Chapter IV

Native Plants: An Innovative Biological Technology

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ABSTRACT

The concept of native plants reflects a new direction in botanical development. The term implies the idea that rather than adapting the environment to the plant, an indigenous plant expresses the best adaptation to an environment and improving on this expression will yield various benefits. Bringing marginal lands into widespread agricultural use often employs technologies and plant species inappropriate to these situations. This occurs with a total disregard for the climatic limitations of the environments. A new approach is required.

Development of native or indigenous plants, particularly those adapted to tropical and subtropical soils, could be beneficial at different economies of scale, In some instances, their development will be small and amenable to use by individual farmers or farming groups, On the other hand, there will be instances where development will be large scale and have international implications.

Native plants can be particularly useful in sustaining fertility on depleted or marginal soils and improving general productivity. They use an "agroecosystem approach" to obtain necessary production. Polycultural (mixed) cropping systems are especially applicable in tropical locations; they rely heavily on the potential of adapted or indigenous plants. Native plants represent an underused resource and constitute an opportunity for positive botanical developments,

The coordinated, integrated development of indigenous plants could allow for multiple and additional benefits greater than the initial goals of soil fertility, food production, or raw materials, There is an immediate need for inventories of existing native crops for their development potential. The world's tropical and subtropical germplasm is poorly known, Throughout the world, knowledge of plants and their uses by indigenous peoples is disappearing because farming systems are being converted to monocultural uses. Germplasm storage of potentially valuable varieties and strains requires immediate attention. Demonstration of practical working models with specific native plants must be performed.

One factor limiting the development of native or other unconventional plants is an institutional bias against them. The major emphasis of plant research during the last 100 years has been directed at the dozen or so primary food crops—to the exclusion of almost everything else.

To overcome this institutional bias will require innovation in policy, research and development, and program implementation. Development of native or adapted plants should allow for an integration of these concerns. The capabilities of various governmental and nongovernmental institutions should be directed toward the goal of sustaining soil productivity in both the short- and long-term context,

INTRODUCTION

The purpose of this paper is to present a nontechnical description and evaluation on the utility of "native" plants as an innovative technology to improve productivity on soils in tropical/subtropical areas. The paper addresses several major questions that appear as subsections, The term *native plant* needs clarification. All plants may be considered native or indigenous to some location on the earth, but when a plant is taken to an area where it is not naturally found, it becomes an introduced species. This distinction is too constraining and can overlook the importance of adaptation—judged either from actual observation or from scientific evidence of ecological similarity. In this report, native species are those plant species growing in an area that have not been exploited for commercial development and export. Some native species may have desirable attributes and a potential for intensive use while others may merely serve to "fill in the spaces" of the plant community and have only minor development potential. This paper is limited to indigenous species that have not been extensively developed.

Native plants hold great promise for meeting the expanding needs of society for food, fiber, fuel, and enhanced land productivity. In the search for a plant or plant product to serve a market or domestic need, plants native to a given region may already express the range of adaptation necessary for sustained use. But they are often overlooked in favor of an imported species. A good example of indigenous plants being overlooked is in rangeland improvement programs in the Western United States where native shrubs were removed in order to plant introduced grasses (11). Although plant exploration and introduction has been emphasized by the economically developed nations, the search for new plant materials has been directed along conventional lines and the potential of native species has been overlooked.

In the past, the common procedure has been to examine existing files or materials found in plant introduction stations to find new plants and plant products rather than to explore locally for possible new products. Because of the increase in energy costs and the energy component in existing production activities, a new look for alternatives is justified. A particularly attractive opportunity to develop native plants exist in tropical and subtropical areas. These areas generally have not been of interest as a source of plant materials because the developed nations are, to a large extent, located in temperate climates. This has limited germplasm collection, research testing, and introduction of new crop species. Additionally, most American primary crop species are introductions from the Old World, and these have been genetically developed over long periods of time for intensive agricultural use.

THE ROLE Of NATIVE PLANTS ON SUSTAININ0 FOOD AND FORAGE PRODUCTION

Native plants serve a traditional role in many tropical and subtropical countries. Various indigenous species have been used for food, fuel, livestock feed, construction, fiber, medicines, and other purposes on a sustained yield basis. The species are either gathered from natural plant communities (forests, rangelands, marshes, etc.) or harvested from small farmed plots under various degrees of cultivation. Cultures as diverse as Mexico, Sri Lanka, and Indonesia have well-documented histories of wide use of indigenous plants for medicines, foods, and other uses. Most of these native plants have not reached a level of development sufficient to make them commercially useful. Notable exceptions include rubber, corn, pineapple, and potatoes. Most species, however, are unspectacular in their attributes and find beneficial use only in the day-to-day existence of the local people.

Overuse of native species brought about by population increases and energy shortages is creating adverse impacts on many species and their systems of production. Where previously a conservative level of plant use generally assured their natural replacement and did not reduce their genetic diversity, exploitation of land resources by overgrazing, intensive agricultural development, forest clearing, industrial development, and widespread soil degradation threatens to eliminate many useful species.

For example, a recent National Academy of Science assessment of environmental degradation of the groundnut basin of Senegal (12) indicates that overuse due to population increase and cyclic drought has resulted in the disappearance of many native species used for fruit and livestock fodder. Theoretically, some of these species are still present in the noncultivated bush areas. An example is Ziziphus *maritiana,* a desirable fodder shrub, that had essentially been eliminated from areas adjacent to intensively cultivated farmlands by overuse. At a conference in Australia on Genetic Resources of the World, concern was expressed that valuable genotypes and gene combinations were being lost due to the impacts of human population expansion. Associated with the direct loss of genetic resources is a substantial reduction in soil fertility and an increase in less desirable plants.

Native plants also play an especially important role in improving crop performance and diversity. Indigenous or locally cultivated relatives of many common crop plants offer significant potentials for crop improvement programs within the temperate and tropical latitudes. Recent discoveries of wild perennial relatives of corn (Zia *mays)* could prove extremely important to the future development of this crop. Similarly, the expression of expanded environmental adaption often inherent in many native plants could allow for much wider cultivation of the species while reducing artificial inputs. Recent work with salt tolerance in major grain crops and tomatoes relies heavily on the adaptive qualities of various native and overlooked indigenous relatives of these important crops (13).

WHERE NATIVE PLANTS ARE BEING USED TODAY

Native plants are being used all over the world, Many species find extensive use in developed agriculture and some native species already enjoy limited commercial use in areas of optimum adaptation (table 1). *Opuntia* cactus fruits in central Mexico are collected and sold locally. Fibers are removed from the *Leghugea* cactus for use in making Mexican mats, shoes, and baskets. Numerous species of native trees such as Mangosteen *(Garcinia mangostana)* in southeast Asia, Naranjilla *(Solarium quitoense)* in Colombia and Ecuador, pejibaye peach palm *(Gudiema gasipaes)* in Central America, and soursop *(Annona muricata)* of the West Indies produce exotic fruits for local markets.

The important point is that the usefulness of some species is known only to local people or is generally not appreciated by a wide audience. A number of examples of fruit, vegetable, fiber, oil, and forage species are described by the National Academy of Sciences in their studies on underexploited plants (18). Such underdeveloped species may possess unique features that could be useful in new applications or supplement existing crop plants if they were screened for optimum size, shape, product quality, and adaptability to various management practices.

The genus *A triplex* is an example of a group of semiarid, subtropical plants currently used but possessing significant potential for increasing rangeland productivity. Various shrubby *A triplex* species are valuable as livestock forage during seasonal dry periods when most grasses are below required levels of crude protein for animal nutrition. The protein content in *A triplex* is high and balanced. The exploitive subsistence level grazing practices and extensive gathering of *A triplex* on the rangelands of Syria, Iraq, and other Middle Eastern nations has nearly caused the disappearance of these palatable shrubs (23). An integrated development program of collection and revegetation with this native species and other adapted

Table 1.—Little Used But Potentially Useful Plants

Common Name	Scientific Name	Useful Portion	Potential Use	Present Growing Areas	State of Cultivation	Present Yield Per Hectare Per Year	Time to First Harvest
A. Humid Tropics							
Cocoyam	*Xanthosoma sagittifolium*	tuber	carbohydrate, protein	Tropical Americas, West Africa	domesticated	30-60 tons wet weight	3-10 months
Peach palm or pejibaye	*Guilielma gasipaes*	fruit and stem	carbohydrate, oil, protein. "heart of palm"	Central and Northern South America	domesticated	3 tons	6-8 years
Taro and dasheen	*Colocasia esculenta*	tuber	carbohydrate	Egypt, Philippines, Hawaii,Caribbean	domesticated	22-30 tons wet weight	6-18 months
Buriti palm	*Mauritia flexuosa*	fruit kernel. Shoots trunk and leaves	oil, starch, vitamins A and C, timber, cork. fiber, heart of palm"	Amazon Basin. Veneuela, Guianas	mostly wild	?	9
Babassu palm	*Orbignya martinia*	fruit and kernel	oil* protein, fuel	Amazon Basin	mostly wild	1.5 tons	10-15 years
Pequi tree	Caryocar *bresilienss*	fruit and kernel	oil. fuel	Amazon Basin, Central Brazil, Guianas	mostly wild	?	9 years
Seje palm	*Jczzenie polycarpa*	fruit	oil resembling olive oil	Amazon Basin	wild	22 kg/ tree per year	?
winged bean	*Psophocarpus tetragonolobus*	pods, beans, tubers, foliage	protein, oil. carbohydrate. livestock feed	Papua New Guinea. southeast Asia. Sri Lanka	domesticated	2.5 tons of dry beans	10 weeks
Durian tree	*Durio zibethinus*	fruit	carbohydrate, fat; vitamins, flavor	Southeast Asia	haphazardly cultivated	?	7 years
Mangosteen tree	*Garcinia mangostana*	fruit	highly prized flavor	Southeast Asia	domesticated	50 kg/tree per year	15 years
Pummelo tree	*Citrus grandis*	fruit	large citrus fruit	Southeast Asia	domesticated	?	several years
Soursop tree	*Annona muricata*	fruit	fruit and juice	Southern China, Australia, Africa. tropical Africa. West Indies	domesticated	6-10 tons	?
Uvilla tree	*Pourouma cecropiaefolia*	fruit	grapelike fruit	Western Amazon	wild	?	3 years
Chaya bush	*Cnidoscolus chayamansa*	leaves	vitamin-rich leafy vegetable	Mexico and Central America	domesticated	?	2-3 months
Ramie herb	*Boehmeria nivea*	stems and foliage	fiber and livestock feed	East and Southeast Asia. Brazil	domesticated	1.4 tons fiber, 20 tons feed	2 months
Cauassu herb	*Calathea lutea*	leaves	commercial wax	Amazon Basin. Central America	wild	0.8 tons of wax	9 months
Leucaena	*leucaena leucocephala*	leaves, wood, pods, seeds. bark	livestock feed, timber. fuel. paper, soil fertilizer, dye stuffs, human food. erosion and watershed control, nurse tree, fire and wind breaks	Central America. Mexico. Southeast Asia. Northern South America. Australia. Hawaii. East and West Africa, Papua New Guinea, Caribbean. India	domesticated and wild	12-20 tons of forage, 20-50 tons of wood	less than 1 year to more than 3 years, depends on variety planted
B. Semiarid and Arid Tropics and Subtropics							
Channel millet	*Echinochloa turnerana*	seed. leaves. and stems	carbohydrate. protein. livestock feed	Central Australia	wild	?	several months after heavy rain
Buffalo gourd	*Cucurbita foetidissima*	seed. root	oil. protein. starch	Mexico. Southwestern United States	mostly wild	2.5 tons of seed, 22 tons starch	2 years
Guar (cluster bean)	*Cyamopsis tetragonoloba*	seed. leaves. and stem	gum, protein, oil. livestock feed	United States. Pakistan, India. Australia. Brazil. , South Africa	domesticated	18-24 tons green fodder. 0.9-2 tons seed	3-5 months

Table 1.—Little Used But Potentially Useful Plants—Continued

Common Name	Scientific Name	Useful Portion	Potential Use	Present Growing Areas	State of Cultivation	Present Yield Per Hectare Per Year	Time to First Harvest
Apple-ring acacia tree	*Acacia albida*	leaves, shoots, pods, seeds	livestock feed, human protein	Tropical and Southern Africa	wild	200 kg protein	several years
Ramon tree	*Brosimum alicastrum*	leaves, twigs, nuts	livestock feed, carbohydrate, protein	Central America, Southern Mexico, Caribbean islands	mostly wild	?	several years
Cassia shrub	*Cassia sturtii*	leaves	livestock feed	Australia, Israel	wild and cultivated	1/2 ton dry weight	1-1.5 years
Saltbush	*Atriplex* spp.	leaves and shoots	livestock feed	worldwide in warm arid zones	wild and cultivated	1-1.5 tons	2 or 3 years
Candelilla shrub	*Euphorbia antisyphilitica*	stems and leaves	hard wax	United States and Mexican deserts	wild	?	2-5 years
Tamarugo tree	*Prosopis tamarugo*	pods and leaves	high protein, livestock feed	Atacama desert of Chile, Canary Islands	cultivated	10-20 sheep	5 years
Jojoba shrub	*Simmondsia chinensis*	seeds	liquid wax identical to Sperm oil	United States and Mexican deserts, Israel	mostly wild	2 tons	3-5 years
Guayule shrub	*Parthenium argentatum*	whole plant	natural rubber	United States, Mexican deserts, Spain, Turkey	mostly wild	1/2 ton	1 year
C. Mountain Environments of Low Latitudes							
Grain amaranth	*Amaranthus caudatus*, etc	seed, leaves	high lysine, high protein, starch, vitamins	Andean region of South America	domesticated	higher than maize	several months
Quinua (grain)	*Chenopodium quinoa*	seed	protein, carbohydrate	Andean region of South America	domesticated	?	5-6 months
Peruvian parsnip	*Arracacia xanthorrhiza*	tubers, stems, leaves	carbohydrate, livestock feed	Andean region of South America	domesticated	?	10-14 months
Naranjilla shrub	*Solanum quitoense*	fruit	fruit and juice	Central and Northern South America	domesticated	1-2 tons of fruit	6-12 months
Winged bean	*Psophocarpus tetragonolobus*	pods, beans, tubers, foliage	protein, oil, carbohydrate, livestock feed	Papua New Guinea, Southeast Asia, Sri Lanka	domesticated	2.5 tons of dry beans	10 weeks
D. Saline Environments							
Eel grass	*Zostera marina*	seed	carbohydrates, protein	tidal flats and estuaries in all latitudes.	wild	?	?
Pummelo tree	*Citrus grandis*	fruit	citrus fruit	brackish marshy areas in Thailand	domesticated	?	several years
Saltbush	*Atriplex* spp.	leaves and shoots	high protein, livestock feed	world wide, including salty soils and saline irrigation waters	mostly wild	1-1.5 tons	2 or 3 years
Tamarugo tree	*Prosopis tamarugo*	pods and leaves	high protein, livestock feed	Atacama desert of Chile, Canary Islands	cultivated	10-20 sheep	5 years
Salt grass	*Paspalum vaginata*	leaves and stems	livestock feed, sand stabilization	seacoasts from Australia to Spain, Argentina to Baja California	mostly wild	?	1 or 2 years
Spirulina, blue-green algae	*Spirulina platensis*, *Spirulina maxima*	entire alga	poultry feed, very high protein human food	Lake Chad, Valley of Mexico	cultivated	3 tons protein	several days

Atriplex species from similar climates could substantially restore rangeland productivity to this region.

Another example of a native plant that is receiving considerable attention on a pilot-scale level is jojoba (Simmondsia *chinensis)*, an evergreen shrub indigenous to the Sonoran deserts of the United States and Mexico. The plant is valued for the liquid wax contained in its seeds. The wax is similar to sperm whale oil and has a potential for use in many industrial processes. Field test plantings have been made in Arizona, California, Israel, Mexico, and Australia. Because the plant is adapted to areas of extremely low rainfall (less than 10 inches), it could become an important cash crop for the appropriate arid areas (10).

RESEARCH EFFORTS ON NATIVE PLANTS

Research on native plants is being conducted by many different groups ranging from private individuals and companies to State, national, and international agencies. However, no coordinated research effort can be expected because of the diversity of potentially useful native species, the various countries where they are growing and could be grown, and the risks involved in developing new crops for ill-defined markets.

As has probably been the case throughout history, plant resources have been developed to meet existing and short-term needs. The difference today is the high cost of bringing new products into a highly competitive market. Opportunities for new products or uses from native plants can occur as a result of changes (or potential for changes) in consumer preferences or as existing products come into short supply and can be replaced by a native plant product.

It is difficult to identify organizations performing research on native plants, but they fall into the following categories:

1 Broad spectrum agencies sponsoring exploration collection and evaluation. Examples:
   - USDA: plant introduction, plant materials centers (nationwide).
   - FAO (Food and Agriculture Organization of the United States) seed exchange, international development.
   - SIDA (Swedish International Development Agency): sponsoring projects to preserve genetic resources.
2. Agricultural experiment stations doing work on individual plant species with local concern. Examples:
   - University of California Agricultural Experiment station, Riverside: jojoba wax.
   - University of Hawaii Agricultural Experiment Station: Leucaena trees.
3. Private organizations, agricultural enterprises working to develop products from various species. Examples:
   - Firestone Rubber Company: guayule for rubber development.
   - Native Plants, Inc.: developing new technology for tissue culture propagation of various plants.
   - Jojoba International, Inc.: encouraging commercial plantings of jojoba.

Funding of native plant research is very dependent on the species in question. Obviously the potential for some species is greater than others depending on the scarcity and quality of the expected product, the abundance of the plants, and the needs of society. Currently, there is a high interest in native plants with potential as sources for biomass energy. Unfortunately, there is little, if any, coordination in research funding for native plant development or in the establishment of priorities. As of 1979, the total U.S. funding for research and development of underexploited plants was limited to less than $10 million, half devoted to jojoba.

The uncertain path of development for a natural rubber product from the native shrub guayule *(Parthenium argentatum)* illustrates the problems of developing a native plant. The National Academy of Sciences (13) pointed out that in 1904 a company was formed to extract rubber from the guayule bush, By 1910 this company was the sixth largest in Mexico but the wild stands of plants quickly became depleted. Expelled from Mexico by Pancho Villa, the company continued limited operations in Salinas, California. Cut off from natural rubber supplies from Southwest Asia in 1942, the United States took over the company and planted over 12,000 hectares of production and experimental plots of guayule. These fields were just coming into production after the war in 1945, but because natural rubber was again plentiful and a fledgling synthetic rubber industry gained the Federal price supports, the guayule fields were destroyed. Recognizing the need for dependable supply of natural rubber, Congress passed the Native Latex Commercialization Act of 1978 which makes $30 million in Federal funds available for research. Subsequently, Firestone Tire and Rubber Company and Goodyear Tire and Rubber Company have initiated field trials of guayule in the Southwest. In Mexico, plans are underway for a natural rubber industry using guayule from native stands and later from established plantations,

Obviously, a more integrated and organized effort will be needed to bring the benefits of other native plants into reality. The research community and society simply cannot be subjected to the vagaries of 70 years when a plant of national value takes so long to be developed. Coordination is needed to stimulate innovation in policy planning, research and development funding, and commercial implementation.

Substantial, integrated programs are necessary to bring native plants into commercial production. We know that genetic quality of conventional crops and appropriate cultural practices have been improved over a long period of time. With this history of development, we can expect that new crops/products from native plants can be developed with even greater efficiency. Significant breakthroughs may take place (such as the application of various biotechnologies) but for the most part, research funds, time, and vision will be needed to unlock these new resources.

One of the first research steps must be to identify promising native plants and describe some of their characteristics. A survey sponsored by the National Science Foundation (22) described six new crops with a potential for development in the United States. A thorough coverage was given to ten new agricultural crops (20) that already have received some attention. Goodin and Worthington (8) helped stimulate interest in native plants with their conference on Arid Land Plant Resources.

Probably the greatest stimulus to the development and use of native plants in recent years has been the series of bulletins published by the National Academy of Sciences. *Underex*ploited Tropical Plants With Promising Economic Value. NAS (18) describes 36 tropical and subtropical plants that have a high potential for use as cereal, root, vegetable, fruit, oilweed, forage, and fuel. The Winged *Bean—A High Protein Crop for the Tropics (17)* provides information on a tropical legume native to Southeast Asia and New Guinea with a potential for improving human nutrition. Guayule: *An Alternate Source of Natural Rubber (14)* is a report on the development potential of a subtropical desert shrub of Mexico and Southwestern United States that produces a latex product similar to natural rubber from Southeast Asia. *Leucaena: Promising Forage and Tree Crop for the Tropics (15)* provides information on a vigorously growing tree and bushy plant that produces nutritious forage as well as restoring soil fertility. Other benefits include timber, fuel, and pulpwood as well as soil conservation and stabilization. *Tropical Legumes, Resources for the Future (13)* reports the findings of a group of legume specialists on 200 species that warrant research and development to achieve their optimum potential. *Products From Jojoba (16)* gives a review of the chemistry of the liquid wax obtained from this shrub native to Southwestern U.S. deserts.

These publications all highlight the immense potential existing within the botanical world to benefit agriculture, forestry, and horticulture, particularly in the developing countries. These and other surveys consistently document the immediate need to inventory indigenous knowledge concerning native plants and their uses, germplasm collection and storage, and conservation of existing habitats. The rapid disappearance of extensive semiarid, subtropical, or tropical plant community compounds the problem of collecting, researching, and developing these under-exploited plant resources.

How DO/COULD NATIVE PLANTS INCREASE OR DECREASE THE NEED FOR FERTILIZER, PESTICIDES, IRRIGATION, AND Machinery?

Any change in the present use pattern of fertilizer, pesticides, irrigation, and machinery would depend completely on the nature of the native plant being developed—whether the particular plant could be developed on an intensive or extensive basis, or the degree to which the plant is susceptible to insects and diseases. However, any move to increase productivity would generally require an increase in the level of inputs. The adaptation of some indigenous plants to multicropping systems or polycultures could significantly reduce the need for artificial inputs. The development of such production systems is just in its infancy, however, and models appropriate to widespread application are virtually nonexistent.

Some specific examples of inputs required by various native plants will illustrate their variable nature.

Fertilizer

Three possibilities for fertilizer use may be seen:

1. Legume species may have minimal fertilizer requirements, needing mainly phosphorus, sulfur, and micronutrients.
2. Some native species may not require high levels of fertilizer because of their adaptation to low nutrient environments.
3. Non-1egume species may require substantial amounts of fertilizer to achieve optimal production levels.

Leguminous native plants are particularly attractive because they can serve to increase soil nitrogen as well as provide useful products such as fuel, forage, and wood biomass. Fast growing Leucaena trees have been shown to provide foliage containing 1,000 to 1,300 lbs. of nitrogen a year and can restore the fertility of tropical soils depleted of nitrogen and organic matter (15). Felker (15) suggested that mature tree legume orchards receiving no irrigation or nitrogen after establishment may increase soil fertility up to four times greater than non-leguminous tree species. Numerous legume shrubs and trees such as *Acacia, Prosopsis, Desmodium, Cassia,* and *Stylosanthes* enhance soil fertility while at the same time serving as live fences, crop interplantings, or range and pasture fodder. Many examples of soil fertility increase are presented in *Tropical Legumes: Resources for the Future (13), Tropical Pastures (21),* and in papers presented at the International Symposium on Browse in Africa.

Some native species may not require large amounts of fertilizer because they are adapted to soils of medium to low fertility. Under such conditions, plant growth and production could be expected to be correspondingly low. If high yields for commercial production are desired, the level of fertility must be increased accordingly. Intensive cropping has been shown to deplete soil fertility and any continuous production in a new agricultural location would eventually require regular soil fertilization.

Non-legume native plants may require large increments of fertilizer to produce at levels sufficient to be commercially attractive and to cover costs of production and development. These species are those requiring optimal soil and water conditions. Possible requirements for fertilizer and other inputs for such crops are summarized in a report prepared for the National Science Foundation (22).

Another potential strategy is represented by the selection and development of native plants adapted to saline environments. The ability to tolerate environmental constraints and still produce utilitarian byproducts is one potential avenue for overcoming high fertilization inputs. This is an approach to native plant development that has been virtually ignored in plant research. The existence of salt tolerant wild selections of existing crops could improve the infertility tolerance of these species and therefore reduce their needs for fertilization. Such possibilities will require concerted efforts to enhance the range of adaptability for most crop species.

Pesticides

Very few, if any, of the native plants having a high potential for development have been studied from the aspect of insect, disease, or weed problems normally associated with intensive cultivation, Whereas many insect or disease organisms may be held in check in a diverse plant community, they may increase to epidemic proportions when their host plant is grown in a pure stand. An example of such an epidemic occurred when black grass bug populations nearly devastated pure stands of introduced wheatgrasses that had been seeded to replace sagebrush and other plants in western rangelands (9). Plantings of native species will require research and plant protection measures similar to those already necessary for the production of conventional crops.

In tropical countries where multicropping systems represent the most sustainable method of farming systems, the pesticide requirements could be minimized by host/predator interaction within the farm plots (7), Testing and development of such models needs to be greatly expanded, however.

Irrigation

Requirements for irrigation will depend on the kind of native plant selected. As a concept, the use of native plants indicates an adaptability to the specific environment and its constraints. Species adapted to tropical soils may not require irrigation if the pattern of rainfall is adequate and meets the critical stages of plant development. Areas of subtropical soils typically have periods of rainfall deficiency and various strategies must be employed to obtain production under such conditions, These strategies include:

1. Choose native plants with low water requirements that can be grown in desert or semi-desert conditions. Some examples are: jojoba, atriplex, guayule, buffalo gourd, guar, cassia, acadia species (19).
2. Develop technologies to increase the effectiveness of natural precipitation or irrigation. Alternate fallow, spaced plantings, water harvesting, or drip irrigation can be effective. Where land is not a limiting factor, these extensive practices can be economically effective. Evanari, et al. (4), demonstrated how an ancient civilization survived in the Negev desert by using precipitation optimizing practices such as water harvesting and spaced plantings. Recent work at the University of Arizona (6) indicates high potential for using water harvesting to foster plant production under desert conditions. Biomass plantings, deep rooted tree crops, and drought adapted species would be most suitable for these technologies.
3. Use available irrigation water to support maximum production of new crops from high yielding native plants. Where soils with a high productive potential may be available for intensive use, possibly by replacing a lower value traditional crop with a high value new crop, irrigation may

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be justified. Close plantings, tillage, pest control, and fertilization may also be needed to optimize production. Grain amaranth, winged bean, and guar are possible species for intensive development, but many other may be considered.

Machinery

Because of the varied nature of native species available for development, no definite statement can be made regarding machinery requirements. Equipment for land preparation, tillage, and transportation of crops to storage and market would be needed. Harvesting may be done by machinery in the case of a uniform plant such as guar or guayule where leaves and seeds are easily available. Where fruits, stems, or roots are not uniformly exposed and are retained on the plant, either hand labor or a specialized piece of machinery may be needed.

In regions of the world where hand labor is abundant for planting, cultivating, and harvesting, the development of new native crops that require hand labor rather than machinery is most appropriate. In other nations, labor intensifying machinery can be developed, This has been the pattern followed in the development of conventional crops.

It is important to recognize that the development of native plants for their various uses can be aimed at local needs as well as at wider industrial and international markets. Machinery and labor requirements will depend on what level of development is pursued.

WHAT IS THE POTENTIAL ROLE Of NATIVE PLANTS TO RESTORE, IMPROVE, OR SUSTAIN FOOD PRODUCTION ON TROPICAL AND SUBTROPICAL SOILS?

There is a high potential for some native plants to positively affect food production on tropical and subtropical soils. One of the most promising strategies is the increased use of leguminous plants as food, livestock fodder, and wood to concurrently improve soil fertility (21). As fertilizer costs continue to escalate in response to energy expenses, fertilizers will become economically prohibitive in many developing countries. Incorporation in the cropping system of a legume rotation, green manure, or animal manures derived from legume feeds may be the best remaining option to replace fertilizers (12) and maintain agricultural productivity.

Non-legume native species have various potentials for positive benefits to food production. Many species are already known locally but have not received sufficient notice to be introduced or developed for use in other (similar) regions. To achieve such recognition will require:

1. A shortage in food from existing crop plants.
2. Development of new lands that are better suited for new crops.
3. Adaptation of new crops to compete economically with conventional crops,

Some form of research and development intervention will be needed to raise the perspective and incentives of local peoples. The likelihood of general use depends on the individual species. For example, the general qualities of seeds from the jojoba plant have been known for many years (10) but only recently has any development effort appeared substantial enough to bring the plant into widespread use,

The shortage and cost of sperm whale oil is a big factor motivating jojoba development in more than five countries. Some applications will be less spectacular, but no less needed. P1antings of the legume tree *Acacia albida* in Mali (24) hold considerable promise for improving subsistence agricultural production there, but the effort is but a "drop in the bucket" compared with the needs in that area of West Africa.

In view of the diversity of native plants available for development and the number of countries with suitable environments, judicious support of native plant development programs seem justified. The likelihood of spontaneous development or widespread use of native plant resources seems unlikely without external encouragement. Otherwise, many useful native plant species and ecotypes stand in jeopardy of being lost as deforestation, land depletion, industrial development, or other activities eliminates the natural plant communities.

WHAT RESEARCH, DEVELOPMENT, AND IMPLEMENTATION SCENARIOS COULD HELP NATIVE PLANTS REALIZE THEIR POTENTIAL OF ENHANCING TROPICAL SOIL PRODUCTIVITY?

Scenario A

The program of planting seedlings of *Acacia albida* legume trees in Mali (24) serves as a model for the development of the potential of a native plant. In this program, CARE set up production nurseries to produce tree seedlings in soil-filled plastic tubes. *Acacia albida* is an indigenous legume tree native to sub-Saharan Africa. The tree has the unique feature of being leafless during the rainy season. This allows for cultivation of other crops directly under the tree. The leaves and pods provide fodder and green manure and the roots fix nitrogen. It is an ideal candidate for selection, improvement, and application to various semiarid agroforestry systems.

Teams of local farmers were employed to plant the seedlings in preselected agricultural/ pasture areas of good soils. Planters were paid on a per tree basis for planting and protection. Subsequently, these local people were encouraged (in their work training orientation) to take a special interest in the seedlings to see that they received appropriate management and protection to ensure their survival from grazing animals. Benefits expected are increases in soil productivity and livestock feed.

Scenario B

A scenario for planting a living fence of a legume shrub to enhance soil fertility by N-fixation and livestock manure might be as follows. Seedlings could be propagated at a government research station after selection from depleted stands of palatable shrubs. These plants would then be distributed to village elders for allocation to heads of families for planting around the fields and houses in the immediate vicinity of the village. This would enhance kitchen garden production and feed small livestock through the dry season, Excess fodder could be used on the farm plots as green manure.

Scenario C

A scenario to develop a high value, native tree, fruit crop would logically start with a program of selecting the most desirable biotypes for their fruit quality, tree size and form, and maturity pattern. Because of the long-term requirements for genetic improvements that would combine the best qualities in various selections, a dual development program would be undertaken. The first would be to vegetatively propagate (by rooted cuttings of a few plants or by tissue culture for thousands) the best selection(s). Propagules would normally be grown in containers until ready for field transplanting. Sufficient acreage would be planted to provide experience in intensive management and production for a local, regional (city), or international cash market. As experience is gained with product acceptance, the criteria for the genetic breeding program would be modified, By the time suitable genetic materials would be available, the market requirements would be sufficiently known to guide large-scale development plantings and improved cultural practices, possibly involving machinery.

Levels of capital and manpower needed could be determined or extrapolated on the " basis of experience with a pilot program. Pilot demonstration programs are a plausible way to approach development of the most promising native plants,

WHAT CHANGES IN ATTITUDE ARE NEEDED?

One of the most critical attitudinal problems in developing new crops from native plants is one of institutional interest in sustainable and diversified plant development. Traditional crops, mostly of temperate origin, have received the majority of institutional attention from government, research, and commercial organizations. A new and more innovative approach to plant development is required when referring to native or adapted plant development. The various groups that directly affect these development efforts include the following:

Cultivators

All efforts should include the local farmers. The objective would be to seek sufficient involvement on planning, planting, and management to bring local people to thinking that the project is theirs—not something imposed from outside by government. The active efforts of an individual farmer in the Dakotas to bring sunflower into widespread cultivation is an example of the importance of this element in the introduction of "new" crops.

Legislators

Politicians should be encouraged to provide a favorable and stable policy for product development, to be optimistic but not raise unrealistic expectations, and finally to be willing to support financial needs of the pilot project. The efforts of the Guayule Commission is an example of this coordinated effort at policy and implementation.

Financiers

Banks and bankers need to be educated about the realities and potentials for development of a new crop. Available capital for second phase development would be needed if the private sector is to follow the pilot development. Orientation and involvement would be needed to assure support when it is needed. Tax incentives and loan guarantees may be useful ways for financial institutions to foster more rapid development and diversification of new crops.

International

Policymakers within the international donor community need to understand the risks as well as the opportunities for a successful program. Stepwise project implementation is a desirable approach where needed research and development experience is gained as the program develops. This approach could be implemented directly by requiring agricultural, forestry, and horticultural development projects to direct a certain percentage of the program to native species or varieties. Means for involving host country politicians, research people, and local farmers are crucial.

WHAT BIOPHYSICAL, CULTURAL, AND SOCIOECONOMIC CONDITIONS WOULD BE CONDUCIVE TO PROJECT IMPLEMENTATION?

Obviously, the best place for a native plant development project would be where it is needed most. However, there are qualifications to this simplistic statement.

Blophysical Conditions

To be successful, a native species needs a high degree of adaptation to the climate, soils, topography, and animal uses, including resistance to parasites. From an ecological standpoint, the approach should be to seek areas that are ecologically equivalent to the original habitat of the native plant species. This is usually done by testing plantings in various locations of similar climate. However, the time period during which the plantings are under observation may not be sufficient to experience the range of environmental extremes that is common to the area. Detailed experiments under greenhouse and controlled environment chambers may help to document the full range of adaptation possessed by the species.

Cultural Conditions

For a new crop or agricultural product to be successfully produced, it must not be contrary to the cultural traditions of the people to grow, consume, or use. For example, an improved high protein maize (corn) variety was considered in India, where there were food shortages. However, the yellow color of the seed coat was objectional because it resembled a grain product fed to animals (l). A social custom study would be advisable to determine if any taboos, customs, or adverse values exist regarding the potential crop and its required production practices,

Socioeconomic Conditions

Critical to the development of any new crop from a native plant is whether the product is socially acceptable and whether local people can handle the costs of development. There is less chance of gaining social acceptance of a project if the payoff period is far into the future. An early return on the investment may be needed to maintain interest and commitment to a project. Further, the amount of capital required may exceed the capacity of individuals or banks to handle. Thus, smaller increments of development and interim returns to investment may be necessary. An example with animals should illustrate this point. A farmer could finance the purchase of several animals of an improved breed of goat or a pen of rabbits, but he may not be able to finance a cow or bull. There is also greater risk in having a high amount of capital tied up in one individual.

The above conditions are most likely to exist in the less developed tropical countries, in the more rural and remote regions of such a country, and with people of tribal or nomadic social organization. The less educated people would likely be more difficult to reach and less willing to accept a development program,

Communication tools such as radio, newspapers, and films could be used to help both in the search for useful plants as well as disseminate information on new uses and opportunities for economic diversification.

WHAT ARE THE MAJOR CONSTRAINTS ON DEVELOPMENT AND IMPLEMENTATION OF NATIVE PLANT USE?

Development of a native plant species to commercial or economically significant levels would not be easily accomplished based on current observations of jojoba and guayule. Many constraints must be overcome to satisfactorily develop the potential of a native plant.

Scientific Constraints

A major scientific problem in plant development is lack of technical information. A sufficient amount of general information is needed to identify plants of high potential. Additional species information can help determine feasibility for development and the suitability of products or uses to meet identified needs. Progress toward development may well depend on technical data regarding planting, management, harvest, processing, and conservation. Pilot demonstration programs designed to answer technical problems are essential.

Particularly needed are scientific studies on ways to establish plants and obtain optimum productivity under arid, semiarid, and tropical conditions. Problems dealing with microorganisms and plant growth, drought resistance, physiology of stress, and application of engineering to improve adaptation present challenges for scientific research on indigenous plants.

Environmental Constraints

Existing land uses may pose one of the largest constraints to native plant development. But such commitments of land must be seen in relation to the long-term values. Where decreasing soil fertility and vegetation degradation are occurring, a shift to a leguminous native plant could bring multiple benefits. For native plants with industrial potential (i.e., guayule), processing may influence air and water quality. Whether costs can be internalized in the value of the product of plant use must be determined. In most instances, the environmental benefits of developing native or adapted plants will most likely outweigh the negative impacts. The potential to reduce existing environmental degradation and more sustained land use must be considered positive consequences.

Culture Constraints

Native plant development may cause social change, community growth, and increased need for services. Such changes need to be addressed, but at this time little information is available. In general, the cultural impacts from developing new crops or practices from native plants should be positive or neutral. In the context of tropical countries, the perceptions of regional, community, tribal, or family groups must be considered. Resistance to change may be manifested by refusal to cooperate or allow project development. Involvement of local leaders and decisionmakers is a necessity.

Economic Constraints

The major economic constraint to development is probably the lack of seed money, venture capital, or government support to conduct pilot-scale programs. From the pilot program, cost data can be extrapolated for planting, production, transportation, and marketing. From these preliminary data, decisions can be made toward major financing and long- or short-term commitment of funds, either by the private sector or through government grants and loans. Because of the generally speculative nature of developing high potential native plants to meet needs that are not clear, private sector funding may have to be government subsidized.

Political Constraints

A major political constraint is the instability and short longevity of many political leaders in less developed countries. Although a new crop development program may be highly favored by one political leadership, the prospect of change must be considered. Because agricultural development is highly important and not as politically sensitive as other sectors of a country, it should be possible to work within political constraints as long as the project does not appear to run counter to current political and social philosophy.

For example, pilot plantings of palatable fodder shrubs in Syrian rangelands by FAO and the Syrian Ministry of Agriculture were described as an extension of cooperative marketing and fattening units to increase meat production and increase the stability of the livestock industry (2). In reality, the system had many free enterprise profitmaking opportunities to increase the incentive of individuals to participate in the scheme. Yet political leaders touted the success of this cooperative project and declared it to be in harmony with the socialistic philosophy mandated by the government. New crops must not appear to compete with existing production systems, but should complement them. Constituents must be convinced that the proposed developments will provide benefits equitably. Additionally, adapted crops that could represent a higher cash return than traditional crops should receive special attention from the international donor community.

HOW WOULD IMPLEMENTATION OF A NATIVE PLANT TECHNOLOGY AFFECT THE NEED FOR CAPITAL?

Because of the varied types of native plants, no specific capital requirements can be determined for all native plants. There is no doubt that a native plant development program would require significant inputs of technology and capital. However, those plants that produce a crop would require greater inputs than those used for reforestation, improving soil fertility, or increasing rangeland forage production.

Careful analysis of the infrastructure of a region or county may give an indication of available processing capacity. For example, vegetable oil extraction facilities are available in the groundnut basin of Senegal and might be available in the off-season to extract hydrocarbon latex from giant milkweed plants that grow in waste places and margins of fields. A small pilot program with these native plants could provide some of the data necessary to determine the feasibility of proceeding to larger phases of development. In a like manner, any proposed new crop should be analyzed for capital inputs and available facilities for production processing and transport.

WHAT WOULD BE THE IMPACT OF WIDE-SCALE IMPLEMENTATION OF NATIVE PLANT USE ON SOCIOECONOMIC STRUCTURE?

It would be false to assume that only a large commercial-type farm or a family-sized farm would be suitable for native plant development. Much depends on the nature of the plant species and the magnitude of development necessary. From table 1, it can be seen that some crops such as cocoyam and buffalo gourd could easily be grown on small plots and collected for commercial markets. In contrast, industrial feedstocks, biomass, and high volume crops such as guayule, ramie, leucaena, and guar would better be grown in large fields and be harvested and treated mechanically.

Small field operations would cause little change on socioeconomic structure except to provide an additional income stream to communities, Large operations may disrupt communities by increasing their population or requiring the establishment of new communities. An excellent example in the United States is the 110,000 acre Navajo Irrigation project near Farmington, New Mexico. This large commercial farm operation has left little opportunity for community development of a traditional native culture, nor has it provided an opportunity for family farm or cooperative group farm development. The project has addressed only the large-scale production-economic aspects of development. Socioeconomic problems remain unsolved as illustrated by the attempts being made to resettle Navajo workers in a modern subdivision quite foreign to existing patterns of community settlement.

In summary, the various options available in native plants of high potential for development could enhance existing social and economic patterns or could disrupt them with large developments depending on the suitability of the land, the adaptability of native plants to given locations, and the institutional insensitivity that might prevail in their development.

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