Chapter V

Developing Guayule (Natural Rubber) as a Commercial Crop

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SUMMARY

This report of Australian and U.S. efforts to develop guayule suggests that new agricultural uses exist for arid lands. In particular:

- guayule is a water-conserving plant, native to the United States, which has important potential strategic and industrial uses;
- Australian research and development efforts have used and advanced those carried out earlier by the United States; and
- continued cooperation is expected to enhance U.S. commercialization of guayule production and to protect both countries from threats to other supplies of natural rubber.

INTRODUCTION

The United States depends on other nations for a number of industrial materials that are important to U.S. industry. Some are called strategic, meaning critical to our national defense, and must be acquired and stored in the United States to meet national defense needs. Study and research is taking place to determine the economic and political feasibility of producing some of these industrial materials from plants. (See table 7 for a list of selected potential domestic crops and the materials they could replace.)[1] One such strategic material, the subject of this chapter, is natural rubber. Because natural rubber is a strategic material, it is advantageous to have domestic control of supplies rather than importing and stockpiling them.

In 1981 the world's natural rubber supply fell short of demand by 110,000 metric tons.[2] The World Bank has estimated that world rubber needs will increase by 5 percent annually for the remainder of this decade; recent changes in the international economy may make that

[1]Howard C. Tankersley, Soil Conservation Service, USDA, and Richard Wheaton, Program Manager, Natural Rubber Program, USDA, "Strategic and Essential Industrial Materials From Plants—Thesis and Uncertainties," (OTA draft), November 1982.

[2]*Natural Rubber **(Guayule)** Research in the United States*, A Combined 1980 and 1981 Report on Implementation of the Native Latex Commercialization and Economic Development Act of 1978, Joint Commission on Guayule, U.S. Department of Agriculture, August 1982 (draft), pp. 2-3.

Table 7.—Potential Domestic Crops and Uses

Crop	To replace
Guayule *(Parthenium **argentatum** A. Gray)*	***Hevea*** natural rubber, resins
Crambe *(**Crambe** abyssinica* Hochst. ex R. E. Fries)	High erucic rape oil and petroleum feedstocks
Jojoba *(Simmondsia chinensis* (Link) C. Schneid)	Sperm whale oil and imported waxes
Lesquerella spp.	Castor oil
Vernonia spp.—Stokesia spp.	Epoxy oils
Kenaf *(Hibiscus cannabinus* L.)	Imported newsprint and paper
Assorted oilseeds	Petrochemicals for coatings

SOURCE: L. H. Princen, *Alternate Industrial Feedstocks From Agriculture* (Peoria, Ill.: Northern Regional Research Center, 1980). Agricultural Research Service, US. Department of Agriculture in "Strategic and Essential Industrial Materials From Plants-Thesis and Uncertainties," OTA draft, November 1982 estimate high. During this decade, however, natural rubber, as opposed to synthetic, is expected to retain its one-third share of the total rubber markets

As the largest single user of natural rubber, the United States greatly influences the world supply-demand formula and the price of natural rubber. Contributing to the rising demand for natural rubber is the boom in radial automobile tires, which require about 40 percent natural rubber, almost twice as much as that required in nonradial tires. While radials wear longer, their growing popularity creates additional demand for natural rubber. Moreover, synthetic rubber still lacks the elasticity, resilience, and resistance to heat buildup of natural rubber, indispensable factors for bus, truck, and airplane tires.[4] Consequently, radial tires have captured an increasing market share of the original auto equipment package in the United States. For example, radial tire sales expanded from 25 percent for the 1973 car models to 99.9 percent for the 1981 models.[5]

[3] National Academy of Sciences, *Guayule: An Alternative Source of Natural Rubber, 1977,* p. 54.

[4] Ibid., p. 2.

[5] Earl Kraher, Statistics Office, Motor Vehicle Manufacturers Association, July 23, 1982, interview.

SOURCES OF RUBBER

Most of the world's rubber comes from two sources: the hevea rubber tree (Hevea *brasiliensis* (wind. ex A. Juss.) (Muell.-Arg.) and synthetics made from petroleum feedstocks. A number of factors raise doubt about the reliability of *Hevea* as a secure and expanding source of natural rubber?

- *Hevea* only grows within a restricted area of the tropics.
- Brazil, a major natural rubber supplier, had its production wiped out by leaf blight early in the 20th century. Leaf blight has been a serious constraint to further production, although blight-resistant strains are being developed. Chemical control also may be a possible, but expensive, answer to controlling future blight.
- *Hevea* is one of the most labor-intensive crops in the world.
- Several of the primary producing countries, mindful of *Hevea's* production costs, are switching to less labor-intensive and more profitable crops.
- Southeast Asia, which accounts for about 90 percent of world production, has been subject to political instability.

Simultaneous with the uncertainty of an adequate future natural rubber supply, the production of synthetic rubber is being affected by rising costs of the petrochemical feedstocks from which it is produced. This relatively recent development reinforces the prediction in a National Academy of Sciences report that the demand for natural rubber will continue.[7]

These factors have contributed to a growing interest in guayule *(Parthenium argentatum* Gray) as a promising alternative source of natural rubber. Guayule is a shrub which grows wild in some semiarid regions of North America.

‘3 National Academy of Sciences, op. cit., pp. 2 and 60; and interview with Richard Wheaton, Program Manager, Domestic Rubber Program and Executive Secretary, Joint Guayule Commission, April 1982.

[7] National Academy of Sciences, op. cit., p. 2.

ADVANTAGES AND DISADVANTAGES OF DEVELOPING GUAYULE

Guayule has a number of properties that make it attractive as a source of commercial rubber:

- Its rubber has chemical and physical properties virtually identical to those of *Hevea.*
- It grows well under plantation conditions

and can be improved through crossbreeding.

- It appears to be only slightly affected by latitude or altitude and therefore may be of interest to nations lying outside the Tropics that cannot produce synthetics.[8]

Certain characteristics of guayule make it particularly suitable for semiarid land cultivation. These relate to temperature and drought tolerance, yield, and durability. Guayule grows well in temperatures ranging from 770 to 1040 F (250 to 40^{0} C), and wild guayule can survive temperatures below 32° F (0° C). Most literature suggests 16 inches (40 millimeters [mm]) of rainfall is optimal for growth. U.S. plantings during World War II showed that 11 to 25 inches (280 to 640 mm) were needed for commercial production. Experience with the shrub also indicates that if precipitation falls below about 14 inches (350 mm), supplemental irrigation may be needed. Within this moisture range, however, rubber yield is only slightly affected as water is reduced toward the lower ranges of tolerance. Finally, the root system can penetrate to a 20-foot depth (6.5 meters), with plants living for 30 to 40 years in their native environment.[9]

Despite these apparent advantages, guayule faces many technical and economic barriers to commercial development. Much technical refinement is required to reduce the cost of producing guayule to a level that is economically attractive. Some of the major difficulties involve solving problems at the early stages of agriculture production, such as developing guayule strains that contain uniformly high quantities of rubber.[10] The rubber content of harvested shrubs, for example, can vary from 8 to 26 percent of dry weight (table 8). *Verticillium* and *Phytopthora* root rots are the major disease problems, both of which are aggravated by excessive soil moisture. In its native habitat, guayule is rarely affected by disease, but under cultivation its susceptibility increases. Another problem is providing a secure supply at a production level that could meet demands consistently. In addition, the economics of the international rubber market must shift if there is to be commercial guayule development. One estimate is that guayule will be competitive when *Hevea* reaches 90 cents per pound.[11] The average price of *Hevea* from January to June 1982 was only 46.6 cents per pound, even though it reached a peak of nearly 74 cents in 1980 (fig. 3). If the international economy revives, market prices might again rise, providing incentive for guayule investment.

In spite of these difficulties, one country with considerable arid and semiarid land, Australia, has begun to research the feasibility of the commercial production of guayule. The next section reviews some of the principal elements of the Australian experience as one example of the growing interest in the commercialization of guayule.

Table 8.—Components of Harvested Guayule Shrub

Moisture	45-60 percent
Rubber	8-26 percent[a]
Resins	5-15 percent[a]
Residue	50-55 percent[a]
Leaves	15-20 percent[a]
Cork	1-3 percent[a]
Water solubles	10-12 percent[a]
Dirt and rocks	Variable

[a]Dry weight basis.

SOURCE: National Academy of Sciences, *Guayule: An Alternative Source of Natural Rubber* (Washington, D. C.: NAS, 1977)

8Ibid., pp. I-10.

9For a more complete description of guayule's characteristics, see L. W. Owens, *Report on Guayule Potential and Research in South Australia,* February 1981, sec. 3 (unpaginated); and A. R. Bertrand, "A Review of Guayule Research: 1941 -1981," memo to Chairman of Joint Guayule Commission, in Joint Commission Report, appendix.

10 National Academy of Sciences, op. cit., p. 12; and E. G. Knox and A. A. Theison (eds.), 1981 *Feasibility of Introducing New Crops: Production-Marketing-Consumption (PMC) Systems,* ch. VI, Guayule, G. L. Laidig, pp. *100-I2o* (Emmaus, Pa.: Rodale Press].

II Wheaton interview (see footnote 6).

Figure 3.—Natural Rubber Prices per Metric Ton

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Price per metric ton[a]	$462	$399	$402	$785	$868	$659	$872	$917	$1,108	$1,423	$1,625	$1,252	$1,027[b]			
Price per pound	21.0c	18.1c	18.2c	35.6c	39.3c	29.9c	39.6c	41.6c	50.3c	64.6c	73.7c	56.8c	46.6c			
% increase or decrease	+ 20%	- 13%	(level)	+ 95%	+ 10%	- 24%	+ 32%	+ 5%	+ 20%	+ 28%	+ 14%	- 23%	- 18%			

[a]New York price R.S.S. 1 Rubber [b]Jan.-June Average

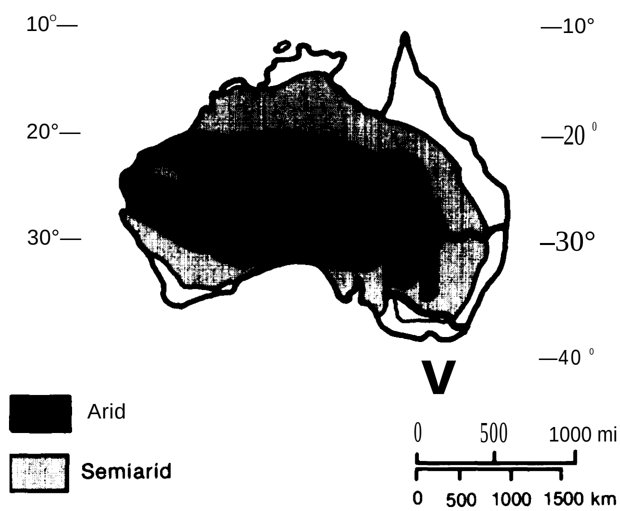
SOURCE: Joint Commission on Guayule, U.S. Department of Agriculture, *Natural Rubber (Guayule) Research in the United States,* A Combined 1960 and 1981 Report on Implementation of the Native Latex Commercialization and Economic Development Act of 1978, August 1982 (draft), P. 3.

RESEARCH ON GUAYULE IN AUSTRALIA

Background

Australia became interested in guayule in **1941,** when the Japanese takeover of Malaya (now Malaysia) cut off its natural rubber supplies. A guayule project was particularly attractive to Australia, a country where three-quarters of its land area—1.9 million square miles (490 million hectares)—was arid and not in any competing use at that time. As can be seen in figure 4, the entire interior of the country is a large arid basin, experiencing high temperatures and an evaporation rate of 100 to 120 inches (2.5 to 3 meters) per year.[12] Some of the area is favorable for guayule production. In July 1942, Australia began a wartime project to investigate alternative sources of natural rub-

Figure 4.—Australia



SOURCE: Distribution of Arid Homoclimates. Eastern Hemisphere. Western Hemisphere. U.N. Maps No. 392 and 393, Revision 1, by Peverill Meigs, UNESCO, Paris, 1960,

[12]R. O. Slayter and R. A. Perry (eds.), Arid *Lands of Australia* (Canberra: Australian National University Press, 1969), p, 56.

ber. A principal focus was guayule, a plant not native to Australia. The United States, which was conducting a similar experiment in the U.S. Southwest, provided Australia with seeds and technical information.[13]

This early Australian experiment made some progress in determining plant growth and rubber production potential. The project ceased, however, when the war situation improved for the Allies in 1943 and *Hevea* rubber became more plentiful. Limited guayule cultivation continued into the 1950's entirely as a research effort with no goal of commercialization, and was abandoned at the end of the war.

Current Research

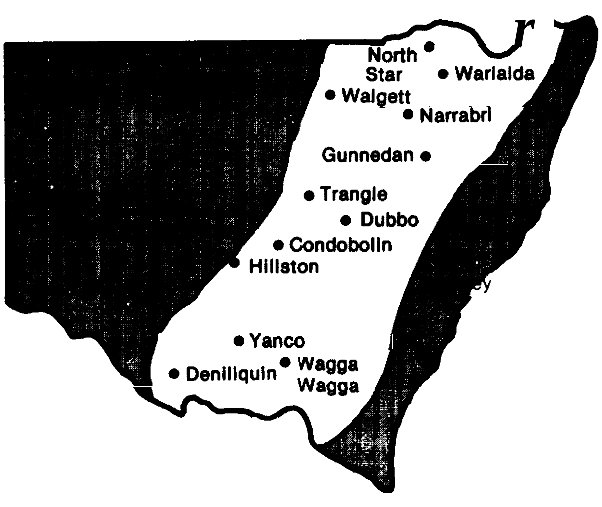
In 1980, guayule research was resumed in Australia in New South Wales, a state in the eastern corner of the country. Figure 5 shows the shaded region considered potentially suitable for guayule development. This area consists of the western slopes and plains which fall along a north-south belt through the traditional cropping areas in New South Wales. Nine test plots in this region were planted with guayule –Condobolin, Yanco, Narrabri, Trangie, North Star, Warialda, Hillston, Wagga Wagga, and Deniliguin. The project was funded for 3 years. Its overall goal has been to determine the feasibility of guayule commercialization under dryland conditions in New South Wales. (See app. C for estimated costs of producing 1 acre of guayule in New South Wales.) The Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia is assisting with the research. In addition, the United States is exchanging research and development information through a joint agreement with the New South Wales Government. The priority research objectives of the project are:[14]

- *Developing techniques for direct seeding of guayule under dryland conditions.*— CSIRO anticipates that higher yields of rubber can be gained by spacing guayule plants in a manner similar to that used in growing cereal grains.
- *Understanding the physiology of guayule growth and rubber production.—Information* from test plots about the effects of solar radiation, temperature, and soil water on key plant parameters will be used to identify the most favorable environments for guayule production.
- *Developing guayule strains best suited to Australian dryland environments.—The* United States is providing some of its highest yielding rubber varieties for testing in Australia.[15]
- *Investigating alternative processing methods for guayule.*

Results of this Australian research already show a number of promising signs. First, there appears to be the potential for considerable savings in seedling costs, one of the more expensive aspects of guayule production. Consultants to CSIRO have projected eventual seedling

[13] For an account of this early project see R. L. Crocker and H. C. Trimble, *Investigations of Guayule in South Australia* (Melbourne: Commonwealth of Australia, Council for Scientific and Industrial Research, Bulletin No. 192, 1945).

Figure 5.—Test Sites, Western Slopes, and Plains (shaded) of New South Wales



SOURCE I A. Siddiqul and P Locktov, *A Feasibility Study on the Commercialization of Guayule in New* South Wales, Australia, December 1981, California Department of Food and Agriculture

[14] G. Alan Stewart, Convenor, CSIRO Working Party on Guayule. Correspondence to Dr. B. T. England, May 17, 1982.

[15] I. A. Siddiqui and P. Locktov, *A Feasibility Study on the Commercialization of Guayule in New South Wales, Australia,* California Department of Food and Agriculture, Division of Plant Industry (Sacramento: December 1981), p. 12.

costs of $6 per 1,000. This is significantly below the price of $80 to $100 per 1,000 seedlings charged by two California nurseries in 1982, although such costs were affected by relatively low production volumes.[16]

Second, Australia is making progress in developing technology for processing the guayule. Table 7 from chapter III shows the components of a harvested guayule shrub. The method preferred by researchers at CSIRO to extract the rubber from the debris includes shrub deresination and solvent extraction of the rubber. This complicated chemical process involves parboiling and cleaning the shrub, hammermilling it through a fine-grade screen to extract the resin, and finally extracting the rubber by dissolving it in a solvent. With this separation process, up to 95 percent of the rubber can be recovered.[17] An alternative extraction method involves a pressure vessel to waterlog the debris accompanying the rubber, which in a subsequent slurry tank sinks, leaving the rubber afloat. But the water requirement for this alternative process is a major disadvantage in arid areas.[18]

Future Research

A report of U.S. scientists who visited Australia in 1982 indicates that the New South Wales project has already made progress. The trip was made under the Memorandum of Agreement between New South Wales and the U.S. Department of Agriculture for the interchange of research information, germ plasm, and scientists involved in guayule research. Extensive research data and information were exchanged, accompanied by discussions in reviewing the problems and potential areas of research in New South Wales. Sites visited included Narrabri, Trangie, Condobolin, and Hillston. The U.S. research team, which traveled some 700 miles (1,100 kilometers) by auto throughout the project site, obtained important information on the environmental conditions under which guayule would be grown in New South Wales. The report recommends priorities for future research in a number of areas, three of which have particular relevance for arid and semiarid lands:

- evaluation of existing varieties, both for resistance to drought and for high rubber yield;
- determination of water requirements under various plant spacings and with cultural practices which conserve or collect water; and
- evaluation of direct seeding in the field under irrigation versus using transplants from nurseries.[19]

In addition, the report recognizes the need for research in areas involving infrastructure for commercial guayule production—namely, harvest mechanization, processing, and marketing. The challenge, as summarized by Australian scientists, is that guayule is "a new crop to Australia and to the world" and "will require a significant research and development effort before becoming a commercial crop on a large scale."[20]

[16] Interim Report, Guayule Working Party, Commonwealth Scientific and Industrial Research Organization (CSIRO), Mar. 25, 1982, p. 16.

[17] National Academy of Sciences, op. cit., p. 35.

[18] Ibid., pp. 50-52.

[19] *Technical Report,* U.S. Scientific and Technical Exchange Team Visit to New South Wales, Mar. 26 to Apr. 17, 1982 (draft).

[20] Interim Report, CSIRO, op. cit., p. 57.

U.S. GUAYULE PRODUCTION AND RESEARCH

Guayule has been periodically exploited for commercial purposes in the United States. Early in this century, for instance, wild stands in parts of Texas were harvested. The guayule rubber industry in Texas disappeared, however, when the wild plants were overused and not replanted. In 1910, guayule mainly from Mexico provided nearly 50 percent of the natural rubber consumed in the United States and 10 percent of world consumption. Production resumed briefly in the *1920's* when British control of Malaya's rubber monopoly caused prices to triple.[21]

The United States again became interested in guayule, as did Australia, in December 1941 when Malaya fell to the Japanese. The United States, like other Allied nations, lost more than **90** percent of its natural rubber supply. The U.S. Government started the Emergency Rubber Project (ERP) in February *1942* to develop guayule commercially. This project involved more than *1,000* scientists and technicians. Supported by a work force of 9,000 workers, ERP planted almost **32,000** acres of guayule at 13 sites in 3 States. The project produced *1* billion guayule seedlings. Toward the end of the project, 15 tons of rubber were being produced daily at mills near the California towns of Salinas and Bakersfield.

In spite of its promising future, the ERP had a short life. By the end of the war, synthetic rubber was being produced in commercial quantities, and surplus stocks of natural rubber began arriving from Southeast Asia. With these developments, the wartime economic and strategic justification for guayule production in the United States faded. When the project formally ended in *1946,* about 21 million pounds of rubber on **27,000** acres had to be burned or plowed under so that the land could be used for other crops. Most of the seeds from the genetic improvement program were destroyed along with hundreds of millions of seedlings.[22]

In recent years, several factors have created renewed interest in developing a domestic natural rubber industry based on guayule. Included among these are larger deficits between world production and consumption, total U.S. dependency on foreign sources, and the increase in Hevea prices over the past decade.[23]

In *1978,* the Native Latex Commercialization and Economic Development Act was passed, calling for the establishment of a U.S. Joint Commission on Guayule Research and Commercialization, The goal of this Commission has been to determine the potential for U.S. commercialization of guayule.[24] Commission members are drawn from the U.S. Departments of Agriculture, Commerce, and Interior, and the National Science Foundation. In fiscal year *1981* these agencies had a combined budget of about **$2.6** million for guayule research, and in fiscal year *1980, $1.4* million. The funds have been used for research in genetics, agronomic, and processing technology. Since its founding, the Commission has developed an additional 7-year program to carry forward research and development beyond the initial authorization period which ends in *1983.* The Commission plan calls for refining the technology for growing and processing guayule to the point where it can be transferred to the private sector for commercialization.[25] The future of the Commission and its work under the Latex Act is uncertain.

Also, in *1978* the California legislature enacted a pilot program to determine the feasibility of the commercial production of guayule in California. The State of California in *1980* entered into a cooperative agreement with the New South Wales Government to assist in establishing a guayule research and development program.

The modest program of guayule research in the United States is being conducted under government auspices or with government assistance. Firestone and Goodyear Tire and Rubber Companies, for example, have been engaged periodically in research on guayule plantings, some of which involves government support.[26] Texas A&M University, New Mexico State University, Los Angeles State and County Arboretum, and the University of Arizona also have been doing selected guayule research with some government assistance,

Generally, the move toward a massive U.S. commercialization project has been tempered

[21] National Academy of Sciences, op. cit., pp. 17-23.
[22] Ibid.
[23] Joint Commission Report, op. cit., pp. 2 and 3 (see footnote 9).
[24] Native Latex Commercialization and Economic Development Act of 1978 (Public Law 95-592).
[25] Joint Commission Report, op. cit., p. 14 (see footnote 9).
[26] Wheaton interview (see footnote 6).

by political and economic constraints. To replace completely the imported *Hevea* with domestically produced guayule, the United States would have to plant more than 5 million acres, an area about the size of New Jersey.[27] Even if this were possible, the implications of total U.S. rubber independence for U.S. balance of payments and foreign trade with present rubber-producing countries make the undertaking politically complicated at present.[28]

A small step in the direction of U.S. commercialization was made, however, in September 1982 when the Department of the Navy awarded a $400,000 contract to the Gila River Indian Community of Sacaton, Ariz., for growing and processing guayule. The contract calls for the preparation of 10 technical reports on growing and processing a prototype domestic guayule rubber industry in the United States. It also provides for a $20 million guaranteed loan from the Federal Financing Bank to undertake pilot research work. Under this contract, the Gila River Indians will cultivate approximately 5,000 acres of guayule shrubs with harvest planned for 1987. They will negotiate a subcontract with the Firestone Tire & Rubber Co. for research and development of the prototype processing facility. The Indians will own and operate the facility.[29]

[27]1977 National Resources Inventory (revised 1980), Soil Conservation Service, USDA.
[28]Ibid.

[29]Press Release, Senator Barry Goldwater (Arizona), Sept. 29, 1982.

U.S. COOPERATION WITH OTHER COUNTRIES

The United States has entered into a few cooperative arrangements with other countries on guayule research. As mentioned earlier, the United States and New South Wales (through their Departments of Agriculture) signed a cooperative agreement in 1982 to help expedite their respective research projects with the exchange of information on research and development several times each year.[30] Exchanges of seed lines, plant materials, and raw rubber products also are planned.

The U.S. and Australian projects complement each other, the former focusing on irrigated guayule production, the latter on dryland production. If Australia is able to fulfill the findings of feasibility studies on guayule commercialization, it could become not only self-sufficient in natural rubber but also “a major exporting nation.”[31] This development could serve both U.S. and Australian national security interests by providing them with an additional, stable source of supply for natural rubber and its products.[32] In addition, the commercial production of guayule in New South Wales may be more favorable than in California. First, the New South Wales land is available at relatively low cost. Second, rainfall is evenly distributed in the proposed planting areas; thereby requiring little or no irrigation.[33]

The United States is also cooperating with Mexico on a less formal basis in guayule research and development through a Joint Working Group on Agriculture, formed under the U.S.-Mexico agreement for scientific cooperation.[34] Of particular interest to American researchers is the Mexican Government’s pilot processing plant in Saltillo, Mexico. This plant, the world’s only commercial processing plant for guayule, uses a flotation extraction process and has a capacity to process 1 ton of wild guayule daily.[35] Joint projects will be developed based on exchanges of plant material, information, and scientists associated with specific projects.[36]

[30]*Summary Report* (draft), U.S. Delegation, Scientific and Technical Exchange between Departments of Agriculture, New South Wales, Australia, and United States, Apr. 9, 1982.
[31]Ibid.
[32]Owens, op. cit. (see footnote 9).

[33]Siddiqui and Locktov, op. cit., p. 10.
[34]Joint Commission Report, op. cit., pp. 12-13 (SH? footnote 9).
[35]Wheaton interview (see footnote 6).
[36]Joint Commission Report, op. cit., app. 15 (see footnote 9).

Other countries have expressed interest in cooperating with the United States in developing guayule as a potential commercial crop. These include Brazil, Chile, India, Kenya, Israel, and Egypt.[37]

[37] 1 bid., p. 13.

TECHNOLOGY TRANSFER CONSIDERATIONS

The United States can expect to gain much scientific and technical information about guayule growth and production from cooperative research with other countries. With respect to the U.S.-Australian exchange, benefits include:[38]

- speeding up the solution of many of the problems of agronomic production, genetic improvement, and new plant selections;
- developing scientific data relative to dryland cultivation and new varieties that will significantly aid U.S. natural rubber development; and
- strengthening the U.S. and Australian alliance, which is important in case of any future interruption of Hevea supplies from Southeast Asia.

More specifically, the United States has recently considered dryland guayule production in Texas, and studies in New South Wales should particularly benefit this U.S. effort. For example, in New South Wales, different methods for extracting rubber from guayule are being compared. Both the United States and New South Wales are interested in finding a use for byproducts of guayule processing. Research has begun in New South Wales to identify oils, waxes, and volatile compounds that can be obtained from guayule leaves. U.S. researchers such as those at the USDA Biomaterials Conservation Laboratory in Peoria, Ill., should find exchange of information most helpful to them in their work.

As these cooperative exchanges have already shown, there can be complementary value to each country in such an effort. Research and international cooperation are important not only for guayule, Plant research and development for industrial feedstocks as well as for food products has national and international benefits. Such research not only provides alternative sources of supply but also develops a better scientific knowledge and research base for extrapolation to other areas where potential may exist for greater use of arid and semiarid plants (see ch. II).

[38] Technical Report, U.S. Scientific and Technical Exchange Team Visit to New South Wales, Mar. 26 to Apr. 17, 1982.