IV.
Findings and Discussion

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OPPORTUNITIES

The potential for developing new sources of valuable plant chemicals is largely unexplored and the benefits from doing so unexploited. Of the Earth's estimated 500,000 to 750,000 species of higher plants, no more than 10 percent have been examined even cursorily for their chemical makeup. An even smaller number are grown commercially: only about 300 plant species worldwide and 100 species in the United States have been developed as crops for food and fiber products. In concentrating on a relatively few crops, other plants that could become important food and nonfood crops have been neglected. Plants are known sources of medicines, proteins, waxes, oils, resins, tannins, and other useful substances, Technologies to extract these chemicals are becoming more advanced, and developed whole-plant utilization schemes in which these substances are extracted and the residue used as a commercial byproduct or for energy production are receiving increased attention. Developing new crops and industries based on plant extracts and extraction residues provides opportunities for agricultural and industrial expansion that could benefit farmers, consumers, industry, and the Nation as a whole. New-crop and plant-product development could:

- diversify and increase efficiency of agricultural production,
- improve and possibly expand land resource use,
- offer increased economic stability to farmers,
- create new and improve existing agriculturally related industries,
- increase employment opportunities,
- provide consumers with new products,
- provide industries with alternative sources of raw materials,
- help supply the country with strategic and essential materials, and
- improve the Nation's balance of payments through import substitution.

Some of the greatest benefits of new-crop development would result from crop diversification. As already pointed out, the U.S. agricultural system is based on a limited number of crops. Because agricultural research and development efforts on these crops have contributed to their increased productivity, over-production has become a regular feature of American agriculture. Federal price support programs and production limitation programs designed to protect farmers from depressed commodity prices are costly. The Congressional Budget Office predicts that agricultural price support programs will cost the Federal Government at least $21 billion in 1983 alone. Alternative crops could help shift production away from traditional crops and into new crops, thus increasing economic opportunities for farmers and reducing Federal farm-support programs.

The concentration of U.S. agriculture on a small number of major crops invites economic instability. The economies of many agricultural areas are based on one or a few crops commonly grown in monoculture, leaving farmers vulnerable to the effects of pests and changing market conditions. New crops could provide alternatives to traditional crops and opportunities to develop new agronomic systems such as multiple-cropping or intercropping. Production of two or more crops offers an economic buffer in the event that one of the crops fails or the market price drops. In addition, the development of whole-plant utilization schemes in which many commercial products are available from one crop offers farmers greater economic insurance against price fluctuations than if they depended on a single product from a crop.

Widening the crop base also would enable the farmer to choose a plant species best suited to local agronomic conditions. U.S. agriculture has been largely manipulative; farmers have modified the land resources to conform to a particular crop. An improved match of crop and resources could help reduce increasingly expensive and scarce inputs of energy, chemicals, and water. For example, assuming that markets for its products can be successfully developed, milkweed, a semiarid-land plant, is a potential substitute for irrigated crops now grown in the western Great Plains where ground water resources are being depleted. Similarly, crambe, another dryland crop, might be more effectively grown than corn or wheat in dry areas marginal for these crops. Plants ecologically adapted to a site might require smaller inputs of pesticides than crops without built-in chemical or biological defenses against local pests.

Widening the crop base might also increase U.S. cropland acreage. If developed, new crops that could be cultivated on marginal lands without large amounts of chemicals, fertilizers, and irrigation water offer the opportunity to extend production to these lands that are unable to support traditional crops. Plants that might be cultivated on arid lands, in areas where the soils are highly alkaline, and on reclaimed strip-mined lands should be investigated. Benefits resulting from cultivating such lands include increased farming opportunities and stimulation of industrial production in economically depressed areas.

New crops could provide the consumer with a wide range of new products, including medicines; essential oils for cosmetics, spices, and drugs; detergents; vegetable dyestuffs; and insecticides, to name a few. One striking example of new plant-derived products is the highly effective anticancer drugs extracted from the Madagascar periwinkle ***(Catharanthus roseus)*** plant. The ended plant ***(Phytolacca dodecandra),*** which contains a potent molluscicide, is another example of a plant that may provide great human health benefits. Although it is still being tested, this molluscicide might prove to be important in the control of schistosomiasis, a tropical/subtropical disease affecting zoo million to 300 million people.

Plant-derived insect toxicants, repellents, attractants, and various biocidal compounds constitute another important group of extracts with potential commercial value. These plant extracts offer alternatives to some synthetic compounds that have negative and long-lasting ecological impacts on the environments in which they are applied. A variety of these natural biocides can be extracted from arid- and semiarid-land plants, including neem tree, sweet basil, and sagebrush. Producing such crops could improve or extend cultivation to lands that are often unproductive for U.S. food and fiber crops. These products could be particularly effective for pest control where other arid/semiarid-land plants are being cultivated.

Just as arid/semiarid-land species represent a group of plants with largely unexplored production and product possibilities, marine plants have been relatively untapped as sources of commercial products. Except for extracting agar, carrageenan, and alginate for the food industry, little commercial processing of marine algae is done in the United States. Research in the relatively new field of marine photochemistry has revealed that marine algae are sources of unique chemical compounds. Certain marine algae show potential as sources of pharmaceuticals, agricultural chemicals, food and food products, enzymes, and chemical feedstocks. Multiple-product development seems promising. With improved mass culture techniques, large-scale production of algae in the ocean and in controlled coastal facilities may be feasible. Development of marine algae for commercial products provides new opportunities to expand the U.S. production base and develop related industries.

New crops could be sources of industrial raw materials such as oils, waxes, gums, fibers, and chemical feedstocks. These raw materials could stimulate the development of new industries and enable existing firms to expand their product lines. Because many of the plants being researched would be cultivated on marginal lands, resulting industrial expansion would occur in places that commonly are economically depressed. These industries could stimulate local employment opportunities not only in the agricultural but in the industrial sector.

Domestic production of plant-derived chemicals could have a beneficial economic impact through import substitution. The United States imported an estimated $23 billion worth of agriculturally produced industrial materials and petroleum for industrial feedstocks in 1979. Domestic crops that could provide direct substitutes for agricultural products or alternative chemicals to petroleum as fuel or industrial feedstocks conceivably would be important in import substitution and for foreign exchange savings.

Domestic production of substances considered strategically important to the Nation or essential to U.S. industry should be encouraged. There are obvious advantages in promoting self-sufficiency, guaranteeing a ready supply, avoiding stockpiling, and reducing reliance on stockpiled materials. Research is being carried out on plants that can serve as sources of industrial and strategic materials and as petroleum substitutes. Certain materials of national strategic importance are required by law to be stockpiled. Listed among strategic materials are castor oil, an important industrial coating and lubricant; sperm whale oil, a heat-resistant liquid wax whose primary strategic use is as a lubricant in jet engines; and rubber.

Half the rubber used in the United States is synthetic; the remainder is natural ***Hevea*** rubber. The United States imports all its natural rubber at an annual expenditure of $1 billion, making rubber the Nation's second-most-expensive import after oil. The United States could reduce significantly its dependence on foreign sources of rubber by producing it domestically. Because of its importance to the military, the Federal Government is funding research on guayule, a desert plant that is a promising substitute for *Hevea* rubber. Guayule is being studied as a potential crop and is being grown on small commercial acreages in the Southwest. *

Jojoba ***(Simmondsia chinensis),*** also in limited commercial production in the United States (about 20,000 acres), is a potential substitute for sperm whale oil. Use and importation of sperm whale oil was banned in the United States in 1970 under the Endangered Species Act. Another possible substitute for sperm whale oil is a chemical extracted from meadowfoam ***(Limnanthes douglasii),*** now being studied at the Department of Crop Science at Oregon State University. ***Limnanthes*** oil can be converted to a liquid wax that has properties similar to jojoba oil.

Castor oil is extracted from castor beans grown in Brazil. Although castor beans have been produced in the United States, a substitute oil is being sought because castor beans have toxic and allergenic properties that are hazardous to humans and animals and pose waste-disposal problems. A possible substitute oil can be obtained from ***Lesquerella*** species, members of the cabbage family that can be grown in the United States.

U.S. stockpiles of natural rubber and castor oil are far below the level required by law. Acquiring, maintaining, and storing these strategic stockpiles would cost the United States an estimated $1.1 billion (in 1979 dollars) by 2000. Domestic production of substitutes could help eliminate the need to stockpile natural rubber and castor oil.

The United States depends on other countries to supply a major portion of its demand for petroleum. The interest of the U.S. Government and the chemical industry in domestic production of plants for fuel and chemical feedstocks has increased as a result of the rise in petroleum prices since the 1973-74 Arab oil embargo. Researchers at the USDA Northern Regional Research Laboratory in Peoria, 111., are investigating several plants as potential petroleum substitutes. Oils or fatty acids from seeds of certain plants may provide substitutes for petroleum-derived chemicals and some botanochemicals. New oilseed crops are found at a variety of stages of development. Preliminary chemical and botanical investigations have indicated crop potential of ***Cupea*** species as sources of lubricants and detergents, *Veronica* species and Stoke's aster ***(Stokesia laevis)*** for manufacture of industrial coatings and plastics, and ***Lesquerella*** species as sources of sub-

*Guayule was grown in the Southwest United States during World War II as a substitute source of natural rubber when imports were cut off. After synthetic rubber was developed and ***Hevea*** rubber trade ***was*** restored after the war, production of guayule in the United States was discontinued.

stitutes for castor oil. More extensive basic and applied research has been carried out on two other promising species: meadowfoam and Chinese tallow tree ***(Sapium sebiferum).*** Small amounts of jojoba (about 20,000 acres) and crambe ***(Crambe abyssinica)*** are further along in their development as new crops; they are being grown commercially on small scales.

Fuel crops under study fall into four categories: oilseeds, hydrocarbon crops, starch / sugar crops, and biomass plants. Oilseeds could provide diesel fuel; hydrocarbon extracts could be cracked to produce gasoline or liquid fuels; starch / sugar crops are used in alcohol production; and biomass crops could undergo alcohol fermentation, gasification, or direct burning. * Research funding available through USDA, the Department of Energy, and the National Science Foundation (NSF) has supported work on milkweed ***(Asclepias spp.),*** buffalo gourd ***(Cucurbita foetidissima),*** and gopher plant ***(Euphorbia lathyris)*** as potential energy crops. Because these and other potential fuel crops could be grown on arid or semiarid lands, they would not compete with food and fiber crops for prime agricultural land. Further technological, ecologic, and economic analyses are needed before these plants could be developed as commercial sources of fuel.

*For more information see OTA 1980 report ***Energy From Biological Processes,*** and OTA 1979 technical memorandum on gasohol.

In summary, the development of new crops for plant extracts offers many potential social, economic, and ecologic benefits on both local and national levels. New-crop development could benefit agriculture through crop diversification, expansion of the land resource base, and increased efficiency of crop production (e.g., rotation and multiple-cropping systems); industry through product diversification and raw material availability; consumers through provision of new products and increased employment opportunities (on-farm and industrial); and the Nation through reduction of agricultural price support programs, import substitution, and independence from foreign sources of strategic and essential industrial materials.

Successful introduction and establishment of a crop, however, require a long and adequately funded period of coordinated R&D. Each potential crop would be faced with a unique set of technical and economic constraints that could threaten its commercial development. The field of new-crop and plant-product development on the whole faces some general constraints. These will be discussed below.

CONSTRAINTS TO NEW CROP DEVELOPMENT

Potential crops require many years of agronomic research and product development balanced with market development for successful introduction. This involves a long chain of R&D steps including selection of plant species (involving chemical and biological characterization); isolation and purification of desired compounds; crop development (including genetic improvement, agronomic research, and harvesting technologies); transportation and storage; processing technologies; and marketing. (Plant-derived pharmaceuticals, biocides —e.g., insecticides, fungicides—and foods for human consumption–e.g., proteins, vegetable oils—require additional research because before marketing they must be tested in compliance with FDA regulations to ensure that they present no health or environmental hazards. Clinical testing for pharmaceuticals is particularly expensive and time-consuming.) Once a product is marketed, further research on agricultural practices, processing, and marketing would be required to fine-tune on-farm and industrial techniques. The future of new-crop development for plant extracts will depend on the existence of appropriate R&D systems that can facilitate breakthroughs and continued improvements.

Many constraints to developing new crops and plant extracts industries are encountered at the four major steps in the development process—namely:

- research,
- crop production,
- industrial processing, and
- marketing.

The following discussion examines problems and potential impacts of new-crop / plant-product development at each stage.

Research

Developing a new plant-extract industry requires research in a number of disciplines, including chemistry, botany, genetics, agronomy, entomology, engineering, and marketing. Expertise in all these fields is rarely concentrated in one institution. For example, most agronomy research is carried out in public, land-grant institution, and USDA, whereas industrial biochemistry and engineering expertise is primarily found in the private sector. Both the private and public sectors depend on the foundation of basic science provided by university researchers. Clearly, coordination of research efforts of Federal and State Governments, universities, and industry is essential if new crops and plant extract products are to be developed efficiently.

Agricultural research in the past has focused on improving yields of existing U.S. crops or on crop improvement of introduced plants. Only within the last decade has much effort been directed toward developing new crops for plant extracts in the United States. Although scattered plant screening and crop development projects in the United States have demonstrated the potential for crop and product diversification, work in this field and support for it remain limited and sporadic. The limited attention of industry is focused mainly on industrial feedstocks. Industry's lack of interest in plant-derived pharmaceuticals is notable.

Funding for new-crop development is only a small portion of USDA's research budget, Combined State and Federal (USDA) appropriations for agricultural research in 1983 total about $1 billion, most of which will be spent on the country's well-established crops. The share of new crop research within USDA's Agricultural Research Service (ARS) is only $3 million this year. * An estimated additional $3 million to $4 million is being spent this year on such research by NSF and other Federal agencies. When research funding is cut, work on new crops often sustains the heaviest budget reductions, losing out to established crops. Ironically, while research on new crops, which offers opportunities for crop diversification and new markets, remains underfunded, the costs for Government price-support programs for overproduced crops continue to expand,

Recent cuts in Federal support for applied research have been made on the premise that the private sector should play a larger role in applied research, freeing public moneys for basic research. At the same time, however, nondefense Federal agency research budgets and appropriations for universities and competitive grant programs, particularly in the life sciences, have been cut, reducing support for basic research.

If the private sector is to play a larger role in research, it must be both able and willing to invest. Within the private sector, venture capital and multinational corporations are most likely to take the initiative in developing new plant products. Multinationals with well-established research branches might be able to expand research efforts to fill gaps in basic research left by Federal cutbacks in research. The private sector, however, tends to wait until enough basic and applied research has been done to demonstrate profit potential before investing in further research. Once profit potential is established, the private sector becomes much more willing to invest in product R&D.

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*ARS research on new crops was carried out in Phoenix, Ariz.; Pasadena, Calif.; Bryon, Ga.; Tifton, Ga.; Peoria, Ill.; Ames, Iowa; Beltsville, Md.; East Lansing, Mich.; Mayaguez, P. R.; and Lubbock, Tex. The total funding for these research efforts was $2.79 million in 1982, $2.95 million in 1983, and is projected to be $2.95 million in 1984. (James T. Hall, Executive Secretary for USDA Research and Education Committee, personal communication, May 1983.)

The process, however, depends on a foundation of basic research. It appears that the public sector must provide leadership by laying the foundation for new crops. Historically, the development of the existing U.S. crops has depended on substantial Federal and State support; new crops will not be exceptions. *

New-crop development will depend on a certain amount of agronomic research carried out by ARS and State Agricultural Experiment Stations (SAES) and perhaps DOE (energy crops), Department of Defense (strategic crops), and Department of Commerce (marine plants). At the same time, however, funding for plant extracts work should be made available through competitive grants programs administered by USDA and other appropriate Government agencies. USDA is authorized under the Food and Agriculture Act of 1981 to conduct a competitive grants program on new crops. Not only is this an efficient way to match research needs with expertise but it reduces pressures within the agencies to maintain or increase traditional crops research at the expense of new-crop development.

Federal funding for new crops and plant extracts work is also available from NSF. NSF grants, however, generally are provided for basic scientific research, not for much needed applied research and development. For example, in the pharmaceutical area, funds are available for biochemical screening but rarely for follow-on research needed for drug development. NSF recently launched a new Small Business Grant program, but it specifically excludes grants for product development work. Bridging the gaps between basic and applied research and between research and product development is one of the major obstacles to new-crop development.

In addition to providing basic research and funding, the Government could be instrumental in stimulating private sector involvement in plant extracts by offering economic incentives for industry to invest in plant products. Given current economic conditions (e.g., recession, high-interest rates), a critical problem for the plant extracts industry will be how to leverage public and private funds for R&D so companies will be neither inappropriately subsidized nor discouraged from entering the industry. In addition to providing publicly funded "front-end" research, the Federal Government may need to provide other incentives such as tax benefits and low-interest loans to stimulate private interest in plant-extracts production. Such incentive systems must meet the needs of the companies, whether venture-capital firms, small businesses, or multinational corporations. Mechanisms available to the Government to encourage new-crop development and shifts in production should be examined.

One reason cited for industry's general disinterest in the plant extracts field, especially in plant-based pharmaceuticals, is uncertainties of patent protection. There seems to be some uncertainty about the patentability of different kinds of products and processes. In addition, some companies claim that they do not invest in natural-product development because it is difficult to obtain a product patent and because a processing patent, which is easier to obtain, does not offer sufficient protection against competitors. Industry also shows some hesitation to invest in research protected under a publicly owned patent. A risk exists that a competitor will use the Freedom of Information Act (FOIA) to obtain proprietary information on work done in an area protected by a public patent. Various agencies treat the FOIA differently; some will allow the sponsoring company to black out items of proprietary interest before information is made available; others will not. A related problem raises if a product or technique is developed in a State-supported institution; the sponsoring company cannot be given an exclusive license for it. The sponsor may be assured first right of refusal but the percentage return on sales must be negotiated, a time-consuming task that university scientists are apt to avoid. Another patent-related disincentive to industry's investment in plant extracts is specific to pharmaceutical companies. The length of a pharmaceutical patent (17 years) includes the time necessary for

*For more information see OTA technical memorandum, "Agricultural Postharvest Technology and Marketing Economics Research," April 1983.

clinical testing, thus reducing the time the product is on the market and protected by the patent. Patent laws should be investigated in relation to plant extracts, and modifications to those laws to offer improved protection to companies investing in certain plant extracts work.

In summary, potential Government roles in encouraging new plant-product development include the following:

1. provide SAES, ARS, or other Federal agency funding to nongovernment research bodies for R&D;
2. provide other incentives or eliminate disincentives in order to encourage private sector R&D;
3. carry out research itself in areas deliberately avoided by the private sector, when it is against the public interest to have research results protected by proprietary interest, and where public research would stimulate increased private investment; and
4. improve coordination of public research with the technical needs "of industry.

Academia is a vital component of plant extracts work. Land-grant institutions provide expertise in agronomy and postharvest technology whereas other universities are relied on for advances in basic sciences (e.g., biochemistry, pharmacology, genetic engineering). While the public and private sectors depend on academic institutions for research advances, universities in turn rely on funding from public and private sectors. As a result of the intense international technological competition of the last half decade, many people feel that public research should be coordinated better with the technical needs of industry. One way to foster improved communication is through cooperative arrangements between industry and universities. Some such arrangements have been developed recently in the plant extracts area (e.g., General Foods Corp. and LPI for tobacco protein research, Procter and Gamble Co. and Oregon State University for cuphea research), but in general, the industry-academia link is strained by the question of proprietary interest. Research findings of universities are usually assumed to be available to the public. However, industry may be unwilling to support university research without some chance of long-term gain provided by proprietary rights to research findings. This raises concern about corporate influence on academic research topics and scholarly communication. While university scientists are concerned about limitations imposed by patenting, licensing, and need for secrecy about research findings, industry seems concerned over the lack of exclusive license for the product or process. In addition, some farmers have expressed opposition to funding by large corporations of agricultural research at universities for fear it will increase even further agroindustry's competitive advantage over small-farm operators or cutoff their access to much needed information. These limitations and conflicts must be resolved to facilitate industry-academia cooperation in plant extracts research.

Clearly, close cooperation is needed among Government, industry, and universities in new-crop development research to bridge the gaps between basic and applied (both agronomic and industrial) research. The respective roles of academia and the private and public sectors should be examined and public policy should be directed toward the goal of improving cooperation between universities and commercial enterprises.

Although each potential crop under investigation requires specific research, there are general research needs in new-crop and plant product development. A major constraint to selecting potential new crops is the unavailability of adequate field-screening techniques. Because plants cannot be screened in the field, large amounts of plant material must be brought in from the field to the laboratory for testing. Effective field-screening techniques would facilitate the discovery of new chemical compounds, new sources of known chemicals, and germ plasm for crop improvement and genetic engineering.

Research efforts involving chemical screening of plants often have been product- or activity-specific; the focus has been on finding particular chemicals or biological activities. For example, the National Cancer Institute's plant-screening program examined 35,000 plants for antitumor activity but made no systematic effort to record other biological activity observed. Plants tested by the program might not have exhibited antitumor activity but may have had other useful medical properties. Just as multiple-product development is cost effective, so is comprehensive screening. Improved communication and collaboration among research institutions would reduce duplication and encourage the development of advanced testing and screening technologies.

Crop Production

The needs and impacts of cultivating new crops, of course, depend on demand for the crop and the land area put into cultivation. Low-demand, high-price "specialty" crops such as the Madagascar periwinkle would require little acreage, so their impact on existing land-use patterns would be minimal. In contrast, new high-demand, high-volume crops such as hydrocarbon and leaf protein crops probably would have substantial impacts on the quantity and quality of national land resources. The following discussion refers to high-volume crops.

Land availability for new high-volume crops must be carefully assessed. Many such crops under study, including milkweed, jojoba, guayule, and crambe, are arid-or semiarid-land plants that thrive on lands marginal for traditional food and fiber crops. On these marginal lands, the decision to shift to a new crop will be largely an economic one and will be made as markets develop. Converting uncultivated arid and semiarid lands, both private and public, however, may be more difficult. Efforts to convert this land to effective cropland may well conflict with other uses such as grazing or recreation and involve complex property transfers.

While the decision of a farmer to shift production to a new crop is ultimately an economic one, the risk of allocating production resources to an unproven crop at first may seem too high. Even if farmers are assured regular markets for their products, initially they may need incentives to risk crop changes. Again, the Government could play a facilitating role in working closely with local bankers to ensure that long-term credit is available to farmers for new-crop production. Further, the Government might sponsor applied research on the crop to overcome farmers' resistance to it.

Assuming obstacles to allocating land for new-crop cultivation are overcome, effects on the quality of the land resources allocated to a new crop must be evaluated. Although some new crops would be better adapted ecologically to certain lands than traditional crops, any change in land use should be made carefully. Many arid and semiarid lands, for example, are highly susceptible to erosion, and unless the new crops are perennials and soil conservation techniques are implemented, erosion on previously uncultivated lands may degrade the land resource. New cropping patterns, such as multiple-cropping, may prevent such damage. Introducing a new crop may create pest and disease problems; new plants could introduce new pathogens or pests to an area or be susceptible to unforseen pest problems themselves. Many of the problems encountered with new-crop production are the same as those of traditional crops. But because new crops may change land-use patterns on marginal lands, which are more likely to be susceptible to ecological disruption, their impacts on the land base may be more pronounced.

Industrial Processing

The most serious technical constraints to new-crop development probably will occur at the product-processing stage. Processing technologies that appear feasible at the pilot level often encounter difficulties when scaled-up to commercial production. For example, although tobacco protein extraction seems technically promising at the pilot stage of development, technical problems with handling plant material, waste disposal, and solvent recovery are foreseen in commercial production. Commercial production also requires that plant capacity be fully used. Unless crop production is possible year-round, storage of the plant material will be necessary. When the quality of a major commercial plant chemical deteriorates rapidly after harvest (e.g., in leaf proteins, milkweed), processing must be coordinated with plant harvest.

Waste disposal, pollution, and other environmental effects from industrial processing represent another constraint on commercial production of plant extracts. Many extraction processes require the use of solvents. If these are not recycled, appropriate liquid-waste-management systems must be developed. Because waste water from processing for leaf protein and other plant extracts commonly has a high biological oxygen demand (BOD), it, too, could be a source of pollution if not disposed of carefully. Other environmental concerns associated with extraction are significant as well, and an economic assessment of plant extract technologies must factor in such costs.

There may be social costs involved when establishing processing and production facilities in areas previously economically depressed or in rural regions. Infrastructure needs, population shifts, inflation, and irregular boom and bust cycles of development are among the consequences of rapid economic growth. Planning for financing the front-end costs of development and for allocating resources within the community must be an integral part of large-scale commercial endeavors in plant extracts industries.

Marketing

Unless a market does or potentially can exist for a plant extract(s), industry probably will not invest in product development research and farmers will not invest in crop production. However, the development of a market depends on farmers' willingness to produce the crop and industry's willingness to invest in product research and marketing to stimulate product demand. This "Catch-22" of which comes first, the product or the market, exists for all new products but can be particularly complicated in the plant extracts field where agriculture and industry must be closely linked. The timing of markets is critical; marketing and crop production must be coordinated effectively. If markets are created before production can fulfill demand, buyers can become disinterested and the product's chance for success will be impaired. If production exceeds market demand, farmers will become disillusioned. Marketing a crop that has specialized uses and few alternative applications may be difficult because production must be closely coordinated with very specific markets. Production and processing of a multiproduct crop must be coordinated with many markets, which also may be difficult logistically.

Another marketing problem may arise if a market exists but well-established products already fulfill the demand. For example, tobacco protein (Fraction *1)* would have to compete with egg albumin in the food processing sector and with alfalfa in the market for beta-carotene. Because both industries—egg albumin and beta-carotene—are well-established, tobacco probably would have a difficult time entering the market. Similarly, some of the products of milkweed (pectin, fiber, livestock feed) would have to compete in the marketplace with well-established domestic sources of these goods.

All new crops would need agronomic refining and new products need processing improvements after scale-up to commercial production. In order for farmers and industrial producers to invest in the crop, however, it would have to be profitable or perceived to have commercial potential even before refinements have been made. One way to overcome this barrier would be to introduce a product from the crop as a "specialty item." This high-priced item could make the crop competitive in the short run with traditional crops and could act to encourage the crop's expanded development. The crop could be grown in small quantities for predictable returns, thus enabling farmers to solve production problems and providing the time necessary for further agronomic and processing research essential for long-term development of the crop. This leveraging method is being employed with jojoba. Small-scale commercial production of the plant is supported by commercial sale in health food specialty markets (e.g., shampoos, skin creams). Once crop and product production methods

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are refined, jojoba can be cultivated on a much larger scale for its potential high-demand oil.

Consumer acceptance of the product(s) is, of course, the most important factor in marketing success, and sometimes the most unpredictable. Soybean meal has been developed and produced as a high-quality, low-cost source of protein for human consumption, but consumers prefer to buy other more expensive proteins. Tobacco leaf protein faces a similar obstacle. Although technical problems remain, the LPI process could be scaled-up to commercial production at this time. The overriding deterrent to commercial production, however, is producers' lack of confidence that consumers would accept tobacco protein concentrates as protein supplements or cigarettes produced from deproteinized tobacco.

In summary, constraints to new-crop development are many and need to be overcome from beginning research to final marketing. Such constraints in research, crop production, industrial processing, and marketing include:

- research:
  - insufficient cooperation among the Federal Government, States, universities, and industry;
  - scant research dollars identified for such research;
  - inadequate linkages between basic and applied research and product development;
  - lack of Federal economic incentives to increase industry's involvement;
  - inadequate field-screening techniques.
- crop production:
  - possible major changes in current land-use patterns;
  - lack of incentives for farmers to take risks with new crops;
  - potential adverse environmental impacts of some new crops on the natural resource base;
- industrial processing:
  - the difficulties in scaling-up from pilot operations to full-scale production;
  - waste-disposal problems faced at full-scale commercial production;
- marketing:
  - the "Catch 22" of which comes first—the product or the market?;
  - breaking into the market that is already filled by established products;
  - developing consumer acceptance of new products.

AREAS FOR POSSIBLE CONGRESSIONAL ACTION

The potential for the technological and scientific screening of plants to find the new useful substances they contain has barely been tapped. Research to date strongly suggests that this is a promising field that could provide wide-ranging benefits to the United States in the near and far term, especially if nonrenewable fossil fuel resources climb in cost. To date, no more than an estimated 10 percent of the world's 500,000 to 750,000 higher plant species have been screened for their chemical makeup even in a cursory manner. Nevertheless, the array of useful and important products extracted from plants is impressive.

Today, a worldwide concern exists among scientists that plant materials as yet unscreened are being lost before their potential value is determined. Loss of genetic plant materials probably is greatest in the Tropics where pressures to clear vegetated land for agriculture to feed rapidly growing populations are extremely heavy. (See OTA report entitled ***Technologies To Sustain Tropical Forest Resources.)***

Discussions of the experts assembled by OTA reflected a need for the United States to address the issues and problems above in a timely fashion. Because of the rate of land-clearing worldwide, society may no longer be able to afford the luxury of postponing action to some far distant date. Three opportunities for possible congressional action emerged from this exploratory activity:

- develop a coordinated, comprehensive plan involving the Government, industry,

and universities to screen plants, assess new chemical resources from the plants, and foster their commercial development;
- assure adequate funding for Government, university, and industry research into plant screening for the extraction of commercially valuable substances and for crop and product development;
- provide incentives (e.g., tax benefits, subsidies) or minimize disincentives (e.g., uncertainties in patent laws) so as to encourage research by industry on new crops for chemical extracts; and
- encourage bilateral and multilateral agreements for cooperative research and evaluation of untested species.

No coordinated, comprehensive U.S. plan involving the Government, industry, and universities exists for: 1) screening U.S. or foreign plants for their natural chemical components, 2) determining the nature and possible uses for the natural plant chemicals they may contain, and 3) fostering development of such new crops and their commercialization. Scattered efforts are under way in the United States to deal with some of these needs but the total effort is small. Traditional major food and fiber crops have strong agricultural lobbies behind them that work hard to maintain Federal and State Government attention and research. Potential new crops and chemical-screening efforts lack the support of similar strong lobbies. Industry generally focuses on deriving benefits from their research over the short term. It is unlikely, therefore, that they would undertake a broad-based, long-term analysis of the thousands of plants as yet unstudied. In addition, vertically integrated, very large food industries concentrate mostly on food processing and generally rely on others to conduct basic research on new crops and new products.

Adequate funding is lacking for R&Din plant screening for chemicals and for development of new crops bearing such chemicals. Competition for current funds is keen. Unstudied plants have no markets or products when they are first investigated, and even with research it is not certain that the plant will yield useful products. Should new products be developed, markets for them may not exist, or if they do exist the market demands already may be being met by other materials from different sources. The history of agriculture shows that the major U.S. crops have depended heavily on large Government expenditures for research, development, and farm subsidies. The development of a new crop in the past has not and probably cannot now depend solely on the efforts and funding of the private sector. Bringing new crops into the marketplace usually requires a long period of time. During this time of R&D the commitment for continuity of support is key to maintaining industry's interest. The private sector is unlikely to be willing to pay all costs for developing a plant product or risk working on the crop at all unless assured that a continuing commitment to the crop's research and development exists. It seems likely that Federal support in the form of Government research and funding for private research will be required to move crop or product development along to a point where the private sector ultimately can take over.

In addition to its role in carrying out or funding research, the public sector has a role in providing incentives or minimizing disincentives in order to stimulate private sector interest in commercial development of plant chemicals. Such incentives might include tax benefits or other forms of subsidies for farmers and industries developing new crops and plant products. Disincentives to industry's participation in this area include uncertainties in patent laws. Some industries seem to feel that existing product or processing patents offer insufficient protection against competitors. There also seems to be some confusion about the patentability of plant material. Although university-industry cooperation represents an advantageous meshing of expertise and funding, industry often hesitates to enter into such arrangements for fear of insufficient control over research results. For the same reason industry may hesitate to engage in research protected under a publicly owned patent, protection of key research findings cannot be assured. OTA workshop participants expressed a concern over perceived problems arising from patent law. They see a need for the Government to examine certain patent laws as they apply to plant-extract industries and, where appropriate, change these laws to provide adequate incentives to industry to invest in plant-chemicals research.

Clearly, if the potential for commercial development of plant chemicals is to be exploited, R&D in this field needs to be coordinated among Government, academia, and industry. * In light of increased concern over rapid loss of genetic plant material worldwide, increased action in this area seems appropriate now. The role of Congress could include the following actions:

1. Congress could request an evaluation of the status of science and technology related to extracting chemicals from plants and the development of associated new crops. The study would assess at least the following three issues:
   - basis for a coordinated plan for commercial production of plant extracts and developing associated new crops;
   - funding requirements for long-term R&D;
   - incentives and patent-law uncertainties that might be a disincentive for industry involvement.

   The study could examine and assess the major constraints to and opportunities for establishing new industries that could extract important chemicals, medicines, and protein, for example, and develop associated new crops. It could assess ways to minimize the constraints and to analyze potential impacts of taking such actions.

   The study could outline possible ways to establish a mechanism for Congress to obtain continuing information and advice on plant-chemical industries and associated new crops, research priorities, and methods for improving coordination among Government, industry, and academia.
2. Congress could hold a series of hearings to address such issues as:
   - the need for a coordinated plan for R&D of plant extracts and associated new-crop development;
   - the needs for R&D funding;
   - incentives and patent-law uncertainties that might be a disincentive for industry involvement; and
   - consideration for the establishment of a "plant extracts/new crops advisory council" comprised of members of Government, academia, and industry.

   Participating committees could be those having jurisdiction over such topics as agriculture, science and technology, commerce, marine environment, international development, medicine, strategic stockpiles, and public health.
3. Upon completion of such hearings, Congress could, if the need is justified, take appropriate actions to form a permanent "plant extracts/new crops advisory council."

*One attempt at coordinating research and development on new crops is contained in Public Law 95-592, Native Latex Commercialization and Economic Development Act of 1978. In the act, a Federal agency coordinating commission was established to oversee R&D work on Guayule. In *1983, the* commission membership and scope were broadened under H.R. 2733, Critical Agricultural Materials Act. As of this writing, the bill has passed the House and full Senate action is pending.