ECOLOGICAL PERSPECTIVE ON THE INCREASING USE OF PLANTS TO PROVIDE USEFUL PRODUCTS

(A Review of the OTA Workshop

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Introduction

Breadth of ecological implication

The suggested broadened use of the world's plant resource base has ecological implications which are considerably more far-reaching than those implied by most alternative technology choices. These potential ecological impacts should be considered as underscoring the significance of this OTA study.

In the eyes of at least one analyst (14), the mechanical-industrial age of the late 1800's and early 1900's gave way during the 1940's to the age of alchemy. We have learned to synthesize innumerable useful products from raw materials. In some instances those raw materials are readily available and seemingly inexhaustible. However, a large proportion of our technological efforts are directed toward developing products from raw materials that are in finite supply—in particular, fossil hydrocarbons. The age of alchemy seems to have been characterized by a narrowing of our technological vision.

In recent years, unlocking genetic codes and developing techniques for cellular manipulation of genetic materials have renewed the interest in developing biological processes and materials to create products useful to humankind. These new techniques may provide the transition tools to take us from the age of alchemy to that of algeny, in which there would be a greater reliance on biological rather than nonliving, chemical processes. It seems that the energy and resource consumption of the chemistry-based technologies of today are nonsustainable. In addition, the environmental loading of slowly biogradable or nonbiodegradable materials has adverse implications for the quality of human life and for native flora and fauna.

Many people are not aware that the new biotechnologies are as dependent upon the availability of existing genetic material as they are on raw materials. For the foreseeable future, we will depend primarily upon existing life forms rather than on artificially synthesized life constructed according to design from some sort of "basic building blocks." The new technologies enable the rather rapid shaping and molding of existing genetic material into more productive and useful forms. The identification of those potentially useful biological materials is the focus of work surveyed in this study.

Far-reaching issues of direction and paradigm

The present dependence on a limited number of plant species as sources of most of our raw products and food permits use of only a small fraction of the Earth's surface for production of useful products. The demand for those products often outstrips the productive capacity of the "arable" land used to produce them. As our technologies focus on an ever-narrowing list of commercial crops for food, fuel, fiber, and industrial products, and as growing demand forces greater production of these few commodities, there is increasing evidence of adverse environmental impact and a subsequent decrease in our production resource base. Nonsustainable levels of soil erosion or ground water depletion are evidence not only of deficient production technologies but also of growing crops that are too resource-demanding. Forcing corn, wheat, soybeans, or other annuals onto land that will not sustain them is a short-term solution to product supply.

The vast areas of land now considered to have low production potential for the present intensively cultivated crops maybe considerably more productive with carefully selected and properly managed alternative crops. Many lands which are now commercially unproductive could be cropped safely to a wide range of perennial crops identified as sources of useful products. Jojoba and sisal for semiarid environments are excellent examples. There are also many potentially valuable biocidal compounds produced in species adapted to semiarid environments. These marginally productive environments (as measured by their ability to produce our current major annual crops) typically are areas of environmental degradation and human poverty. Broadening our crop focus and making use of potential production resources could help arrest resource deterioration and improve the quality of life in these areas.

Benefits of using biologically produced materials

One of the adverse effects of "the age of alchemy" has been the environmental loading of synthetic materials, particularly biocides. While biologically produced materials may have equally disruptive short-term effects, they are biodegradable and rarely persist over long periods, so cause little, if any, long-term disruption. Once having identified such compounds, it is often possible to synthesize them. In the case of the insecticide pyrethrum, however, insects have not built up a resistance to the naturally occurring form, but they have to the synthetic: form (2,4).

A disadvantage of relying on plant-derived biocides is that they seldom have narrow selectivity and do not move systematically in plant tissue, They can be used near the time of harvest, however, because of their short residual time.

The importance of genetic diversity

Much has been written in recent years on the subject of crop diversity. The widespread incidence in the United States in 1970 of corn leaf blight, which caused an estimated 15 percent loss of our corn crop, aroused considerable interest and concern. The National Academy of Sciences' study "Genetic Vulnerability of Major Crops" (5) became the benchmark to a series of subsequent reports. The report's primary recommendations focused on increased emphasis on plant breeding and improved germ plasm collections, Subsequent NAS reports have dealt with the desirability of increasing the world's crop base *(6,7,8,9,10,11,12).* There continues to be considerable alarm over decreasing crop genetic diversity (15). Increased crop diversity reduces the buildup and spread of plant pathogens and insect pests. From the standpoint of the individual farm, a variety of crop options vastly increases the economic stability of the operation and provides the "tools" needed to structure a resource-efficient operation. The vast array of crops grown on a typical Chinese vegetable farm nicely illustrates the point (3). Having an array of crop options permits the establishment of rotations to reduce cost of controlling weeds and soil-borne insects and diseases.

The energy saving of greater self-reliance

The identification of plant sources for industrial products, pharmaceuticals, and pesticides would have a positive impact on developing countries. In some cases the new crops could provide the basis for a new export industry, but the greatest impact would be to permit a greater degree of self-reliance Having a greater capacity for in-country production of raw materials rather than a worldwide network of product flow with highly centralized synthesis and distribution reduces the service, handling, shipping, and, ultimately, the energy costs of a product. In the future energy-and-resource-limited world, a new balance between production and service costs must be reached. We will no longer be able to afford the energy-intensive open supply loops of the past (1).

The USDA Economic Botany Laboratory's Data Base on Minor Economic Plant Species

by James Duke

Much, if not most, of our crop movement and related agricultural development work over the past several decades has, ironically in an age of computer and systems science, been done empirically (3). The USDA's data base on minor economic plants, if extensively used, would help match crops to their "best fit" environment. It would assist significantly in development planning by suggesting the best crop options for target environments and by helping to minimize crop development efforts in environments that are marginal or unsuited to the crop species. Marginal environments typically mandate the use of extreme measures, either in modifying the environment or in protecting the crop. Under stress conditions, most crops are more sensitive to a pest or pathogen. A "best fit" crop-environment situation generally leads to optimal crop-environment biological stability with minimal need for drastic intervention with biocides or other harmful production inputs or technologies. The ecosystematic file described by Duke has potential for the greatest positive environmental impact of all technologies discussed in this workshop.

The USDA data base can play an important role in dealing with the spread of pests or diseases. Plant scientists recognize the need for extreme caution when moving plant materials. There are elaborate protection mechanisms to safeguard against the spread of pests and diseases. The recent movement of the Mediterranean fruit fly to California is an example of a detrimental introduction. In all likelihood this pest was introduced through transporting produce rather than plant genetic material. One finds, however, that when dealing with "exotic" or noncommercial plant species, the normal plant quarantine coverage often is less stringent than with commercial species. If a little-known species does not appear on the list of "regulated" species in a country, it often can be moved in or out freely. Most scientists, in their concern for making rapid progress, hope for ease of moving materials, despite the dangers. It seems that the present U.S.

quarantine laws with respect to movement of seed and plant materials are adequate, but budgets, staff, and facilities are not adequate to accomplish much more than perfunctory formalities.

There is one further consideration concerning the biological stability of materials moved to different environments. The USDA's ecosystematic file is based on environmental classification according to various factors of the physical environment. The species composition of the plant flora constitutes a second order of classification. As Dr. Duke suggests, this helps define environments where a given species can be expected to perform well. However, more attention should be paid to the pest/pathogen balance of a species. If a species has inhabited a given environment for decades or centuries, it and its pests and pathogens can be expected to have co-evolved so they are in relative equilibrium. That is not the case with a species introduced into an environment that is physically similar. Even if the introduced seed or plant material has left behind its complement of pests and pathogens, in all likelihood some of the insects or pathogenic organisms in the new environment will be able to use it as a new host. There is little, if any, way to predict or guard against such occurrences with information available today. Such unknowns should not impede crop movement, but the crop should be carefully monitored in its new environment. The USDA Economic Botany Lab's pest file could be helpful in providing information relevant to crop introductions, especially if the file is expanded to record the ecological amplitudes of pests and diseases.

In light of the potential of the USDA data base for providing long- term environmental benefits, the lack of sufficient funds and the inactivation of such a useful and beneficial program are regrettable.

information Gathering and Data Bases That Are Pertinent to the Development of Plant-Derived Drugs

by Norman Farnsworth and William Loub

Most of the comments on the Duke paper apply equally to this work. The desirability of diversifying our agricultural crop base supports any efforts leading to that end. Despite the wide ranging potential benefits of developing plant species for pharmaceutical extracts, U.S. pharmaceutical companies show little interest in this field.

Farnsworth and Loub state that "typical industrial drug development has increasingly involved synthesis of molecules based on structure-activity relationships" and that "not a single pharmaceutical manufacturer in the United States is involved in a research program to discover new drugs from higher plants." This pattern is also followed by companies developing agricultural biocides,

The major ecological problems in researching and developing pharmaceuticals from plants involve the movement of plant materials and depletion of natural sources of diversity. In the screening phase, it is usually desirable to collect plant materials directly from their native habitat for laboratory processing, extraction, and testing to save money and time. Where materials are to be used for laboratory processing, precautions must be taken to minimize the danger of spreading unwanted organisms. This requires constraint on the part of the research laboratory to avoid replanting materials not screened for propagation, Once a species is identified as having potential, however, greater quantities of material are needed for more extensive extraction and testing, The extent and amounts of the species should be evaluated before extensive and voluminous collecting is done so as not to deplete existing genetic diversity. This could severely limit future breeding work. Likewise, once a useful product is known and commercial extraction begins, agricultural production of the species must be started if the species is not plentiful in the wild. A high price for a raw product of a wild species can quickly drive the species to extinction. This is true for the entire range of useful plant products, particularly those of high value.

An Alternate Use for Tobacco Agriculture: Proteins for Food Plus a Safer Smoking Material

by Samuel Wildman

An overriding issue in the development of tobacco is the desirability of subsidizing research and development of a crop that has a large economic demand but few socially redeeming features to balance its high social costs.

The crop has severe adverse environmental impacts. When grown in the traditional manner, *it* quickly reduces the natural soil fertility. The many field operations, including cultivations and vehicular and field worker traffic, lead to compaction and deterioration of soil structure. The soils of the warm, humid tobacco areas are subject to erosion.

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These problems could be alleviated by growing tobacco in a carefully planned matrix of cover crops, rotations, and limited tillage systems, so they are not necessarily overwhelming. Of even greater concern are the large quantities of chemical inputs needed for field production.

It is argued that biomass production reduces the need for insecticides. The 10 to 12 sprayings required for a crop of smoking tobacco can be reduced considerably if processing for protein extraction can avoid the "cosmetic" quality restrictions of whole-leaf tobacco. The problems of seedling establishment require either "clean" or previously unused land or fumigation. Fumigation is an extremely environmentally disruptive process. Depending on the materials used, the presence of the chemical fumigant can be of short duration, but the disruption of soil microflora and microfauna is longer lasting. The alternative of transplanting requires less area in seedbed but higher costs of growing and handling the transplants.

From any standpoint, tobacco is an energy-intensive, fertilizer- intensive crop with high environmental impact. A saving factor under present practice is that commonly it is grown in relatively small fields because of the allotment system and labor requirements. This mitigates its adverse effects to some extent. It is conceivable that the more concentrated area production necessitated by a processing facility would present greater environmental problems.

An energy analysis of tobacco production and of its leaf protein extraction should be accomplished before much more work is done. In the long term, energy costs closely parallel dollar costs. There must be crops that could produce equal quality leaf protein at considerably lower cost. From an environmental standpoint, it seems that the greatest contribution of a tobacco leaf protein industry would be to decrease tobacco acreage.

The statements in Wildman's text that "agriculture in developing countries in the, tropics is notable for lack of crops of high protein content" or that "soybeans also cannot be grown in the tropics" simply are not true. Tobacco, in fact, has increased pest problems in tropical environments so that it is even harder to grow it.

Loaf Protein Extraction From Tropical Plants

by Lebel Telek

The work of screening tropical plant materials for protein content, fractionation properties, and evaluation of the resultant protein fraction is environment-neutral. Telek's paper points out nicely, however, the complexity of production systems required for effective use of protein extraction technology. With production of standard human food or animal feed-grade protein, the integration of several industries is essential. The complexity of interactions between those industries and the environment render a simplistic summary of environmental impact of little use. The following types of analyses of each industry segment maybe required for any particular environmental zone of production:

1. Raw product production impact—energy cost, environmental impact of the crop production (soil loss, ground water use and impact, biocide requirements and impact);
2. Raw product quality—the production-related materials that may be present to contaminate the protein and product;
3. Extraction process impact—energy requirement; cost of holding air- and water-effluent discharges to acceptable volume and quality; cost of solvent recycling or disposal;
4. Impact of related industries that use various plant fractions.

At this early stage in the development of plant protein isolation processes, an analysis of energy efficiencies of alternative protein use pathways would be in order. Comparing whole-plant use by various fish and animals with fungal or bacterial digestion would give rough estimates of threshold energy efficiencies that must be achieved by fractionation systems in order to be competitive. As far as possible in these analyses, it is essential to internalize the costs for avoiding environmental disruption. Conservative estimates by today's standards of permissible environmental loading would be appropriate if the model is to be applicable in the future. Such analyses will be complex and costly and should not be required for each enterprise being considered. Such analyses would be useful at this early developmental stage to provide guidelines and estimates of the practicality of a given pathway. Few data are available, and energy and cost effectiveness of the fractionation methods are difficult to assess.

Third World production of many, if not most, of the species tested—particularly the perennial crops—presents no environmental problems not already well recognized for those species. Given a choice, one would prefer to grow the crop requiring the lowest nonsolar energy input and having the greatest amount of stability with respect to pest and disease incidence.

Insecticides, Insect Repellants, and Attractants From Arid/Semiarid Land Plants

by Martin Jacobson

With increasing emphasis on integrated pest management, there is increasing opportunity to use a wide range of materials affecting insect behavior. Because many of these materials seem to have evolved to a greater extent in arid/semiarid plants, a search for such compounds could be productively targeted at these plants. It is unfortunate in that production in such environments on a commercial scale must be carefully managed with respect to ground water use and soil conservation. As with all other plant-derived products, the recycling or disposal of solvents used in the process is important.

The areas of plant-derived biocides and insect behavior modifying compounds has potential for having a significant impact on the ecological effects of modern agriculture. Many of our present synthetic biocides are extremely persistent in the environment, and their accumulation is the source of considerable concern.

An example is Temick, an insecticide that has been used by many Long Island potato growers against the Colorado potato beetle. Because of its persistence it has leached through the sandy soils of Long Island to reach ground water aquifers in relatively high concentrations. In years past a material comprised of ryania, rotenone, and pyrethrum—all plant-derived insecticides—had been used with equal effectiveness. Its use was discontinued because of the lower cost of Temick and other synthetic materials. An effort is under way to bring back the plant materials to replace Temick.

With the exception of pyrethrum, a commonly used household insecticide, the work on commercial use of plant insecticidal materials has been limited to small companies specializing in "alternative" agricultural products. Little indication exists of industry interest in such products, a situation analagous to that of the pharmaceutical industry.

A wide range of insect-behavior-modifying substances that have little biocidal activity exists in plants. Work at Rodale Research Center shows that camphor, a compound present in many aromatic plants, has strong insect-repellant activity. Camphor wood, in fact, has been used from ancient times because of its durability. Little work has been done to identify such compounds. These compounds, along with plant-derived insecticides, could have a positive and widespread impact on agricultural systems by replacing many of the more environmentally disruptive materials now commonly used in agricultural production.

Environmental impact studies should be conducted for plant-derived pesticides. Most botanical are nonselective but of relatively short persistence.

Molluscicidal and Other Economic Potentials of Endod

by Aklilu Lemma

Ended has broad-spectrum biocidal activity as a molluscicide, spermatocide, insecticide, and bactericide. Here, again, the range of its effects should be studied before it is used widely in the United States. Its effects on humans, wildlife, fish, and a broad spectrum of biological organisms likely to be affected by common application should be determined. The research detail and resultant cost for this work seem to necessitate the creation of patent rights and protection which would make the expenditure attractive to industry. Government support in the form of research funding may also be essential.

Each of these potential crops should be included in a refined USDA data base on minor economic plants species, and their likely growing areas should be determined before a major research commitment is made. If a species has fairly broad production area potential, it would be a more attractive investment.

The Role of the Alkaloids of Catharanthus Roseus . . . .

by Gordon Svoboda

Many of the points raised previously apply to this paper. They are the:

1. need for careful collection of the crop in the wild prior to production;
2. need for caution in moving plant materials;
3. need for analysis of recycling or disposal of production solvents and chemicals; and
4. potential for residues of production chemicals to find their way through the extraction process.

The energy cost of such extraction is less relevant because the product is of low volume and high value.

The production impact should be monitored; however, with extremely small acreage the production is relatively easy to frame within production of rotation crops and other environment-protecting practices. A significant adverse environmental impact from crop production is unlikely.

Chemicals From Arid/Semiarid Land Plants: Whole Plant Use Of Milkweeds

by Robert Adams

Most of the previous comments relevant to dryland agricultural production apply here. The dry areas where milkweeds have been tested commercially are very prone to erosion. In evaluating the production costs, it will be necessary to factor in conservative erosion control practices from the start. Zero till, crop overseeding, sod culture, narrow strip cropping, and a range of other options should be evaluated. In the near future solutions to erosion problems must be found. Those solutions will have associated costs which will have to be included in the crop production cost.

The potential of milkweed or similar crops as weed pests should be evaluated. Nevertheless, milkweed, with its potential as a dryland crop in a low rainfall area, might be able to replace irrigated crops in areas now experiencing ground water depletion.

Marine Plants: A Unique and Unexplored Resource

by William Fenical

This area of study is quite different from those of terrestrial plants. Areas of environmental concern include:

1. The undesirability of studying "fragile" marine organisms for potential use. For instance, species of coral that are limited in extent and slow-growing probably could not be used effectively even if they contained useful compounds. The studies should be limited to those that are either relatively plentiful or not too difficult to culture.
2. The Presence of contaminants in the marine environment can be a limiting factor for some species or products if they are difficult to remove in the fractionation process.

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