Rubber Production in the Desert: Guayule Bounces Back

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Guayule (Parthenium argentatum) is a known producer of rubber similar in nearly all characteristics to hevea, Hevea brasiliensis, and as a plant adapted to arid conditions it is presently receiving a large amount of attention.

Guayule is not a newcomer as far as knowledge of its rubber bearing characteristics is concerned. Early Spanish explorers in the sixteenth century reported its use by native people to produce rubber balls for games. The rubber was obtained by communal chewing of stems of the shrub.

The plant's rubber producing capabilities first came to international attention in 1888 when the New York Belting and Packing Company imported 100,000 pounds of guayule from Mexico and extracted the rubber by immersing the shrub in hot water. By 1910, half the rubber used in the United States was obtained from native Mexican stands of guayule. Because the whole plant was pulled for harvest, these stands were completely depleted. An interesting point here is that when demand for rubber increased during World War II, it was found that these stands had regrown. Again they were depleted to supply wartime rubber needs, but recently it has been found that the stands have made an astonishing recovery.

The guayule plant is a small gray-green shrub with a silvery cast, hence, the specific name argentatum. In its native habitat a mature plant is one to two feet in height, branching from the ground and above to form a compact shrub. The leaves are long and narrow, usually with one or two tooth-like projections. The flowers are clustered in heads on stalks 4 to 6 inches long, with seven flower heads per stalk. Each flower head consists of 5 fertile ray florets and 10 sterile tubular disc-florets in the center. The center flowers are sterile, but each of the 5 ray florets may produce a very small seed, which falls free with various plant parts attached.

Rubber formation in guayule occurs in the cells. There are no latex tubes as in Hevea. Rubber is found in all parts of the plant except the leaves. The largest concentration is in the bark, which contains 75 to 80 percent of the plant's total rubber. More than two-thirds of the rubber is in the branches. Rubber concentration is higher in the secondary roots than in the main roots.

Resin canals occur throughout the plant, but principally in the bark. The resins include essential oils, parthenyl cinnamate and partheniol, betaine, fatty acids, an unidentified wax and other constituents. Resin concentration, which may be as much
as 10 percent of the dry weight, is highest in the bark and lowest in woody stems and roots. Young stems contain more resin than old stems.

It is not known whether the rubber is of any value to the plant. It is the end product of a synthesis in which long chain molecules are formed. Apparently these do not serve as reserve food materials, as they do not break down when other food reserve material is exhausted.

There are large seasonal fluctuations in the rate of rubber accumulation. Concentration percentage is highest during cool seasons and periods of moisture stress; lowest during periods of lush growth. In its native range, the dry period largely coincides with the cool season and plants are more or less dormant from October to April.

Guayule is native to the Chihuahuan Desert of north-central Mexico and the southwestern United States, particularly the states of Coahuila, Chihuahua, Durango, Zacatecas, San Luis Potosi and Nuevo Leon in Mexico and the adjacent Big Bend area of Texas. It grows in scattered patches on calcareous foothill and outwash slopes in regions with an annual rainfall of 5 to 15 inches, most of which falls in late spring and early autumn. It does not penetrate the alluvial soils of the wide intervening plains and valleys.

Its elevation range is 2,000 to 10,000 feet, but guayule grows mainly at elevations below 6,500 feet. In Texas, the elevation range is between 2,800 and 4,200 feet. The most extensive guayule area lies about 30 miles south of Alpine at an average elevation of 3,700 feet.

Seasonal and diurnal temperatures in its natural habitat vary greatly: maximums of 115°F and minimums of 0°F have been recorded. Unless dormant, guayule is not tolerant of temperatures below 15°F but it can withstand droughts.

Guayule grows best with temperatures between 90° and 100° Fahrenheit. Growth slows markedly when the temperature falls below 60°F. Guayule does not seem to have a definite seasonal growth rhythm. It grows, flowers, and fruits whenever, and as long as, conditions are favorable. In its native habitat it normally flowers in summer, but it may do so any time in the year when growth is active, depending on the amount of rainfall. When irrigated the plant may continue to flower from early spring to late fall.

Guayule has been grown on a production basis in California areas with dry summers and winter rains, in Arizona with both winter and summer rains and in New Mexico and Texas where the principal wet season is in summer and fall. In all but the California Coastal area and southern Texas, rainfall was supplemented with irrigation.

Guayule is a prodigious seed producer. During the first growing season, irrigated plants in the San Joaquin Valley produced 25 to 40 pounds of clean [unthreshed] seed per acre and 500 pounds were not uncommon in older plantations. Unirrigated plantings in the Salinas Valley yielded 10 to 20 pounds the first season and 100 to 200 pounds in subsequent years.

In commercial practice, ripe seeds are cleaned with standard seed cleaning equipment to remove stems, leaves, clusters of sterile florets, insects and weed seeds. Guayule seeds can then be stored indefinitely if dried to a five percent moisture content. Threshing is beneficial, reducing dormancy and improving percentage germination.

The guayule seed has some physiological dormancy but the chief cause of dormancy lies in the seed coats. When cultivation was first attempted it was found that germination was very low resulting in failure to establish plantations.

W. B. McCallum, an employee of the Mexican guayule rubber company later known as the Intercontinental Rubber Company, might be considered the father of commercial rubber production from guayule. He solved the germination problem by treating the seeds with calcium hypochlorite [later sodium hypochlorite "chlorox" was used]. The process involves long soaking in water, treatment with the hypochlorite solution and thorough rinsing. Treated seed can be dried and stored, or planted immediately. It can also be kept moist and sown after germination has begun.

McCallum brought the first seeds into the United States in 1912 and established a plantation at Valley Center, California. He moved his operation to Continental, Arizona in 1916. Not being satisfied with results there he moved to Salinas, California in 1936 where the operations of the Intercontinental Rubber Company were continued until the company was purchased by the U.S. Government at the beginning of World War II for the Emergency Rubber Project.

Because of serious difficulties encountered in establishing seedlings in the field, McCallum had developed a system of nursery production that was continued by the Emergency Rubber Project. Seeds were sown in seven 2-inch bands on a four foot bed by a planting machine which then covered the seed
Figure 1. A one-year old Guayule plantation in the Salinas Valley of California.

Figure 2. A Guayule nursery showing overhead sprinkling devices and beds with plants ready for lifting.
with a shallow layer of sand. Moisture was provided by an overhead oscillating sprinkler system. Weeding was a serious and expensive problem until overcome by the development of oil sprays during World War II. These reduced the necessity for hand weeding to one tenth of what it had been.

Plants were grown in the nursery for periods of four months or longer, depending on the rate of growth, and the need for planting stock. After being hardened by having moisture withheld, seedlings were mowed to a height of one to two inches, undercut by a sharp tractor-pulled blade at a depth of about seven inches, sorted and packed in small crates for transportation to the field. Plants could be held for several days without refrigeration and as long as 30 days if properly refrigerated. The transplants were planted by 4- or 6-row planting machines, originally designed for planting vegetables. A crew of 10 could plant an acre an hour.

Nursery problems and disease losses were minor as long as the nursery beds were restricted to well drained sandy loam or loam soils and the beds carefully leveled. Sprays that were too coarse resulted in sand splash injury. Snow fences or other wind breaks were found essential to control spray drift and to prevent seedlings from being blown out of the ground.

The selection of plantation fields is very important as guayule grows best on soils within the range of loamy-fine sands to silty clay loams with good aeration and internal drainage. Unsatisfactory growth and yield result when soil conditions make moisture available for short periods followed by extreme drought, as occurs on very light soils and heavy soils with coarse substrate at shallow depths.

Guayule plants grow well in soils with a pH from 6.0 to 8.5, and are stunted at pH 4.5 or pH 10.5. Optimum growth occurs from pH 7.2 to 8.3. Guayule tolerates a salt content up to 0.3 percent anywhere in the soil profile, but a salt content of 0.3 to 0.6 in the top 2 feet greatly retards growth and over 0.6 percent in the surface soil results in death.

It was found essential that irrigation runs be of moderate length to insure uniform wetting without flooding. Flood or basin irrigation was generally not satisfactory.

Because of the desire for rapid growth, there was a strong tendency to overirrigate. At first it was thought that a large shrub could be grown and later filled with rubber through stressing by withholding water. This assumption was wrong. It was learned that growth and slowdown for rubber development must alternate, and either cool temperatures or decreased moisture could provide the “stress” necessary for rubber formation.

Shrub spacing was found very important in controlling growth of individual plants and obtaining maximum shrub and rubber production. Over a three year period maximum production was obtained by closely spacing plants in rows about 14 inches apart. The 20-inch spacing used during World War II was too sparse for short cycles (two years or less), but probably close to optimum for a four year rotation.

Weeds were found to be a problem in field plantations. Young guayule plants do not compete well with weeds, and as cultivation was not sufficient to control weeds some hand weeding was necessary. The need for hand weeding was later reduced by the use of cultivators designed to weed within the rows and by the use of oil sprays. After plant top growth closed in the space between rows, cultivation was unnecessary.

The shrub was harvested by digging the entire plant, as one fourth of the plant's rubber is in the roots. Mowing was tried as an intermediate harvest and, as far as survival and growth of the plant was concerned, it was successful if done during the dormant season. However, harvesting and milling costs and related processing problems discouraged this type of harvesting.

After shrubs were dug they were windrowed before removal from the field. During the earlier years it was thought that sunning was essential, but this was later found untrue. In fact it proved to be detrimental to the rubber. The Intercontinental Company used an ensilage cutter to chop up the shrub before hauling to the mill. Because of the difficulty of defoliating cut shrub, the Emergency Rubber Project resorted to baling and storing in bales. The leaves contain almost no rubber, so their removal in processing is essential to reduce bulk. This was accomplished by immersing the baled shrub in hot water and passing through a rotating screen.

The original rubber extraction practice was developed by mining engineers who adapted equipment with which they were familiar and devised other equipment as needed. The first step was to cut the shrub as fine as possible, then pass the material between rollers to break down cell walls. The shrub was then fed into large, rotating horizontal pebble mills where the pounding of the shrub in water released the rubber. The rubber was then separated
Figure 3. A typical Guayule plant.

Figure 4. A native stand of Guayule in Texas.
from the fiber in flotation tanks. The rubber, sticky because of its resin content, was dried in sheets and pressed into blocks for shipment.

At the end of World War II synthetic rubbers were considered sufficient for our rubber needs, and all guayule fields except for a few experimental areas were destroyed. Research was continued on a reduced scale, but even this was halted in the late nineteen fifties. The research did provide, however, advances in processing, some additional experiences in growing guayule, and produced a number of mostly untried new varieties.

Research and production remained dormant until the early seventies when word reached the United States that Mexico was carrying on guayule research and had developed improved processes resulting in a product equal to hevea rubber. With this aroused interest, a conference was held in Tucson in 1975 and researchers began to look for seed sources. The only available source in the United States, except for seed from native stands, proved to be the National Seed Storage Laboratory in Fort Collins, Colorado, where very small amounts of seed from twenty-five varieties had been stored.

Based on this source of seed and recent collections in Texas and Mexico, breeding and production studies were initiated at several places in the Southwestern United States. Limited financial support became available from the National Science Foundation, the Four Corners Regional Commission, Southwest Border Regional Commission and some state agencies.

A second meeting was held in Saltillo, Coahuila Mexico in 1977 and the interest in guayule expanded and the pace of research accelerated. One of the more recent developments was the funding of a technological assessment of the commercialization of guayule conducted jointly by the Office of Arid Lands at the University of Arizona and the Midwest Research Institute in Kansas City, Missouri.

In Mexico, the Centro de Investigacion en Quimica Aplicada, supported by funds from the Comision Nacional de los Zonas Aridas, has operated a pilot plant for extracting rubber from guayule since March 1976. The facility has a capacity to process one ton of shrub a day. Processing methods are based on the techniques developed by U. S. engineers during the 1940's and 1950's, but incorporates several new techniques. Principal advances are in a more complete deresination, and dissolving the rubber in hexane to remove all but two percent of the non rubber substances. More recently Firestone has developed a solvent method in which the shrub is deresinated in acetone prior to extraction of the rubber. These techniques produce much higher quality rubber. In fact, the guayule rubber now being produced is considered to be the equivalent of hevea rubber in nearly all respects.

In addition to improvements in plant culture and extraction methods guayule has a great potential for genetic improvement.

Guayule is a plant breeders dream. It is the only one of the seventeen American species having appreciable quantities of rubber, and it can be crossed with other species to develop desirable characteristics such as size, branching habit, or cold tolerance. Like some other members of the sunflower family, it tends to be apomictic — that is, it produces progeny without pollen fertilization although the pollen may be necessary to stimulate seed production. It was discovered during World War II that the chief varieties were largely apomictic and hence, not readily crossed for development of improved hybrids. But this difficulty was overcome and it was found possible to make desirable crosses and later select desirable progeny for apomictic reproduction.

The basic chromosome number is 2x=36. No 18-chromosome plants have been found, but varieties with 54, 72 and 108 are common. The cultivated varieties have 72 chromosomes, as does the non-rubber producing Mariola (Argentatum incanum) which commonly occurs along with guayule but has a much greater northern range and greater cold tolerance.

In summary it appears that guayule has a great potential for production of high quality rubber, and with ever increasing shortages of petrochemicals and rising rubber prices, there is a strong possibility that guayule will become an important crop plant in the warmer portions of the Southwestern United States and northern Mexico.