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Biotechnology and Natural Rubber--A Report on Work in Progress

ISSUE: Biosynthesis of natural rubber, and the development of a new, natural rubber-producing plant, guayule, for temperate climates of the North.
IMPACT: U.S. is world's largest importer of natural rubber. Development of guayule as domestic rubber source for U.S. could displace up to 25% of U.S. imports of natural *Hevea* rubber by the end of the decade, resulting in depressed prices on world rubber market. Millions of small-scale rubber producers in Asia, Africa and Latin America could be adversely affected.
ECONOMIC STAKES: Approximately (US) $3.7 billion annually.
PARTICIPANTS: United States government, Firestone Tire Co., Goodyear Tire Co., and academic research groups in U.S., France, England, India and South Africa.
WHEN: Commercial-scale guayule rubber production in U.S. expected to scale-up by 1996-97. Research on rubber biosynthesis still in early stages--not commercially viable until after year 2000.

History

Virtually all natural rubber comes from *Hevea brasiliensis*, a species originating in the tropical forests of Brazil. A leaf blight in the 19th century decimated the early Amazonian rubber plantations, making it virtually impossible to cultivate rubber trees on a large scale in South America. Twenty-two rubber plants smuggled out of Brazil in 1876 were later transplanted to British holdings in Southeast Asia, where the cultivation of natural rubber flourished.

Today, Asian nations account for over 92 percent of the world's natural rubber production. Three Southeast Asian countries, Malaysia, Indonesia and Thailand, account for three-quarters of worldwide production. Africa accounts for 6.4%. Central and South America, where *Hevea* originated, produce only 1.2% of the world's natural rubber supply.

Value of Rubber to Third World Economies

After coffee and sugar, natural rubber is the South's most valuable agricultural export, worth approximately $3.7 billion annually. According to Dr. Prachaya Jumpasut, Chief Economist for the International Rubber Study Group, there are 3.5 million people in Malaysia (the world's top rubber producing nation) who are directly or indirectly dependent on natural rubber. In Indonesia, natural rubber has become a source of living for more than 8 million households, and in Thailand, there are about 4.5 million people involved in the rubber sector. Worldwide, an estimated 77.5% of all natural rubber is produced by smallholders (usually less than 2 hectares of rubber trees).[1]

Worldwide, demand for natural rubber is expected to grow from 5.1 million metric tons in 1989, to 6.5 million metric tons by the year 2000.[2] But despite forecasts for increasing demand, Third World rubber growers may be the last to benefit. While demand for natural rubber has steadily increased, the price of natural rubber on the world market actually *decreased* an average 6.9% annually from 1980-1989.[3] The long-term decline in rubber prices results from new technologies and intensified competition in the world economy.

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With the development of new biotechnologies for biosynthetic production of natural rubber early in the next century, as well as new natural rubber-producing plants, the scenario for Third World rubber producers is likely to worsen.

The Demand for Rubber

Approximately 60% of the world's consumption of natural rubber goes into tires, and as much as 85% is used in automotive-related products.[4] Not surprisingly, the world's major consumers of natural rubber are the countries with the greatest output of automobiles. These include: United States, Western Europe (as a combined entity), Japan, Central and South America, Korea, Eastern Europe. The United States alone accounts for around 16-17% of the world's total.

The major buyers of rubber are a handful of giant, transnational corporations. Globally, six companies control 80% of the tire market, and analysts predict that four to five companies will soon dominate.[5]
(See chart on leading companies, p. 4).

The Quest for Alternative Rubber Sources

The desire to find alternative sources and synthetic substitutes for natural rubber is not new. Though rubber is an agricultural commodity, it is classified as a "critical and strategic" material by the United States government. Despite the availability of petroleum-based synthetics since World War II, natural rubber is considered "irreplaceable."[6] No synthetic substitute provides the high elasticity, resilience and resistance to high temperatures found in natural rubber. Aircraft tires and radial automobile tires are made from 50% natural rubber. The fluctuating costs of petroleum-based synthetics make natural rubber even more attractive. And the AIDS epidemic has created a huge demand for surgeons' gloves and condoms--both made from natural rubber latex.

Although *Hevea brasiliensis* is the principal rubber plant of commerce, some 2,000 plant species are known to contain rubber, but only a few yield sufficient quantities for commercial use.[7] Researchers seeking new sources of natural rubber readily admit that most of the lesser known rubber producing plants are "hopelessly outclassed" by *Hevea* in quality, yield and ease of treatment.[8] In short, the low-cost of producing natural rubber from *Hevea* makes it difficult for new rubber plants to compete economically.

Because of the critical importance of rubber to its strategic defense and economy, however, the United States government has committed millions of dollars to the development of new, natural rubber-producing plants. Citing problems of "political upheaval," and "potential crop failure" in major rubber producing countries, the U.S. Department of Defense and U.S. Department of Agriculture devoted approximately (US) $60 million to the creation of a domestic natural rubber industry over the past decade. The urgency of this effort intensified when the world's largest rubber plantation in Liberia (operated by Firestone) went out of business during the 1990 civil war. This plantation was the largest single supplier of latex to North America.

Guayule--An Alternative Source of Natural Rubber for the United States

Guayule (*Parthenium argentatum*), a perennial desert shrub native to the southwestern United States and northern Mexico, is the rubber-producing plant of greatest promise for the United States. Guayule is not a new source of rubber--but an undeveloped one. (In 1910, guayule provided 10% of the world's natural rubber.) In 1982, the U.S. Department of Defense entered into an agreement with the Firestone Tire and Rubber Company to grow and process guayule using the most advanced technologies available. Their goal was to increase annual per-acre guayule rubber yields to above 1,200 pounds, and to have a commercial-size guayule processing plant in full operation by 1996. **Ultimately, the U.S. government and private industry aim to use guayule as a replacement for at least 25% of the natural rubber consumed in the United States.**[9]

Since 1982, plant breeders have doubled guayule yields from 400 lbs./acre/year, to 800 lbs./acre/year, and new varieties promise yields of 1,000 lbs./acre/year. Seven new germplasm lines have been released, and 50

more are being evaluated. New varieties of guayule were also collected in Mexico.[10]

In April, 1991, the U.S. Department of Agriculture (USDA) announced that the Goodyear Tire and Rubber Company would begin experimental manufacturing of A4 and F18 aircraft tires using 50% guayule blend with 50% hevea rubber.[11] If the tires meet quality standards, the company will begin making 100% guayule tires for the same aircraft. **According to USDA officials, under good conditions it will take a minimum of 4 years to scale-up guayule production, and we could see a commercial guayule manufacturing firm in place within 5 years.**

Biotechnology and Natural Rubber

The vast majority of work on guayule involves traditional plant breeding, but the U.S. government and private industry also support research on the use of new biotechnologies to boost guayule rubber yields and develop new sources of natural rubber.

According to biotechnology industry analysts, now that modern techniques of molecular biology are penetrating into guayule research, "expect commercial development of guayule to accelerate rapidly over the next five years."[12]

Plant physiologist, Dr. Katrina Cornish, heads up USDA's research effort on genetic engineering of guayule and alternative rubber sources at USDA's Western Regional Research Center in Albany, California. According to Dr. Cornish, the research is "still in early stages," building on work initiated by Genentech and Goodyear Tire in the mid-1980s.[13] Both companies attempted to find the main enzyme responsible for making rubber, but were unable to sustain a long-term research program. Industry research was turned over to USDA researchers and academic groups, with hopes that they "would get the bugs out."[14] USDA's current biotechnology research is described in a recent issue of *Bioprocessing Technology*:

"Although the research is in an early stage, plant physiologists at the USDA foresee a fermentation system of micro-organisms producing high-quality rubber in a bioreactor for large-scale production within this decade. Their initial focus is on isolating and cloning the gene encoding rubber transferase from guayule and the Brazilian rubber tree."[15]

According to Dr. Cornish, natural rubber biosynthesis is no easy task. It is not enough to successfully transform and express the genes involved in natural rubber biosynthesis. The rubber must also be of high enough quality to be useful in manufacturing processes. In addition to guayule and *Hevea*, Dr. Cornish is experimenting with a variety of plants that already have a "pathway" to make rubber.

In addition to U.S.-based efforts, there is basic biosynthesis research on natural rubber by French, British, Indian and South African scientists. Rockefeller University in New York (USA) also collaborates with scientists in Singapore on biosynthesis of natural rubber.

Despite the fact that natural rubber is deemed "irreplaceable," industry giants still aim to develop new synthetics that may eventually displace a larger share of the natural rubber market. Particularly noteworthy is the recent merger of Monsanto and Exxon's "thermoplastic elastomer" businesses to create a new company with 450 employees and annual worldwide sales of $100 million. The company's president, Gary E. O'Connor, told *Chemical and Engineering News* that the venture aims to replace both natural and synthetic rubber in the engineering elastomers market (a worldwide market of approximately 2.3 million metric tons per year).[16]

Conclusion

The goal of current research on natural rubber and biotechnology is two-fold: 1) to develop high-yielding guayule plants as a domestic source of commercially acceptable natural rubber for the United States; and, 2) to develop a biological system for producing natural rubber in various plants and microorganisms. This involves the isolation and expression of genes which control the rubber-making function of plants, and fine-tuning that expression for the production of high-quality rubber.

Officials with the U.S. Department of Agriculture predict that commercial-scale

guayule production may be possible by 1996, and domestic production of guayule may replace one-fourth of U.S. natural rubber imports by the end of the decade. It is not likely that biosynthesis of natural rubber will be viable on a commercial scale until early in the next century.

Third World rubber producers are not threatened with immediate loss of a major agricultural export commodity. Despite increasing worldwide demand for natural rubber, however, new technologies and natural substitutes for *Hevea* rubber will contribute to the long-term decline in rubber prices. As the largest single importer of natural rubber, if the U.S. succeeds in substantially reducing rubber imports, the price of rubber on the world market will drop. Small-scale rubber producers of the Third World will be the first to suffer the consequences.

--This issue of RAFI Communique prepared by Hope Shand.

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3. Fischer, Bernhard. 1991. "From Commodity Dependency to Development," in The OECD Observer, April/May, p. 27.
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5. Anonymous, 1991. "Consolidation Craze Coming to Conclusion," in Rubber & Plastic News, May 13, p. 50.
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11. Kugler, Daniel E., "Guayule Information Memo: A4 and F18 Aircraft Qualification Tires from Guayule Rubber--Goodyear Tire and Rubber Co., Danville, VA," USDA, Office of Agricultural Materials, April 24, 1991.
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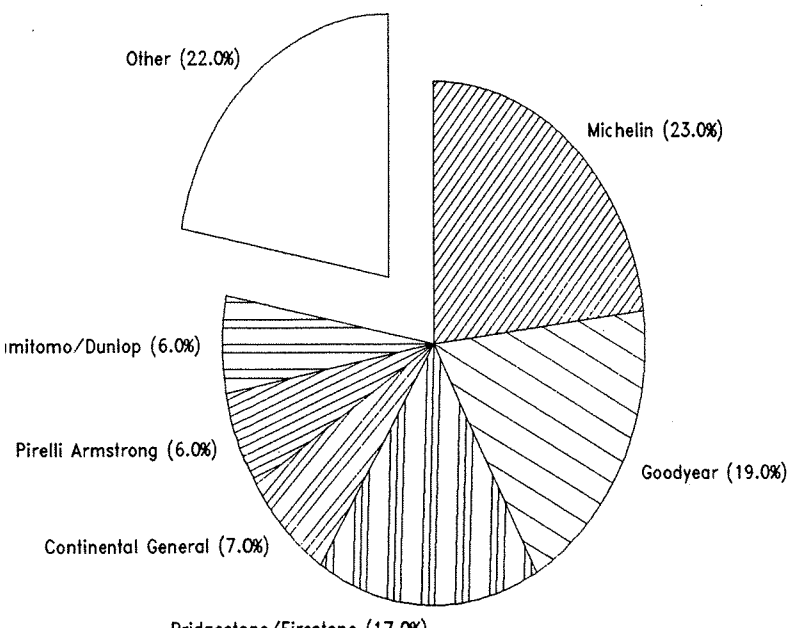
Control of Global Tire Market

Market Share by Company



Top Six Corporations Account for Approximately 80% of Global Market

Michelin/Uniroyal - French
Goodyear - USA
Bridgestone/Firestone - Japanese
Continental General - German
Pirelli Armstrong - Italian
Sumitomo/Dunlop - Japanese

Source: Harry Millis, Fundamental Research, Inc.

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