect places the eggs in the ovary, thus transporting the pollen from the anthers to the stigma. Under natural conditions, in each period of flowering, great quantities of fertile seeds are produced, which are reproduced sexually and asexually by tillers in the apical parts of some species.

Pollination biology of a population of 250 *Y. elata* plants was studied in southern New Mexico. *Yucca elata* and *Y. Prodoxid*, and *Yucca* moth *Tegeticula yuccasella* have shown a mutualistic association that is essential for the successful sexual reproduction of both species. However, wide ranges of other invertebrate species visit flowers during the day and night. *Yucca* moths and other invertebrate visitors play active role in pollination and fruit sets. During the flowering period *Yucca* moths were found most active in night. It was assessed that none of the flowers exposed only to diurnal visitors set fruits. It was determined that 1) flowers opened at dusk and were open for two days on average, but were receptive to pollen on only the first night of opening; 2) pollen must be pushed down the stigmatic tube to facilitate pollination; and 3) most of the plants required outcross pollination to produce fruit. It was concluded that *Yucca* moths are only moth species effecting pollination in *Y. elata*, and that other species play a role only rarely (James et al., 1993).

In a subsequent study to investigate the low efficiency of mature fruit production by *Tegeticula yuccasella*, it was observed that the fig wasps only lay eggs on short-styled flowers, as they were unable to reach long styled flowers. This limits egg deposit and shows a balance of self interests rather than a purely symbiotic relationship with the moth (Moore, 1993).

An evolutionary stability of mutualism was observed between *Yuccas* and *Yucca* moths. A strong positive relation exists between the number of pollinations received and the probability of flower retention. Selective maturation of fruit with low egg loads and high pollen loads provides a mechanism to increase the quantity, and possibly the quality of seeds produced and simultaneously selects against moths that lay many eggs flower^{-1} or provide low quality pollinations. The results demonstrated the stability of this type of interaction and also selection for high quality pollination indicated a mechanism to explain the evolution of active pollination among *Yucca* moths (Pellmyr and Hutch, 1994).

The reproductive ecology and breeding systems in plain populations of *Y. glauca* were studied in northern Colorado. The preferred habitat of *Yucca* moth in *Yucca* was compared with those in sites at the edge of the local height distribution. *Tegeticula yuccasella*, the sole pollinator, was abundant at plain sites and fruit set was significantly higher than in foothills, where fruit set is limited by the paucity of moths (Dodd and Linhart, 1994).

6. Growth and Development

In general, the species of the genus *Yucca* grow and develop slowly. It is estimated that they grow only 3.8-7.6 cm year^{-1}. The plant begins to fructify with one or two rosettes at 20th and 22nd year. Many disappear before they reach this stage as they are cut down for fencing in hilly agricultural lands to prevent erosion or are exploited for cellulose extraction. Above all, the environmental conditions have a significant effect on growth.

The fruit matures from October to December-January. Then, it follows a process of hydration, rotting and fall. Generally, the seeds exhibit 60-80% germination which may fall as low as 48%. The number of plants that reach to adult stage through reproduction by seeds is low, mainly because of the lack of moisture, insects, or browsing by livestock.

During its growth, the plant acquires a succulent form, whose embryonic leaves last one year, and then these are finally

replaced by the characteristic leaves of the adult stage, which last for 8 months to 3 years.

7. Uses

The fiber is of good quality and high strength. Several species are used, but better fiber is obtained from *Y. carnerosana* and *Y. filifera*. Fiber obtained mainly from the species of *Y. carnerosana*, *Y. filifera* and *Y. elata* are used in the manufacture of cords, strings, seed sacks, handbags, linens, cables, sandals, belts, brooms, and brushes, and for materials used in falcons (Ridaura-Sanz, 1980). Besides, the fibers of high industrial value offer many benefits to the human and livestock population and constituents of commercial values mentioned below. The edible parts of the plants are the flowers and fruits (date palms) which are consumed by the inhabitants of arid lands. The flowers are also sources of feed for livestock. Good quality fruits come from *Yucca carnerosana* (Roman, 1980) which can be eaten raw or cooked; flours or alcoholic drinks are fermented from the dry fruits. The seeds contain compounds such as 8% sarsapogenin, 16% pharmaceutical hidropregnanolone acetate.. 50% of the fruit is the mesocarp, which is edible and is used in the preparation of balanced feed for cattle. Linoleic oil is also obtained, which can be used as fuel. The oil obtained from the seeds is the crude material used in the manufacture of aromatic essences.

Saponins extracted mainly from the roots and leaves can be used as substitute for soap. The content of saponin and steroids in *Yucca* is of great pharmaceutical importance, since these are the sources of raw material for the fabrication of corticoids. Some common saponins are gatogenis, sarsagenin, texogenin, and yucagenin.

The leaves and stems are used in rural construction in arid lands. The stems have high cellulose content and are used to manufacture paper. Judicious exploitation of this crop is suggested as overexploitation may lead to total destruction of the plant and increase deteriorations in the desert eco-systems.

With respect to the influence of *Yucca* extract on ruminal metabolism in cows, working on rumen-cannulated lactating cows; the results revealed that the application of *Yucca* extract at 4 g day^{-1} did not significantly affect rumen digestibility of organic matter and acid detergent fiber.

In the context of the above discussions *Yucca* serve as important source of many useful products of great importance for the benefit and better economy of the poor inhabitants of arid lands of Mexico.

8. Exploitation for Fiber

About 3,000-5,000 people in Mexico work in extraction of fiber mainly from the plants of the *Yucca* genus, the most important being *Y. carnerosana* (Marroquin et al., 1981).

In the ixtle region, this plant holds first place as source of economical revenue for the inhabitants of the desert lands. Because the annual precipitation of 400 mm in these regions is not sufficient to raise an annual or basic crop, the arid zone community also breeds goats, mines and gather 'piñon', honey, among other natural resources. The women extract fibers, while the men carry out other productive activities. The women toil whole day and then the men carry the fiber in the centers from where the fibers are transported to factories where they are processed by high technology machinery. There should be good facilities offered by government to the farmers to sell their hard earned product. In many cases the middlemen cheat them.

Heavy demand and over-exploitation pose a great threat to the existence of this valuable natural resource. This natural resource has long been exploited indiscriminately which has caused imbalance in the desert ecology; and over-exploitation is threat to the extinction of this valuable resource in near future, probably never to be recovered. For fiber extraction, the trees are cut down to keep the land barren thereby causing a great damage in desert ecology and flora and fauna. *Yucca* flowers serve as source of nectar to the honey bees and other insects. To our wonder no attempts were made to deforest/propagate species. Surprisingly, *Yucca* plant takes at least 20-25 years to grow to a height of 5-6 m, when it can be cut down in less than an hour. The exploitation of central leaf whorls often kills the plant. Quantification of these natural resources is essential in view of over-exploitation. Plant height, height of the main timber, stem diameter, and branches are reliable parameters to assess the productivity of *Yucca* spp.

The desert species of the *Yucca* genus offer alternative products for commercial exploitation. However, the system of exploitation and the lack of information on the technical methods impede an adequate management of the wild population.

A comparative study by Villarreal-Rivera (1988), and Villarreal-Rivera and Maiti (1991) on morphology and anatomy of *Y. carnerosana* in different localities of Mina, Nuevo Leon, Mexico, indicated that the morphological characters (leaf length, breadth at the base, middle and apex), which are considered as yield components, showed significant differences in two localities; the dry fiber weight and the number of fiber filaments varied largely in two localities. Highly significant correlation was found between leaf length and leaf base width at the base (r=0.77), in the middle (r=0.81), and at the apex (r=0.69). This relation varied in different localities. A good relation was found between morphological characters and fiber yield $leaf^{-1}$(Villarreal-Rivera and Maiti, 1991).

The developmental anatomy of fibers in *Y. carnerosana* was studied (Villarreal-Rivera and Maiti, 1991; Villarreal-Rivera et al., 1994). The fiber cells are derived at the mersitematic region at the base and increase by cell divisions and elongation. The

growth and development of fiber cells follow three principal phases; cell division, cell elongation, and cell wall thickening. The fiber cells are developed by the modifications of procambium at the base of the young leaf of the central whorl. This phase is followed gradually by vertical elongation of the fiber cells along the leaf length through the mesophyll. The fiber cells at the leaf apex are highly lignified and mature, and form a sharp stiff spine. Plate 1 illustrates the anatomical features

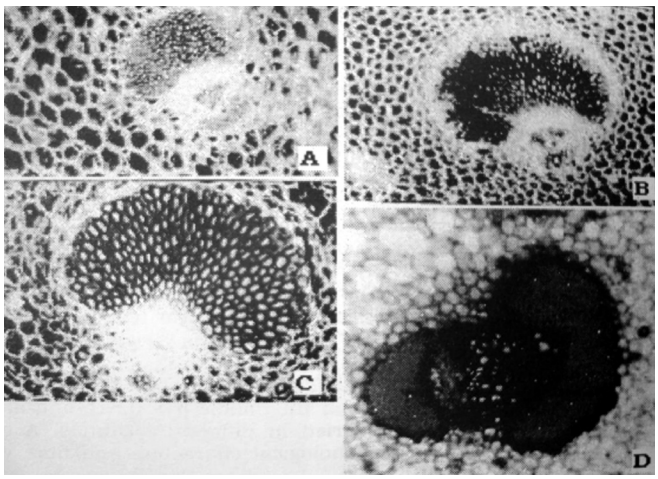

Plate 1: Transverse section of leaves showing the structure of fiber bundle in *Yucca carnerosana* at different positions of leaf (A. base, B. middle, C. Tip and D. mature fiber bundle)

of *Yucca* fibers at different positions of leaf.

9. Harvesting and Fiber Extraction

Several methods are used to extract *Yucca* fiber. The methods/processes include

- Fermentation, fiber extraction and drying.
- Washing, fermentation, fiber separation and drying.
- Cooking, fermentation, fiber extraction and drying.
- Cooking, smashing, fermentation, fiber extraction and drying.
- Smashing, cooking, fermentation, fiber extraction and drying.

The exploitation of the 'cogollos' is the most conventional method for fiber extraction. Cogollos are harvested by means of an instrument called 'cogollera' and a 'huaca" or sack to carry or transport them. The cogollera has a long neck with a cutting knife of iron at one end. This instrument is inserted at the base of the cogollo to remove it and collected in the sack. When the sacks are full, they are placed in a container with water to be cooked for 10-12 h. The leaves of each cogollo come off and are processed in a man-made local device called 'tallador' to remove the parenchyma tissue that is used as livestock feed. After extraction, the fibers are sun-dried, and then are packed and sent off for sale or further processing. Plate 2 shows *Yucca carnerosana* plants growing under natural conditions, and the removal of cogollo by local tools is sown in Plate 3.

Sometimes extraction is carried out mechanically. In other methods of extraction, fiber is obtained from mature leaves. However, this practice is unusual and must be strictly controlled in view of the risk of ecological deterioration and the possibility of affecting the income of the inhabitants of these zones. Rigorous methods of conservation should be applied for this slow-growing natural resource.

10. Fiber Processing

Fiber is processed in the factory through a series of steps for obtaining the final product.

10.1. Selection

Hard and rigid fiber bundles are separated. The undesirable fibers are rejected and fibers that appear suitable for the manufacture of particular products are retained.

10.2. Softening

The selected fibers are mixed with an emulsion of water and petroleum or oil to a variable concentration. They are completely submerged in the emulsion to facilitate in the following

Plate 2: *Yucca carnerosana* plants growing under semi-arid conditions (left panel) and *Yucca carnerosana* leaves (right panel)

Plate 3: Field view of *Yuca carnerosana* plants growing under natural conditions, inflorescence and removal of cogollo using local tools

phases.

10.3. Carding

The fiber is combed so that the filaments remain parallel, in this phase the process is the same as that used for jute, but here it should be repeated three times. The combed fibers have a width of approximately 10 cm. Then they are cut in the middle in two. After each repetition of the combing process, the fibers are passed in rollers and are packed in cylinders.

10.4. Yarn

After combing, the fiber twists and stretches out over rollers. A thin thread is formed and constitutes a large quantity of fibers of high strength.

10.5. Thread

The threads are twined in rolls or spools which are then knit and joined with other spools in a continuous system.

10.6. Weaving

Fabric is made of variable sizes. The cloth is received in spools, ironed, and cut to a conventional size in order to manufacture sacks.

10.7. Packing

The sacks are packed in bundles for sale.

11. Quality

The fiber has poor luster and thick strands, but it is very strong compared to other vegetable fibers.

12. Research Needs

For efficient utilization of fiber, research needs to be directed in the following direction.

- Identify ecological conditions for maximum yield and locate the zones that produce fiber of best quality.
- Identify the stages and parts of the plant that give maximum production.
- Improve the methods of fiber extraction.
- Exploit other related species and compare the quality according to the several uses.
- Carry out anatomical studies that determine fiber quality and production.
- Improve the socio-economic condition of those depending on this resource.
- Expand the markets with the objective of increasing the economic condition.
- Investigate other possible applications of the products as feed, and in industry, chemistry or fabrication of paper.
- Determine the magnitude of available resources in order to prevent the extinction of species.
- When plants with ramifications are exploited, the rosette must be propagated or propagation may be done by seeds which have high germination capacity.
- Anatomical research could predict the quality of the fibers from different leaves.

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