Guayule and Jojoba: Agriculture in Semiarid Regions

The United States could obtain renewable sources of some materials that must now be imported, large areas of wasted land could become productive, and some impoverished Indians of the Sonoran Desert of California and Arizona might achieve economic self-sufficiency if cultivation of drought-resistant crops in the semiarid Southwest should prove economically feasible. Several different species have been considered for this purpose, but the two that seem most promising are guayule (wy-oo′-lee), a scruffy flowering bush that produces rubber, and jojoba (ho-ho′-ba), a somewhat taller bush whose seeds contain a liquid wax.

The cultivation of guayule is strongly urged in a recent report from a National Academy of Sciences panel,* and a feasibility study for the development of jojoba plantations on Indian reservations has been drawn up by another academy panel and is expected to be released in about a month.† These plants seem particularly valuable because of their products and because of their ability to prosper in desert soils with only a minimum of water and care.

The first of the plants to be cultivated on a significant scale will probably be jojoba [*Simmondsia chinensis* (Link) Schneider]. The seed of jojoba contains as much as 60 percent of a light yellow, odorless, liquid wax that is composed of unsaturated fatty acids esterified with unsaturated fatty alcohols. This liquid wax is thus almost identical to the industrially important oil of the sperm whale, but it is more uniform in composition and contains fewer impurities.

Sperm oil is a very important component of lubricating oils because of its ability to cling to or "wet" metals, thereby providing continuous lubrication. This and other properties make it highly valuable in automatic transmission fluids, paper coatings, electrical insulation, clinching and cold rolling of steel, and for lubrication of high-grade machinery and precision instruments. In the late 1960's, about 25 million kilograms of sperm oil were imported by the United States each year.

But the importation of sperm whale products has been forbidden since 1970 because the sperm whale is an endangered species. Since liquid waxes are exceptionally difficult to synthesize, industry has been hard pressed to find satisfactory substitutes. The price of sperm oil on the world market is now about $0.88 per kilogram, but there is apparently a substantial black market in the United States with prices approaching $2.20 per kilogram. The price is expected to go much higher in the next 10 to 15 years as international sanctions against killing sperm whales continue to reduce the supply. There seems little doubt that jojoba oil can compete economically.

Much of the recent research on jojoba has been conducted by Demetrios M. Yermanos and his associates at the University of California at Riverside and by Meir Forti and his colleagues at the Ben-Gurion University of the Negev in Israel. They have studied ways to cultivate and harvest the plant and to extract the oil; they have also investigated the physical properties of the oil. Because of the potential economic value of jojoba to Indians, much of the recent work in this country has been funded by the Bureau of Indian Affairs.

Jojoba Products Marketable

Progress in the research was summarized in an NAS report of 1975. The report concluded that jojoba products are marketable, that jojoba can probably be grown on 26 Indian reservations in California and Arizona, and that operation of successful jojoba enterprises could possibly lead to economic self-sufficiency for some of the smaller tribes. Of particular importance, the panel said, is the fact that jojoba needs only limited irrigation during the first year after planting and little or none thereafter. Jojoba also tolerates saline and alkaline soils and saline irrigation water; intolerance of these conditions has prevented cultivation of most other agricultural crops on Indian lands, despite the fact that Indians have treaty rights guaranteeing them access to irrigation water. The report concluded that jojoba cultivation should begin as soon as possible.

To implement the NAS panel's recommendations, the Bureau of Indian Affairs commissioned an advisory panel of jojoba scientists to draw up the master plan on the feasibility of cultivation on Indian lands. The plan calls for the establishment of about 80 hectares (200 acres) of jojoba on each of five reservations during the first year. The amount planted will be increased each year until 4000 hectares are in cultivation on at least ten reservations at the end of 5 years. Start-up is expected to cost about $175,000 per 100 hectares. The plan also calls for spending about $700,000 to $900,000 each year for research and development on jojoba, technical and management assistance, capital equipment, and scholarships and fellowships for Indians to study agriculture. The projects will eventually be run solely by the Indians.

Five years after jojoba is planted, each hectare should produce about 2000 kilograms of oil, even if there is no genetic improvement in the plants. (Some experimental plantings have produced five times that amount.) After 10 years, the 4000 hectares should be producing a minimum of 900,000 kilograms of oil at a price of about $0.86 per kilogram. If there were a profit of only about $0.22 per kilogram, then some of the smaller reservations on which the plantations were located could become economically self-sufficient.

There are at least two different bills now in Congress that would provide funds for implementation of the master plan. But even without these bills, momentum is gathering. There are now about 38 hectares of jojoba in cultivation on Indian lands, and individual farmers in California are expected to have as many as 400 hectares in cultivation by the end of the year. Large agribusiness corporations such as the Tenneco Corporation have small experimental plots. And the governments of Mexico and Israel are each expected to plant about 400 hectares of jojoba in the next 4 years. Several cosmetics and lubricant companies, furthermore, are already buying and utilizing jojoba oil (mostly from wild stands) for cosmetics and for industrial research.

Guayule (*Parthenium argentatum* Gray), in contrast, has already been utilized for rubber production. Early in this century, wild guayule stands in northern Mexico and Texas were harvested for this purpose; in 1910, guayule was the source of nearly 50 percent of all natural rubber consumed in the United States and 10 percent of world consumption. But a variety of factors, including reckless exploitation of the wild stands, the Mexican Revolution, and the depression of 1929 combined to destroy the industry. When rubber supplies from Southeast Asia were cut off during World War II, the United States spent $30 million on the successful Emergency Rubber Project to develop guayule as a domestic

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**Guayule: An Alternative Source of Natural Rubber* (National Research Council, Washington, D.C., (1977). †*Jojoba: Feasibility for Cultivation on Indian Reservations in the Sonoran Desert Region* (National Research Council, Washington, D.C., 1977).

source of rubber again. The crop was grown on high-quality farmland in California, and after the war the farmers wanted their land back. With the renewed availability of cheap rubber from Asia and the new availability of completely synthetic polyisoprene rubber, the government withdrew its funding and ordered the 11,000 hectares of guayule fields burned.

But the economic situation has changed considerably since the war. The price of both natural and synthetic rubbers is increasing and seems likely to climb much higher. The Asian rubber tree (*Hevea brasiliensis*) seems to have about reached the limit for genetic improvement of yield, and the trees are in constant peril from the leaf blight that has destroyed natural rubber production in South America. And Southeast Asia is very unsettled politically. All these factors, the panel concludes, argue strongly for the development of an American source of natural rubber.

Natural rubber is essential to American industry. Its elasticity, resilience, tackiness, and resistance to heat are unmatched by any synthetic rubbers now available. Conventional automobile tires, for example, contain about 20 percent natural rubber; and radial tires, which now dominate the U.S. market, contain as much as 40 percent. Large tires on aircraft, tractors, and earth-moving vehicles are made almost entirely of natural rubber. For these and other uses, the United States in 1974 imported 719,000 tons of natural rubber at a cost of $500 million.

Guayule rubber could serve for all of these uses, the NAS panel says, because its chemical and physical properties are virtually identical to those of hevea rubber. No chemical differences between the two have been detected in several studies, even with sensitive techniques that can demonstrate as little as 0.5 percent of structural difference. The key question, then, is whether guayule cultivation is economically viable.

Part of the answer to that question may come from experiments now being conducted by the government of Mexico, where, in the northern and central regions, more than 2.6 million tons of adult guayule shrubs grow wild. In 1976, the Mexican government completed a pilot plant in Saltillo; this plant is now processing about 1 ton of wild guayule per day. The Mexicans plan to increase the capacity so that, by 1979, they will be processing about 300,000 tons of shrubs annually and producing 30,000 tons of rubber. The pilot plant uses conventional milling techniques to break up the shrubs and extract the rubber. Also, a newly developed solvent extraction technique is used to remove the terpenoid resins that have been a serious contaminant in guayule rubber in the past. Rubber produced by the pilot plant, says the project's director, Enrique Campos-López, is of a quality comparable to that of hevea rubber.

The United States, however, has few wild stands of guayule so that cultivation will be necessary. To make cultivation economically feasible, the NAS panel concludes, it is important to isolate and breed guayule strains that contain uniformly high quantities of rubber. Preliminary projects to achieve this are already being conducted by David Rubis of the University of Arizona and George P. Hansen of the Los Angeles Arboretum. This process should be speeded substantially by a new technique, developed by James Schoolery of the Varian Corporation, in which carbon-13 nuclear magnetic resonance spectroscopy is used to determine the amount of rubber in the shrub's branches. Genetic manipulation may not be the only way to improve the content of rubber. Henry Yokoyama of the U.S. Department of Agriculture's Agricultural Research Service in Pasadena, California, has found that the rubber yield can be at least doubled by spraying the shrubs with certain chemicals that have previously been shown to increase the concentration of carotenoids in citrus fruits (*Science*, 10 May 1974, p. 655).

U.S. and Mexican Collaboration

In addition to urging commercialization of guayule, the panel recommends that the United States and Mexico collaborate on guayule research to take advantage of their mutual expertise. The panel also recommends that experimental plantings be established in the Southwest, and that the government centralize all its records on guayule research at an institution in that region.

The initial goals are rather modest, says the panel's chairman, Reed C. Rollins of Harvard University's Gray Herbarium. Their implementation would probably require initial funding of about $2 to $4 million annually. This would support 15 to 30 full-time investigators and provide for the construction of a pilot processing facility. With this amount of support, he argues, it should be possible within 5 to 10 years to determine whether guayule farming is practical.

The economics of both jojoba and guayule cultivation could be improved substantially if the secondary products are marketed. Jojoba oil, for example, can be hydrogenated to produce a white, crystalline wax that is nearly as good as carnauba wax, which is the best now available. Carnauba wax costs as much as $4.50 per kilogram. This is the form of jojoba oil that is most commonly used in cosmetics, and there are many other potential applications. After the oil is extracted from the jojoba seeds, furthermore, the residue contains as much as 32 percent protein, and is therefore a potential animal feed.

Extraction of the rubber fraction from guayule leaves substantial quantities of bagasse (wood fiber) that could be used as a fuel or in the production of cardboard or paper. The resin removed from the rubber fraction is similar to that obtained from pine trees and has many potential uses. And the leaves of guayule are coated with a wax that appears to be even better than carnauba and more easily extractable. Each of these by-products will probably play a role in the commercialization of the two plants.

Several other plants are also being considered as potential agricultural crops for the semiarid regions. Rubis and George White and his associates at the Department of Agriculture have done preliminary work on *Lesquerella*, another plant that produces oil seeds. Bill Miller of the Bureau of Indian Affairs argues that *Sesamum indicum* or sesame, still another oil seed crop, could complement jojoba very well. At least one farmer in the Southwest is already believed to have about 40 hectares of sesame in cultivation.

Some other species where further research seems justified include:

▶ *Euphorbia lathyrus* and *E. tirucalli*, which produce a hydrocarbon that might be a renewable source of petroleum (*Science*, 1 October 1976, p. 46).

▶ *Euphorbia antisyphilitica* or candelilla, which produces a wax. About 5 million kilograms of candelilla wax from Mexico are consumed in this country each year.

▶ *Pinus eldarica* or the Afghanistan pine, which grows about 2.5 meters tall in 3 years, even with less than 30 centimeters of rain, and which has potential as a domestically grown Christmas tree.

▶ *Cucurbita foetidissima* or buffalo gourd, which produces an edible oil containing as much as 35 percent protein.

Cultivation of any of these crops is still far off in the future, but the successful introduction of jojoba could very well pave the way for one or more of the others.—THOMAS H. MAUGH II