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STAFF SUMMARY REPORT:

NAS PARTICIPATION IN SECOND CARIBBEAN COMMONWEALTH

MEETING ON UTILIZATION OF NATURAL PRODUCTS

Port-of-Spain, Trinidad

April 22-27, 1979

NATIONAL ACADEMY OF SCIENCES
Washington, D.C.

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This report is a staff prepared summary of NAS participation in the Second Caribbean Commonwealth Meeting on Utilization of Natural Products, organized by the Commonwealth Science Council.

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STAFF SUMMARY REPORT

The Caribbean economy rests mainly on sugar, a very tenuous foundation. Reliance on only a small number of plants carries great risk, for monocultures are vulnerable to catastrophic failure caused by disease, variations in climate, technological developments, and changes in world market conditions.

The Caribbean must seek, therefore, to exploit other plants--both for food at home and for markets abroad. Fortunately, because the islands have one of the world's best climates--warm and sunny year-round and a range of rainfall zones, altitudes and soils--plant products can continue to be a mainstay of the nations' economies. But diversification must be encouraged.

To help feed, clothe and house a rapidly increasing population, it is time to consider plant species that heretofore have been little known, underexploited or neglected in the region.

The apparent advantages of the plants that are widely cultivated in the Caribbean over those that are not, often result chiefly from the disproportionate research attention they have received. Many species of potential importance were disregarded during the colonial era, when consumer demands in Great Britain and among local British residents largely determined local

agricultural research priorities. The selected crops--such as nutmeg, coconut, sugar--received much research attention. Even after independence, the pattern of concentrating on a few crops changed little since markets abroad were already established and the countries needed foreign exchange. The educational system still reflected colonial priorities.

Nevertheless, the promise of plants remains enormous. There are 500,000 species in nature, yet only a few hundred are used intensively. As we move closer to the day when fossil fuels run out, the world will be forced to return to dependence on renewable resources--largely those from plants. Thus, the age of natural products is fast approaching.

In 1975, the National Academy of Sciences (NAS) sponsored the visit to Sri Lanka of a team of U.S. plant scientists with financial support from the U.S. Agency for International Development. Together with local scientists, they produced a report that identified projects to exploit plants that could be produced in Sri Lanka.

After reviewing this report, the Commonwealth Science Council (London) asked the NAS to participate in a similar meeting being convened by the Council to assist Caribbean nations to organize collaborative natural products research in the region.

The meeting, held in Trinidad on April 22-27, 1979, was hosted and organized by CARIRI, the Caribbean Industrial Research Institute whose headquarters are at St. Augustine, Trinidad.

The workshop brought together chemists and botanists from the region to consider new species, new priorities, methods for fostering regional collaboration, and other subjects.

Members of the National Academy of Sciences panel were:

Edward S. Ayensu (Cochairman), Director, Office of Biological Conservation, Smithsonian Institution, Washington, D.C.;

Richard E. Schultes (Cochairman), Botanical Museum, Harvard University, Cambridge, Massachusetts;

Geoffrey A. Cordell, Associate Professor, Department of Pharmacognosy and Pharmacology, University of Illinois, Chicago, Illinois;

Donald L. Plucknett, Deputy Director, Board on International Foreign Agricultural Development, Washington, D.C.;

Frank H. Wadsworth, Director, Institute of Tropical Forestry; Rio Pideras, Puerto Rico;

Paul J. Scheuer, Professor of Chemistry, University of Hawaii, Honolulu, Hawaiii;

Peter S. Ashton, Director, Arnold Arboretum, Harvard University, Cambridge, Massachusetts; and

Noel D. Vietmeyer (Staff), Professional Associate, Board on Science and Technology for International Development, National Academy of Sciences

Some of the specific observations made by the NAS Panel regarding aspects of natural products study that it found in Trinidad follow.

1. Agricultural textbooks. Panelists could find no textbook on crop production on the Caribbean region. There is need for such a publication to coordinate the accumulated information on management and care of the major and minor crops. It would also be useful as a reference book. The production of such a book would be a workable, useful regional project for the University of the West Indies, the Caribbean Agricultural Research and Development Institute (CARDI), and other interested institutions.

2. Vegetable crops. It was surprising to see the lack of variety in the vegetables in the Port of Spain Friday market--perhaps from 12 to 20 different species. By contrast, farmers on the island of Java (which is about the same size as Panama) cultivate about 550 different species and far more cultivars. The Caribbean needs an aggressive, dynamic program to collect and exchange seed, to test new varieties of fruits and vegetables,

to test new species, and to collaborate with fruit and vegetable scientists worldwide. A continuing program to monitor vegetable crops elsewhere in the tropics is vital because there is a wealth of nutritious new species or better-tasting or better-yielding varieties yet to be tried in the Caribbean.

3. Botanical gardens. Botanical gardens such as those in Port of Spain, Jamaica and Guyana were organized originally for the purpose of testing new plants. Only recently have they become places for families and perambulators on Sunday afternoons. Unfortunately, as their practical value was reduced, so too was much of their funding. Now, rising costs and urban sprawl are making it difficult for botanical gardens in tropical countries to survive. And with their demise, collections of potential new crops are being lost.

Caribbean governments should capitalize on the region's botanical gardens, whose trained horticulturists are capable of assembling species of crops from different parts of the world with potential for establishment in the Caribbean.

4. Handicrafts and artifacts. Tourists love to buy materials made locally, but the American group was shocked to find that the hotel, airport and city shops in Port of Spain had almost no indigenous artifacts for sale. They expected to find a large variety of artwork and wood carvings, as well as ornaments and artifacts made from shells, seeds, coral, batik and basketry. Wood carving, in particular, does seem to interest local artisans. Saman trees (Samanea saman) are common on Trinidad, and they produce the famous monkey-pod wood, which is in such demand in Hawaii, for example, that the trees have systematically disappeared throughout most of the Pacific. Saman grows fairly quickly, and its wood is extremely valuable. It can be grown in populated areas (along boundaries, roadsides, fence lines, for instance), helps improve soil, and provides beautification and shade for people and animals.

5. Perfumes. Entrepreneurs in Honolulu and Singapore have built thriving small industries by making perfumes from flowers that can be locally grown and sold in the local markets. This is a far cry from the giant multinational-dominated perfume industry, and it is something Caribbean natural products chemists, businessmen and plant scientists should consider. Highly perfumed plants such as plumeria, jasmine and gardenia should grow well in the area. It also seemed to the NAS group that horticulturists could very successfully grow and sell exotic flowers to local hotels for use in weddings, and for export.

6. Food imports. The American group was incredulous to find that the orange juice served in our hotel had been imported from Florida. Apparently, the Caribbean is one of Florida's largest markets for fruits and vegetables, despite the fact that Caribbean soils and climate are more salubrious for these crops than those in Florida.

A full proceedings of the Trinidad workshop is being produced by the Commonwealth Science Council. The appendices that follow were prepared by the NAS staff or by the individual panel members noted for presentation to the workshop, especially to the working group on Future Trends.

APPENDIX I

OPENING REMARKS*

We have been assembled here to help examine the potential that exists in the natural resources in the Caribbean Commonwealth countries and to assess how best such resources can be used rationally for the benefit of the countries involved and for the region as a whole. Having had some experience in similar exercises in other parts of the world, I would like to offer a few observations and to provide some guidelines which I hope will draw upon our collective experiences to enable us to accomplish our mission successfully.

In order for any country to exploit its natural resources, it is essential that there be a strong and determined desire by the people to succeed. Usually, such desire should be accompanied by a strong political commitment by the government and the people to formulate development objectives that are practical and are within their competence, mechanical skill and ingenuity. Naturally, most countries cannot boast of possessing the full complement of the needed man-power and financial resources to accomplish their goals. It is therefore essential that each country provide carefully balanced incentives and the proper atmosphere to attract the needed capital from private and international finance houses, bearing in mind the overall

*This section is contributed by Edward S. Ayensu.

objectives of the nation.

It is important that we do not overlook the very special features that often characterize the economies of small islands. The general tendency is for such islands to depend entirely upon imports and on capital inflows, especially since a number of such countries lack easily marketable essential natural resources.

The existence of the Caribbean Development Bank, for example, is a welcome enterprise. However, the usefulness of such a regional institution would depend in large measure on its ability to secure adequate financial resources at reasonable terms to on-lend to member countries. In this regard, I am thinking of loans from the World Bank and the International Monetary Fund, as well as major private financial houses in the United States, France, Germany, Japan and the well-to-do Commonwealth countries to help turn meaningful projects in the region into reality.

There are certain basic institutions that already exist within the Caribbean. The University of the West Indies, for example, could be enticed to direct its research activities towards helping the economies of the region without losing its main objective of providing scholarly education. In the biological and chemical faculties, quite a number of screening programmes on medicinal plants and other forest products could be undertaken. In addition, the economic and engineering faculties should be called upon to participate in the development of the new-style projects for the rural and urban areas. All the faculties can help upgrade the agrarian activities and participate in the quest for solutions to reduce food losses. An involvement of this nature could be viewed from two perspectives. Firstly, it will encourage the faculties to place more emphasis on practical application of

accumulated knowledge, and secondly, it will demonstrate the direct contribution academia can make to the mainstream of the region's economies.

In assessing the resource potential in this region, I want to offer a suggestion of how we may want to perceive the available natural resources. We may want to examine the resources that come in the form of products such as minerals, oil, gas, coal, forest, agricultural products and the like. These are resources that can be sold and transported, and therefore can provide substantial foreign exchange that will be needed to develop major aspects of a country's economic programmes. The second set of resources are those that are in the form of amenities such as waterways, waterfalls, natural harbours, fertile soils, sandy beaches, solar radiation, etc. that can be exploited for agriculture, industry, transportation and tourism. The two sets of resources have something in common. They can all be exploited for the economic benefit of man and country.

While embarking on the exploitation of the natural resources of the region, it is essential that they be looked upon as either renewable or as non-renewable resources. The exploitation of resources such as oil, gas and many minerals fall under the non-renewable resource category; therefore, their expenditure must of necessity be very carefully evaluated. Resources such as forests and soils are generally considered renewable resources if, for example, in the case of plants, careful exploitation and management practices are undertaken. We should not lose sight that soils, for example, may become depleted and exhausted if careless agricultural practices are encouraged.

In this connection, I would like to remind ourselves that throughout our deliberations, we should strive to indicate the need for careful exploitation of the natural resources so that air, water and soil may not be polluted. I firmly believe that the exploitation of natural resources should take into consideration the maintenance of the quality of the biosphere. In fact, I

consider such a step as an important aspect of any programme of resource development. I do not believe that it is a necessary step to pollute one's environment in order to achieve a high standard of living and prosperity.

In order to introduce technological innovations that depend upon the available natural resources, it is essential that nations acquire adequate knowledge of the status of their resources. Such an exercise requires substantial exploration, research and development efforts before a sufficiently detailed knowledge of the nature and usability of a resource can be obtained. In most developing countries, this necessary first step towards economic development is often not achieved. In countries where considerable knowledge even exists for a particular resource, the lack of effective planning often undermines its actual utility.

The current development attitudes of some of the countries are a carry-over of their colonial and, to some extent, the cultural heritages. It seems essential that a post-colonial posture towards an aggressive economic development be pursued. The establishment of development priorities will make it possible for each country to assess its potentialities and to engage in the kinds of industries that will service the relatively small markets at home, as well as to play an active role in regional economic integration.

The Commonwealth is an association of sovereign states that have decided voluntarily to articulate the concept of interdependence. This regional meeting is an example of the "Commonwealth Experience." There is no doubt that the complexion of the former six-nation club of more than a quarter of a century ago has changed dramatically. More colour has been added to the association during the past twenty years. During the same period, the obligations of the developed country-members of the association to their less fortunate members have assumed unavoidable, and in some cases, politically

unacceptable dimensions. Yet still, the flexibility within the association, as well as the common heritage which the members share, make it possible for certain practical measures to be taken to help each other.

At the end of this meeting, I hope we would accomplish among other things a consideration of the role that industrialization, as a dynamic instrument of growth, could play in the strategy of development in this region. I would like to see a consideration of intensive actions aimed at the full and effective mobilization of the human and natural resources for the economic and social transformation of the region. There should be full accounting of the impact of short, medium and long-term needs of the industrial complexes in the region. In addition to multilateral arrangements with the developed world, I would like to see a desire for the region to secure the fullest cooperation with developing nations in both technological and financial areas.

It is my fervent hope that our deliberations at this regional meeting will prove successful in fulfilling the economic objectives of the member countries and the region as a whole.

APPENDIX II

UNDERUTILIZED FOOD CROPS

PASTURES UNDER COCONUTS*

Coconuts have a very long economic life, from 60 to 80 years or so, and farmers always face a problem in determining how to manage the understory of their palms. Some cover is needed to control erosion, yet uncontrolled weed growth competes with palms for moisture and nutrients, attracts harbor rodents and other pests, and makes nut collection difficult. Conventional weed control by herbicides, manual slashing or pulling is expensive and onerous. Many farmers have found that the grazing of livestock, particularly cattle and domestic buffalo on either natural or improved pastures under the palms, can be profitable because of extra income from meat and milk. This is a useful management tool in keeping down weed growth and thereby improving nut collection.

Farmers in a number of coconut areas grow cattle under coconuts to control weeds and increase farm income.

Many coconut farms in Trinidad and Jamaica could benefit from grazing of cattle and from improved pasture management under the palms. Until weed

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* This section is contributed by Donald L. Plucknett

control needs are met, there will be little need to plant improved pastures, particularly for pasturing of steers or dry stock. This may not be true if the natural pasture species present are undesirable or unpalatable. Improved pastures will probably be required for weaned calves and pregnant females. The technology for managing cattle and pastures under coconuts is available and is generally applicable in most areas. The Caribbean region has had some research on the topic; for example, the Coconut Research Board in Jamaica studied fertilized pangola grass pastures under coconuts in Jamaica, and Antoine (1973) studied the economics of cattle/coconut enterprises in Trinidad and Tobago.

References and handbooks on the topic are available from the ASPAC Food and Fertilizer Center in Taipei, Taiwan; the South Pacific Commission, Noumea, New Caledonia; the University of Queensland (Dept. of Agriculture, Dr. P.C. Whiteman), St. Lucia, Queensland, Australia; and the University of Hawaii (Dept. of Agronomy and Soil Science, Dr. D.L. Plucknett), Honolulu, Hawaii 96822.

A number of pasture plants can be used under coconuts. Such plants should have the following characteristics: (1) be shade tolerant, (2) not be very competitive with coconuts for moisture and nutrients, (3) generally should be creeping or prostrate so as not to interfere with nut collection.

Natural pasture species of value as pastures include (1) *Mimosa pudica*, (2) *Centrosema pubescens*, (3) *Desmodium triflorum* and *D. heterophyllum*, (4) *Pueraria phaseoloides* (5) *Axonopus compressus*, (6) *Paspalum conjugatum* and (7) *Panicum maximum*. These are the main species.

Improved pasture plants for coconuts include: (1) *Desmodium heterophyllum* (2) *Pueraria phaseoloides* (3) *Centrosema pubescens*, (4) *Brachiaria decumbens*, (5) *Brachiaria brizantha*, and (6) *Brachiaria miliiformis*.

Of the above improved species, (1), (2) and (3) can be obtained as seed from commercial seed sources in Australia (Yates Seed Co.; Terranova Tropical Pastures; Wright Stevenson and Co.; etc.). The Brachiarias are mostly propagated vegetatively, and it will be necessary to check as to their availability in the country. Brachiaria miliiformis is available from Sri Lanka.

YAM BEANS*

Yam beans (Pachyrhizus erosus and P. tuberosus) like potatoes, yams and manioc, produce a fleshy underground tuberous root. But yam beans have the legume family advantage: the rhizobia in their root nodules make nitrogenous compounds available to the plants and even enrich the soil in which they are grown.

Yet yam beans remain a primitive crop. There has never been a concerted effort to advance it, despite the fact that root crops are much in demand throughout the tropics and that yam beans grow easily and resist pests. Further, they grow well in the difficult environment of the hot wet tropics (such as the Amazon Basin) and, with their succulence and crunchy texture, appeal to most palates. They are increasingly exported from Mexico to the United States in part to supplement scarce water chestnuts used in Chinese cooking and as a low calorie snack food.

Two edible yam beans are known. Pachyrhizus erosus is native to southwestern Mexico; Pachyrhizus tuberosus, to the Amazon headwater region of South America and to parts of the Caribbean. Centuries ago, P. erosus was carried to Asia with the Spanish galleons that annually voyaged from Mexico to the

*This section is adapted from the National Academy of Sciences report, Tropical Legumes: Resources for the Future

the Philippines: it became a favorite crop of Chinese market gardeners throughout Asia. In 1889, the Royal Botanic Gardens at Kew distributed P. tuberosus widely throughout tropical British colonies including those in the West Indies..

Yam bean plants are among the most vigorous-growing legumes. They are coarse, hairy, climbing vines that grow rapidly, can reach 5 m in length, and bear many beautiful white or violet flowers. Although they grow well in locations ranging from subtropical to tropical and dry to wet, for good yields, they require a hot climate with moderate rainfall.

WINGED BEAN*

Perhaps no other crop offers such a variety of foods as the winged bean (Psophocarpus tetragonolobus). Yet it, too, is a little-known, poor man's crop, used extensively only in New Guinea and Southeast Asia. Taken together, the winged bean's products make up an impressively palatable and nutritious diet, one that appears to meet many dietary needs of the tropics, especially of the wet tropics where protein deficiency is not only great but difficult to remedy. Every bit of the winged bean plant is eaten—leaves, pods, shoots and flowers all go into the cooking pot, and when the season is over, the villagers dig up the fleshy, tuberous roots and roast them. Any stems that remain are fed to livestock.

The winged bean is a particularly good poor man's crop. It grows easily and quickly in tropical climates and yields profusely. Bacteria in its masses of root nodules (many hundreds have been counted on a single plant)

*This section is contributed by Noel D. Vietmeyer.

convert nitrogen from the air into nitrogenous compounds that the plant uses to build protein. Indeed, protein pervades virtually every part of a winged bean plant.

A bushy pillar of greenery with viny tendrils, blue or purple flowers, and heart-shaped leaves, the winged bean resembles a runner-bean plant. It forms succulent green pods, as long as a man's forearm in some varieties. The pods, oblong in cross-section, are green, purple, or red and have four flanges or "wings" along the edges. When picked young, the green pods are a chewy and slightly sweet vegetable. Raw or boiled briefly, they make a crisp and snappy delicacy. Pods are produced over several months and a crop can be collected every two days, providing a continuous supply of fresh green vegetables.

If left on the vine, the pods harden, but the pea-like seeds inside swell and ripen. When mature, the seeds are brown, black or mottled. In composition, they are essentially identical to soybeans, containing 34 to 39 percent protein and 17 to 20 percent of a polyunsaturated vegetable oil. The protein is high in the nutritionally critical amino acid, lysine.

In addition to the pods and seeds, the winged bean's leaves and tendrils make good spinach-like potherbs. Its flowers, when cooked, are a delicacy with a texture and taste reminiscent of mushrooms.

But perhaps the most startling feature of the plant is that, in addition to the foods it produces above ground, it also can grow fleshy, edible tuberous roots below ground. These have firm, fiberless, ivory-white flesh and a delicious and delicate nutty flavor. The winged bean is something like a combination soybean-potato plant. Not all types produce tubers big enough to eat, but those that do are potentially important as root vegetables in the humid tropics where sweet potatoes, yams, cassava (manioc) and other roots are already staples. This is because winged bean tubers are uniquely rich in

protein--they can contain more than 10 times the protein of cassava, for example.

The winged bean is so popular in the diet of highlanders in Papua New Guinea that tribes often hold winged bean sing-sings (festivals). The plant is also well known to villagers in Indonesia, Malaysia, Thailand, the Philippines and Burma. Yet it was not until 1973 that the first concerted efforts to investigate the crop's agronomy were begun. In 1975, the plant was given worldwide recognition in a National Academy of Sciences booklet, and so many researchers and landowners have introduced it in so many countries that a special newsletter, The Winged Bean Flyer, is now published just to keep up with their findings.

So far, this long-humble crop is withstanding the scrutiny of modern science and most research results are positive. The winged bean seems to be well on its way to becoming a sort of tropical soybean, a highly nutritious vegetable specially suited to the small plots, market gardens and backyards of the Caribbean.

AMARANTHS*

At least five amaranths (Amaranthus species) are half-wild, multipurpose New World plants that are rich sources of vegetable protein, food energy and fiber. So far, they have been largely neglected by research organizations.

Amaranths--major grain crops in the tropical highlands of the Americas at the time of the Spanish Conquest--reached Asia, New Guinea and Africa in Spanish Colonial times and were spread and assimilated by poor men themselves without outside help. Today, they are important to rural farmers in Central

*This section is adapted from the article, "Pity the Poor Man's Plants," by Noel D. Vietmeyer.

and South America and to hill tribes in Asia, New Guinea and parts of Africa.

Amaranths belong to a small group of plants termed C_4 whose photosynthesis is exceptionally efficient. The sunlight they capture is utilized more effectively than in most plants, and amaranths grow fast. Vigorous and tough, amaranths have been termed self-reliant plants that require very little of a gardener. They germinate and grow well under adverse conditions. They are easily cultivated and adapt well to the rural farmer's small plots and mixed cropping. Furthermore, they are relatively easy to harvest by hand and to cook.

Amaranths are annuals which reach 2 m in height and have large leaves tinged with magenta. They are cereal-like plants producing full, fat seed heads, reminiscent of sorghum, up to 30 cm long and 12 cm wide. (A related ornamental amaranth is called Prince of Wales' Feather because of its brilliant crimson seedhead.) The seeds are small but occur in prodigious quantities. Their carbohydrate content is comparable to that of the true cereals, but in protein and fat, amaranths are superior to the cereals.

When heated, amaranth grains burst, and a popcorn-like confection is made from them (called alegrias in Mexico, laddoos in India and Pakistan). However, in many areas, the grains are more often parched and milled into a flour, one high in gluten and with excellent baking qualities. Bread made from this flour has a delicate nutty flavor. Pancake-like chapatis made from it are a staple in the Himalayan foothills.

Recently, W. J.S. Downton, an Australian researcher, has found that the grain of at least one amaranth (Amaranthus caudatus var. edulis) is rich in protein and exceptionally rich in lysine, one of the critical amino acids usually deficient in plant protein. Indeed, the amount of lysine exceeds

that found in milk or in the high-lysine corn now under development.

Grain amaranths worth much greater attention from researchers worldwide are:

- Amaranthus caudatus (a native of Andean regions of Argentina, Peru and Bolivia)
- Amaranthus hypochondriacus (highlands of Mexico, Himalaya foothills)
- Amaranthus cruentus (Guatemala)

In addition to their seeds, these species have edible and nutritious leaves that are widely eaten as a boiled vegetable. Two other species, Amaranthus lividus and Amaranthus tricolor, are common potherbs in Asia and are grown and eaten in the western world under the names "Chinese spinach" or "Malabar spinach."

PEACH PALM*

The peach palm or, in Central America, pejibay, is a tree providing the major food at fruiting season for many habitants of tropical America. Unknown in the wild, its exact home is not known, but it is cultivated on a dooryard basis from sea level to 3600 feet or more on heavy clay or clay loam, preferring areas where the rainfall is less than 7 feet a year.

Reported by early Spanish writers, Guilielma speciosa is almost unknown beyond Central America and northern South America. Perhaps, nutritionally, the most balanced of tropical foods, the fruit contains carbohydrates, proteins, oils, minerals and vitamins. The fruit can simply be boiled in water or gently roasted. Boiled fruit can be dried and kept for months and re-boiled

*This section is contributed by R.E. Schultes.

when needed. The oily kernel is sometimes eaten. The fleshy mesocarp is made into a meal by Indians of the northwestern Amazon and kept for months for use in ways reminiscent of cassava flour. The starch-rich mesocarp tastes like roasted chestnuts. It has twice the protein content of banana and provides more carbohydrate and protein per hectare than maize.

Although a few small plantations exist in Costa Rica, there is no doubt that such a nutritious fruit of such versatility should be cultivated on a large scale.

The palm which usually has a number of very spiny trunks from one root, attains a height of some 50-60 feet. The peach-shaped yellow or orange fruits, 2-6 cm. long, are borne in bunches of up to 300 fruits weighing 12.5 kg. One tree may produce up to 13 bunches, and two harvests are customarily harvested a year.

In the Amazon Valley and probably elsewhere, there are numerous strains in which the seed aborts, resulting in a fruit wholly farinaceous. There exist also sports devoid of spines on the trunk. The species is extremely variable. A living collection of all strains available should be established for agronomical and genetical work which might well create from this already promising cultigen a "super crop" tree.

JESSENIA PALM*

Of the numerous American palms producing edible oils, Jessenia polycarpa stands out as extremely promising. Jessenia, together with the closely allied genus, Oenocarpus (which may possibly be the same), has 18 species native to the humid tropics of central and northern South America.

*This section contributed by R.E. Schultes

The seje, milpesos or patana occurs in great abundance in lowland areas of the Amazon regions of Colombia and northwestern Brazil. Although much exploited in the wild by Indians, the tree has never been cultivated.

Jessenia polycarpa which may attain a height of 60-70 feet, has purplish fruits 3 cm long in large panicles containing up to 30 lbs of fruit each. The oil is comparable with that of olives. The percentage of oleic acid is nearly equivalent to that found in olive oil - 80.5% vs. 76.4%. In addition, the percentage of palmitic acid, which lowers the quality of edible oil, is an almost equally low 8.8% vs. 9.4% for the olive. In contrast, African palm oil has almost 39% of palmitic oil.

The natives cut the racemes, which frequently are produced twice a year, macerate the fruit in water to produce a nutritious drink or steam, and make them to remove the pulp which is then preseed. The oil is clear yellow or green and has a nutty flavour. The oil is sometimes found in native markets in Colombia, sold for use as a medicine for pulmonary troubles. The seeds may be eaten as foods.

Patana oil might easily be substituted for olive oil which sells in New York for 86.7 ¢ a lb (African palm oil: 27.4/lb).

Wild trees under primitive Indian production yield from 5-10% of the weight of the fruit in oil. An average palm yields 60 lbs of fruit a year, so a production 3-6 lbs of oil a year might be expected. It is not unreasonable to presume that a programme of improvement and cultivation would increase these yields of wild trees.

Another species, Jessenia bataua, growing more widely throughout the Brazilian Amazon and in the Orinoco basin, yields 18-24% of a yellow-green oil. It is likewise almost equivalent to olive oil, but its production is even less than that of J. polycarpa. A Peruvian species, J. weberbaeri,

has unusually large seeds measuring 4 cm in length. Little is known of the Trinidadian species, J. oligocarpa, or of its potentialities.

CHAYA*

Chaya (Cnidoscolus chayamansa and Cnidoscolus aconitifolius), also known as tree spinach, is a fast-growing ornamental and shade shrub that is a source of nutritious green leaves and shoots. It requires little maintenance (for example, the soil around it does not need tilling) and produces large amounts of greenery for years. A few plants grown experimentally in Puerto Rico have outgrown and outproduced all other leafy vegetables.

The attractive shrubs, 3-5 m tall, are often seen as hedges in Mexico and Honduras. Native chaya grows in thickets or open forest (often in rocky places) at altitudes of up to 1,300 m. There are two forms: Cnidoscolus aconitifolius is found in native dooryards from southern Mexico to Costa Rica; Cnidoscolus chayamansa is grown as a hedge or dooryard plant in the peninsula of Mexico and in British Honduras. Cnidoscolus chayamansa is occasionally grown in Florida and Cuba, but seems not to have been disseminated to other regions.

Chaya's young shoots and tender leaves are cooked and eaten like spinach. Reportedly, they are high in protein, calcium, iron, carotene, thiamine, riboflavin, niacin and ascorbic acid. They are probably suitable for canning or freezing for local and export markets, but this has not yet been attempted.

So far, chaya appears free of the pests and diseases that plague green garden vegetables in tropical climates, an important economic and ecological

*This section is adapted from the National Academy of Sciences report, Underexploited Tropical Plants with Promising Economic Value.

advantage. However, horn worms can rapidly defoliate it (though the plants quickly recover their leaves).

Chaya is propagated from stem cuttings, and woody stem sections germinate readily. Edible greenery is produced within 2 or 3 months. Because of the softness of the wood, the plant is easily pruned and maintained within reach of the ground. The plants tolerate heavy rainfall and respond with luxurious growth. Drought is also tolerated, and plants recover well when the rain returns.

BURITI PALM*

The buriti palm (Mauritia flexuosa), which grows by the millions throughout the Amazon basin, Venezuela, Suriname and Guyana, has a remarkable range of uses. It is known as the tree of life because some Indian tribes depend on it for all aspects of their livelihood--food, drink, shelter and clothing.

It may well be the most plentiful palm in South America, yet only minor attempts have been made at commercialization. Potential products from buriti include oil and starch for food; wine; timber; cork; and industrial fiber for twine, sacking, nets and hammocks. Feasibility studies of buriti production and exploitation are recommended to researchers, private investors and government agencies.

Buriti palms grow mostly at low altitudes in groves near swamps and springs in damp soils that are useless for agriculture. Their presence often indicates the existence of water in dry country.

The buriti have leaves 3 m long and reach heights of 25 m. The green, scaly fruit is roundish (about the size of an egg) and grows in bunches.

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*This section is adapted from the National Academy of Sciences report, Underexploited Tropical Plants with Promising Economic Value.

After scraping, the fruit is soaked to soften the scales that cover the thin pulp. It has a pleasantly sweet, tangy taste and is reported to have as much vitamin C as citrus fruit. The fruit could be canned or candied and would probably enjoy wide distribution. The fruit pulp contains 8-9 percent edible oil which contains 300 mg of beta-carotene per 100 g. This oil is said to produce more vitamin A than any other oil (and even more vitamin A than carrots and spinach).

The kernel inside the fruit is contained in a woody shell that cracks fairly easily. It yields almost 50 percent of a light-yellow oil that can be extracted with equipment already used for other oilseeds. Buriti kernel oil appears to be similar in quality to more commonly used vegetable oils such as that from the Afrian oil palm kernels.

Its shoots can be harvested for "hearts of palm." A sago-like starch, roasted by Amazon Indians to make a bread is obtained from the pith of its trunk. (Buriti could also be a source for industrial starch.)

Wines are often made by the Indians from the fruit and from the sweet sap of the trunk and unopened flower cluster (inflorescence).

The hard outer part of the trunk yields light (but tough) buriti wood, which is used locally, much in the manner of balsa wood, to make rafts and floats. A cork-like material obtained from the leaf-stalk (petioles) has been used in the manufacture of sandals and for bottle-top linings.

Stripped from the outer skin of young leaves is a thread-like fiber that makes a strong twine. Though not fully tested, the fiber's wide use in Indian fishing nets, hammocks, mats, hats and baskets indicates that it deserves further research.

APPENDIX III

PLANT-DERIVED INDUSTRIAL PRODUCTS

CARYOCAR*

The 15 species of Caryocar are trees of the Amazon, central Brazil and the Guianas. The seeds of a number of species, especailly C. villosum and C. brasiliense, provide an excellent edible oil which has limited local consumption, but which could well be industrialized. Sir Henry Wickham, who introduced hevea rubber trees to the Old World tropics, was as enthusiastic about the potentialities of Caryocar or piquié and sent seed with the rubber. But this oil tree was never given the attention it merited in the Asiatic colonies.

The fruit, C. brasiliense is fleshy, weighing up to 4 kg., and is comprised of a shell or endocarp, a fibrous husk or mesocarp and 1-4 kidney-shaped kernels. Ten percent of the fruit is starch. The kernel is coated with a yellowish fat providing a sweet oil which is excellent for cooking fat and as a butter substitute. The oil, composed mainly of glyceride esters of palmitic and oleic acids, can be utilized for the same purposes as palm

*This section is contributed by R.E. Schultes

oil. While they are hard to crack, the kernels contain an oil much employed by the Indians of the Amazon. The endocarp may be used directly for fuel or made into charcoal. The endocarp of C. glabrum is pounded and mixed thoroughly with mud for use as a fish poison by the natives of Amazonian Colombia: the ichthyotoxic properties are due to a high concentration of saponin. This species is known as soap wood in the Guianas.

The trees may attain a height of 30 feet in 9 or 10 years.

Caryocar amydaliferum of northern Brazil, C. nuciferum of Brazil and the Guianas and C. tomentosum of the Guianas are known as sauri nut trees and yield an oil used in foods. C. nuciferum has been cultivated to a limited extent in the West Indies whence sauri nuts have been exported.

CARYODENDRON ORINOCENSE*

This tree yields a large harvest of edible and oil-rich seeds. In South America, it is just beginning to be domesticated, although it has long been exploited from wild stands in the Orinoco Basin region of Colombia and Venezuela. The seeds are roasted before being eaten. The oil, which is still expressed by crude methods, finds limited sale in Colombia for uses ranging from cooking to soap and cosmetics.

The tree, relatively fast growing, can successfully be grown on poor, lateritic soils in hot, humid tropics (300 - 1,000 feet altitude), but will tolerate areas where there is a marked dry season of four months.

Information and literature on this potential new crop is available from the Departamento de Botanica, Universidad de Nariño Pasto, Colombia, S.A.; planting material may be solicited from the Agricultural Experiment Station at Palmira, Colombia.

*This section is contributed by R.E. Schultes.

PATCHOULI OIL*

The price of petroleum-based starting materials are rising so high that essential oils are becoming economically more attractive all the time.

Patchouli oil is obtained principally from Pogostemon cablin, a small perennial shrub native to the Philippines. The plant has been introduced into several tropical areas and its oil is now produced mainly by Indonesia, Madagascar, Brazil and the Seychelles. It seems certain that the patchouli plant would thrive in the coconut-growing areas of the Caribbean.

Patchouli growing is suited to small landholders and to intercropping between tree crops. Young leaves and shoots are clipped off every six months. They contain up to six percent oil; after a few days of drying, they are distilled (often just using boiling water in primitive equipment) to yield the oil.

One of the finest fixatives for perfumes, patchouli oil is added to soaps, tobacco, hair tonic and carpets. It is used widely in the aromatic chemicals industry. Almost all essential-oil-utilizing companies purchase it, since it is a basic ingredient for many fragrances. The major ingredient, and the important component in the oil, is patchouli alcohol, a complex molecule that is unlikely to be synthetically produced in commercial quantities in the near future.

There is a worldwide demand for patchouli oil; with the expanding essential-oil markéts of the future, large-scale production of patchouli oil seems to hold much promise for the Caribbean's future economic development.

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*This section is adapted from the National Academy of Sciences report, Natural Products for Sri Lanka's Future.

VETIVER OIL*

The oil from vetiver root is the basis for many fragrances. Almost all essential oil companies use it. Though the vetiver plant is native to Sri Lanka, it is other countries such as Haiti and Réunion that exploit it. However, a world shortage now exists and vetiver could be produced as an intercrop between coconut in the Caribbean. Increased production from such plantations should be fostered.

GUM KARAYA**

The United States imports large quantities of gum karaya from India. The demand is so great that India is now growing plantations of Sterculia urens from which the gum is obtained by tapping--like tapping rubber from Hevea trees. Used in ice cream and foods, this gum is in growing demand.

The Sterculia gum tree has long been exploited in its native India. However, in the past 40 years, the world demand for gum karaya increased to such proportions that it has led to excessive and uncontrolled exploitation, which has decimated the wild Indian stands. Consequently, the Indian Government initiated technical planting of Sterculia urens. At the present time, tapping is strictly controlled.

The major use of gum karaya is in the ice cream and confectionery industries in many countries. Since its properties resemble those of tragacanth, it is sometimes called "Indian tragacanth." Commercial grades are based on color: red, yellow and black.

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*This section is adapted from the National Academy of Sciences report, Natural Products for Sri Lanka's Future.

**This section is contributed by R.E. Schultes.

Sterculia urens is a large tree, from 60 to 70 feet tall, with a distinctive white-grey bark, which grows best on dry, rocky soils that cannot support many other crops. The tree produces the gum freely as a soft, solid mass when its bark or branches are cut or injured.

Literature is available, especially in India, on recent agronomic research and on properties of the gum. Planting of the Sterculia tree is a long-term enterprise, but in view of the climate of parts of the Caribbean and of the ever-growing world demand for this versatile gum, its economic potentialities for filling local needs, and eventually in providing an export commodity, seem promising.

CALATHEA LUTEA*

Known as cauassú (the Brazilian name), Calathea lutea is native to annually flooded sites along the Amazon River. It is one of the first plants to invade secondary growth areas and might be especially valuable to plant in moist habitats that have been logged or otherwise disturbed. The plant can be propagated from seed which are set abundantly or vegetatively by inserting pieces of the rhizome into the mud. One hectare can accommodate up to 75,000 plants. Harvests are possible one year from planting, and leaves may subsequently be cut every six months. Cutting appears to stimulate leaf growth. It is calculated that yields of 800 kg/wax/hectare may be obtained.

The wax occurs in tissue-paper thin layers on the underleaf surface. An average leaf has a yield of 0.7 gm. of wax. The leaves may be sun dried and the wax shaken off. No machinery is needed, and the plant lends itself to homestead cultivation even in isolated regions. While extraction of the

*This section contributed by R.E. Schultes.

wax is time consuming, it is not laborious and can be carried out at odd hours by women and children whilst the men folk are occupied with heavier agricultural or other duties. For some uses, cauassú wax must be treated with a solvent to remove a resinous constituent.

CANDELILLA*

For appropriately arid regions (with less than 1 1/2 feet of rainfall) of rocky or sandy, well drained soil poor in humus, candelilla wax from Euphorbia antisyphylitica can profitably be produced.

The leafless stems of this shrub have a coating consisting of an amorphous solid, yellow-brown wax which can be employed as a substitute for beeswax and carnauba. Once refined, it can be used to mix with soft waxes for candles, chewing gum, sealing waxes, paper sizing, electrical insulating material, varnishes and lacquers and for other industrial applications. Almost half of the 5,000,000 kg used annually in the U.S. goes into coatings and polishes, one-third into chewing gum.

While candelilla wax is produced from wild starches in Texas, New Mexico and northern Mexico, no attempt at cultivation of the shrub has been made. Propagated easily from cuttings in wet sand, the plant reaches commercially feasible production in 2-5 years and can be harvested year-round. The waxy coat separates upon boiling the stems in water or the wax may be extracted with various solvents. Production methods which are still rather primitive result in a yield of only 2% of the weight of the plant as wax and tend to contaminate the wax with coloured impurities. Much greater yields and a purer product have been attained in laboratory tests.

*This section is contributed by R.E. Schultes

Euphorbia antisyphilitica provides good forage for goats and rabbits. It appears not to suffer from serious diseases or pests. Research could easily adapt the plant to cultivation and reduce costs of harvestings; long term selection might well find higher yielding strains.

APPENDIX IV

FAST-GROWING TREES*

Many tree legumes have a hardy, irrepressible character, suited to a wide range of soils, climates, altitudes and environments. Like other pioneer species, they have a precocious nature and grow quickly in an attempt to overtop and preempt the space of their plant competitors.

Because of this innate competitiveness, these tree legumes are easy to establish and cultivate. Some can be direct-seeded (avoiding the expense of nurseries and of transplanting fragile seedlings), and in some tests, even aerial seeding has proven feasible. Many occur naturally in dense, pure stands, suggesting that they probably can be grown in monoculture without being decimated by pests.

A most important feature of many legume species is that they have nodules on their roots within which bacteria chemically convert nitrogen gas from the air into soluble compounds that the plant can absorb and utilize. Thus, for average growth, these species require little or no additional nitrogenous fertilizer. Some produce such a surfeit of nitrogen--largely in the form of protein in their foliage--that they make excellent forage crops and the soil around them becomes nitrogen-rich through the decay of fallen foliage.

Some examples worth testing in Caribbean nations are described below.

*This Appendix is contributed by Noel D. Vietmeyer.

LEUCAENA LEUCOCEPHALA

In the 1960s, University of Hawaii professor James Brewbaker found in the hinterland of Mexico certain varieties of this otherwise bushy plant (commonly known as leucaena) that grow into tall trees. In equable tropical climates, they have grown so fast that just six months after planting they can be twice the height of a tall man; after two years, as high as a three-story building; and in only six or eight years, as tall as a six-story building, with a trunk cross-section as big as a large frying pan.

In the Philippines, one hectare of these tall leucaenas has annually produced 30-50 cubic meters of wood and over 100 cubic meters per hectare per year has been recorded by Filipino researchers in one vigorous stand. Even among the world's champion fast-growing trees, this is exceptional.*

Leucaena wood is thin barked and light colored. For such a fast growing species, it is remarkably dense (comparable to oak, ash, or birch), strong and attractive. Its fiber is acceptable for paper-making and the wood can be pulped satisfactorily and in high yield.

But leucaena, a multipurpose plant par excellence, also has other uses. It can supply forage (researchers in Hawaii and tropical Australia have found that cattle feeding on leucaena foliage may show weight gains comparable to those of cattle feeding on the best pastures anywhere), fuel (leucaena wood makes excellent firewood and charcoal), and fertilizer (if the nitrogen rich foliage is harvested and placed around nearby crops plants, they can respond with yield increases approaching those effected by commercial fertilizer).

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*By comparison, a well-managed pine plantation in a temperate zone produces about 10 cubic meters per hectare per year, on average.

ACACIA AURICULIFORMIS

A savanna tree of Papua New Guinea and northern Australia, this species demonstrates the almost incredible ruggedness of some legume trees. In northern Australia, it has been successfully established on alkaline (pH 9.0) sand dunes as well as on acid (pH 3.0) slag from uranium mining. In Malaysia, it has colonized barren spoil dumps left after tin mining. In Indonesia, it has stabilized steep, eroding hillslopes.

In a recent 10-year test in northern Papua New Guinea, 19 tree species were planted on a degraded grassland with such low soil fertility and poor drainage that it had been abandoned for agricultural use. Acacia auriculiformis and Eucalyptus tereticornis grew so outstandingly that this difficult site has now become a productive forest. In only two years, the trees grew six meters tall (diameter five centimeters) and in eight years, they towered to seventeen meters. Now a distinctive feature in an otherwise almost treeless landscape, the plantations have not only shown that the former wasteland is capable of producing rapid tree growth, but have led private citizens to plant their own trees throughout the district.

Despite these successes, Acacia auriculiformis still remains virtually unknown outside southeast Asia.

ACACIA MANGIUM

A decade ago, the Australian forester, D.I. Nicholson introduced to Sabah (Malaysia) seeds of this Queensland native tree. Though never previously considered as a plantation species, it has performed spectacularly. On good

sites, it has matched growth with the fastest-growing, better-known-species (e.g., Gmelina arborea, Pinus caribaea and Albizia falcataria), reaching 23 meters tall (23 centimeters diameter) in only nine years. (Annual production, 46 cubic meters per hectare.)

But on disturbed or burned sites, on degraded lateritic clay and on soils so worn out that even shifting cultivation had been abandoned, Acacia mangium outstripped all competition. Sabah foresters have now converted over 1,200 hectare of degraded lands into productive forests of the clean, straight-stemmed Acacia mangium.

It seems likely that this first—and only—experience with the plant is ushering in a major new tropical resource.

CALLIANDRA CALLOTHYRSUS

In 1936, horticulturists transported seed of this small Central American tree from Guatemala across the Pacific to Indonesia. They were interested in it as an ornamental, for like other Calliandra species, it has flowers that are gorgeous crimson powderpuffs, glowing in the sunlight like red fireballs. But Indonesians instead took up Calliandra callothyrsus as a firewood crop. Indeed, for 25 years, steadily expanding fuelwood plantations of it have been established until they now cover over 2,000 hectares in Java.

This small tree--barely taller than a bush--grows with almost incredible speed. After only 6-9 months, it averages 2.5-3.5 meters tall. After just one year, it can be harvested. The cut stump resprouts readily, giving new stems that can be 3 meters tall within six months. Up to age 15 or so, the trees can be harvested annually, each year providing 35-65 meters of wood per hectare.

The wood is too small for lumber, but is dense, burns well and is ideally sized for domestic cooking. It is also useful for brick, tile and lime kilns, and for fueling copra and tobacco dryers.

Indonesian villagers now cultivate Calliandra callothyrsus widely on their own land, often intercropping it with food crops. The plant's value is dramatically exemplified by the village of Toyomarto in East Java. There, land that was once grossly denuded and erosion-packed is now covered with Calliandra forest and is fertile once more. Today, the villagers make a good living from selling the firewood, actually earning more from it than from their food crops.

SESBANIA GRANDIFLORA

An Asian native, this small tree rivals leucaena in the number of products it can provide: food, forage, green manure, wood, pulp and paper. Yet its many values remain largely unrecognized.

In northern Australia, Sesbania grandiflora specimens have outgrown all trees tested, reaching heights up to 8.3 meters in the first year. Wood yields of 20 - 25 cubic meters per hectare per year, with rotations of five years, are commonly achieved in Indonesia even on fairly poor sites.

Easy to propagate, Sesbania grandiflora has been planted over large areas in Indonesia by direct--including aerial--seeding. The seeds germinate well, roots penetrate most soils, and the vigorous seedlings grow up through the weeds. On Timor, it now grows abundantly on worn out swidden land, abandoned by slash-and-burn farmers.

The wood is white and soft, useful for fuel and perhaps for pulp and paper, but not of high quality for lumber. Cattle relish the foliage.

The young leaves, tender pods and giant, beak-like white flowers are favorite Asian vegetables, used in curries and soups, or fried, lightly steamed or boiled.

Only Taiwan and Indonesia have so far used Sesbania grandiflora for major reforestation purposes. In Indonesia, the species is becoming so widely established that the word "turinization" has been coined after the plant, which is known there as "turi."

This, too, could become a most valuable reforestation species in the Caribbean.

* * * *

These are brief descriptions of five species of small leguminous trees that have recently proven useful in combating deforestation in Southeast Asia and the Papua New Guinea region. Elswhere are found many other exciting possibilities. In Korea, foresters intercrop bushy Lespedeza species to provide firewood during the early years of the establishment of pine and other forests. In Central America, there are Enterolobium cyclocarpum and Schizolobium parahyba; in South America, Mimosa scabrella (M. bracatinga), Schizolobium amazonicum, Tipuana tipu and Clitoria racemosa; and in the Pacific Islands, Albizia minahassae and Archidendron oblongum. In Africa, several fast-growing Albizia (A. adianthifolia and A. zygia, for example) are indigenous, and two legume trees introduced from India, Acrocarpus fraxinifolius and Dalbergia sissoo, have shown exceptional growth rates on appropriate sites.

Although some of these tropical legumes produce useful lumber and paper pulp, over all, they complement conventional silviculture rather than compete with it. In foresters' terms, many have "poor form" and are of little value for construction timber or luxury wood purposes. Rather than competing

with teak, mahogany, dipterocarps or tropical pines, these are species for:

- farms, backyards, pasture lands, roadsides, canal banks and fencelines, or what one might call "peoples' forestry";
- village woodlots and energy plantations to fuel kilns, electricity generators, cooking stoves and crop dryers;
- agrisilviculture (agroforestry), because they provide a wealth of products including forage, green manure and food;
- use in shifting cultivation, because the natural drop of protein-rich leaves, pods and twigs contributes nitrogen, organic matter and minerals to upper soil layers and can markedly speed up the rebuilding of worn out soils;
- quick rotation cash crops, both for the private landowner and the government forest department; and
- utility purposes such as beautification, shade and shelter belts.

APPENDIX V

MEDICINAL PLANTS OF THE WEST INDIES*

Current health planning strategies in developing countries are taking into account the need for serious evaluation of traditional medicine as part of the overall health delivery programme. This new motivation stems in part from the spectacular successes in traditional medical practices in the People's Republic of China, and the recent active promotion and development of traditional medicine by the World Health Organization. Although for centuries, most of the rural population of the world has relied almost exclusively on herbal medicine to help solve health problems, it is only recently that the WHO and other world bodies interested in health delivery systems have been paying serious attention to the practicality of traditional medicine.

In a recent briefing document on "Drugs and the Third World" issued to the media by Earthscan (an information unit on global environmental issues supported by the United Nations Environment Programme and the International Institute for Environment and Development), it was pointed out that a number of United Nations agencies, including WHO, UNCTAD, UNIDO, UNDP AND UNICEF,

*This Appendix is contributed by Edward S. Ayensu.

are collaborating with Third World countries to fight multinational drug companies that are charging excessive prices for drugs. The report further stated that the multinationals put undue pressure on Third World doctors to prescribe unnecessary drugs, thus making excessive profits which are transferred out of the developing countries. This whole situation has been described by Dr. Halfan Mahler, Director-General of WHO, as "drug colonization."

To combat the actions of the multinational drug companies , it has been suggested that bulk buying of essential drugs at reduced prices, the development of small-scale drug manufacturing industries, the establishment of new drug patent laws, and the full-scale screening and utilization of medicinal plants should be undertaken.

In recent years, there has been intensified exploration of medicinal plants in a number of developing countries. In many cases, the plants collected are sent to laboratories in developed countries for screening and analysis and the subsequent preparation of drugs, which are in turn sold at exorbitant prices to the primary raw material-producing countries. The economic gains to the developing countries are obviously minimal at best. The logical answer to such a situation is the local production of basic drugs. This could take the form of wholly locally owned establishments or concerns supported by investment from foreign investors.. Where multinationals are concerned, developing countries should resist any attempts to force them to restrict their formulation to drugs using active ingredients that have to come from parent foreign companies at exorbitantly high prices. Developing countries should also be aware of "transfer pricing" that involves tied purchases at inflated prices, as well as the unfair guarantees sought by foreign companies that make it impossible for host governments to gain from fair taxation, tariffs and the effects of exchange rates that affect profits and royalties.

The development of self reliance in drug manufacturing industries in the Caribbean could bring satisfaction to many West Indians who could ill afford to pay inflated prices for basic drugs. It is welcome news that the concept of developing regional drug centers has been accepted by some Caribbean countries. The first regional center for the West Indies involving Guyana, Jamaica, Barbados and Trinidad is currently being set up under CARICOM. This CARICOM drug establishment will determine which drugs are most needed in the region; expand the existing Caribbean "pooled drug procurement" systems; compile a Caribbean formulary; help each country to set up its national centralized drug purchasing system and revise its patent laws; and explore the possibilities of cooperation with other developing countries on market information, trade and technology.

Various drugs of natural origin, especially those principally obtained from plants, have been in use by different cultures including the peoples of the Caribbean for many years (cf. Ayensu 1978; Schultes 1972; Tippo and Stern 1977). Some information on such medicinal plants has been collected from many of the islands mainly by foreign scientists and researchers. However, there is a lack of documentation on the plants that are currently in use in the local pharmacopoeia from the individual islands. Even more scarce is detailed information on the phytochemistry of the known medicinal plants from the region.

It is hoped that a vigorous attempt will be made, possibly on a regional basis, to study the phytochemistry of the plants and the chemical compounds that exhibit their therapeutic properties (cf. Swain 1972).

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EDITOR'S NOTE. Dr. Ayensu presented to the workshop a 143 page compilation of

plant materials reportedly used for medicinal purposes on 24 islands in the Caribbean. This is to be published elsewhere. Interested readers may contact Dr. Ayensu at the Office of Biological Conservation, Smithsonian Institution, Washington, D.C. 20560.

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APPENDIX VI

PLANT-DERIVED PHARMACEUTICALS

World markets for pharmaceuticals from plants are very large and they offer opportunities for Caribbean nations and scientists to exploit. Species worth considering include:

1. *Catharanthus roseus*
2. *Vinca* minor
3. *Isertia* species
4. *Acnistis* species
5. *Cassia* species
6. *Lonchocarpus* species

CATHARANTHUS ROSEUS*

Grown as an ornamental throughout the Caribbean region, *Catharanthus roseus*, the common periwinkle, contains several alkaloids in demand for pharmaceutical purposes in Europe and the United States. These alkaloids include ajmalicine, vincaleukoblastine (VLB) and leurocristine (VCR).

*This section is contributed by Geoffrey A. Cordell

Catharanthus roseus is currently being grown commercially in Florida and Texas, but the main supplies of VLB and VCR come from Hungary. This is no mean technical feat since only 1 gm of VCR and 15 gm of VLB are isolated from a ton of the dried leaf material.

Several new developments in this area in recent years have revolutionized the potential availability of the most critical of these alkaloids, VCR. Because VCR is less abundant, substantial efforts were made to synthesize VCR from VLB. In 1976, these efforts proved successful, and yields in the region of 50-60% have been claimed for this process.

More important, however, is the recently reported synthesis of VLB itself. Attempts had been made for several years to join together the two monomeric units and this was finally achieved in 1976 to afford anhydrovinblastine. In April 1979, the formal synthesis of VLB was announced. To put this in perspective, the two monomeric alkaloids, vindoline and catharanthine, used in the synthesis of VLB are major constitutents of the leaf material. Clearly, the potential now exists for the isolation of vindoline, catharanthine, vincaleukoblastine and leurocristine, each of which is of commercial significance. Studies should be initiated to determine the possibilities for the cultivation and partial processing of the plant material.

The roots of the plant produce ajmalicine and the leaves, a related alkaloid serpentine. Ajmalicine is quite widely used in Europe in preparations for the treatment of heart disease, and new suppliers are needed.

VINCA MINOR*

Closely related to the genus Catharanthus is the plant, Vinca minor,

*This section is adapted from the National Academy of Sciences report, Natural Products for Sri Lanka's Future.

although the alkaloids obtained are characteristically different. The most important of these is vincamine which may be obtained in good yield from Vinca minor. Current interest in this alkaloid is high because clinical reports indicate that it increases oxygen supply to the brain. It is currently under investigation for marketing in the United States. Experimental cultivation of Vinca minor should be studied in the Caribbean in the event that vincamine becomes widely used.

ISERTIA SPECIES*

In Guyana, Trinidad and other Caribbean nations are found the "wild tobaccos," Isertia parviflora and related species. The large leaves of these weedy shrubs probably contain valuable alkaloids. Amazon species of Isertia have high levels of psychotrine, and this alkaloid can be chemically converted to emetine which now sells at very high prices. This is because emetine is expensive to synthesize chemically and because the traditional natural sources are being wiped out by rapacious harvesters. Emetine is the major drug used for treating amoebic dysentery and in the most modern treatments for malaria. Malaria is increasing in many areas (including Louisiana, USA) and virulent strains of the parasite, unaffected by older drugs, are appearing. Adding emetine, however, restores the effectiveness. Thus, emetine is in great demand, particularly as it is the only drug yet found that acts this way. The wild Asclepias species (Ipecacuana) of Panama and Colombia, now exploited for emetine, have never been cultivated and are running out, thus making the "wild tobacco" a new crop and a potential foreign exchange earner for Caribbean nations.

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*This section is contributed by R.E. Schultes and N.D. Vietmeyer.

Needed are:

- trial cultivation of the plant;
- development of extraction methods;
- development of fall production techniques.

All of these are within the capabilities of Caribbean scientists and institutions.

ACNISTUS SPECIES*

These small trees are native to the Andes and to Caribbean highlands (although a specimen is growing well on the U.W. I. campus at St. Augustine). Leaves of the Andean species contain scopolamine in heavy concentrations. This alkaloid is used widely in drugs including sleep-aids, amaesthetics and tonics. It is now expensive because it is extracted from slow-growing plants in the Balkans where wages are high. The Caribbean Acnistus species might prove to be a better scopolamine source for world markets, especially because of its fast growth and the year-round growing season.

Experiments are needed to determine scopolamine content in the Caribbean Acnistus. In addition, trials of cultivation and extraction techniques should be undertaken. Again, all of these are within the abilities of Caribbean scientists and institutions.

*This section is contributed by R.E. Schultes and N.D. Vietmeyer

CASSIA SPECIES*

Cassia acutifolia and *Cassia angustifolia* are the commercial sources of sennosides A and B which are widely used as laxatives. These compounds are in limited supply and new sources are being sought. The Caribbean region has several indigenous *Cassia* species that should be evaluated for the presence of these compounds.

LONCHOCARPUS SPECIES*

Lonchocarpus species have an extensive folklore in the Caribbean region as fish poisons; an activity almost certainly due to the presence of rotenone. This compound, which is used worldwide as an insecticide, could possibly be obtained commercially from the available *Lonchocarpus* species in the region.

*These sections are contributed by Geoffrey A. Cordell.

APPENDIX VII

MEDICINAL AND TOXIC PLANT PRODUCTS*

There is a popular misconception in the United States and throughout the world that the present drugs in the prescription and over-the-counter markets are derived by synthesis. Without doubt, this notion has contributed markedly to the impression, prevalent among the large pharmaceutical manufacturers, that natural sources have little to offer in the way of new compounds for commercial development.

There is clearly an element of public relations that has been sorely missing in this area. Few have stood up and said, "Examine what plants have done for you in the past, consider what modern techniques could bring forth tomorrow." Steadily, the budget for natural products research in the major pharmaceutical houses has diminished in the past years. Yet almost certainly, this is short-sightedness on a most alarming scale.

In the beginning, there were natural products; in the end, there will still be natural products. They will still be there waiting to be found unless we do something about developing these natural resources. There is a world concern about energy, particularly the fossil fuel, yet how much energy is wasted each year producing and processing drugs from petroleum

*This Appendix is contributed by Geoffrey A. Cordell.

products by synthesis? Think of the energy that nature employs in producing all the hundreds of thousands of organic chemicals distributed in the fungal plant and animal worlds at no expense to us. Until we make a concerted effort to investigate the pharmacologic properties of some of these compounds, this incredible amount of energy is being sorely underutilized. But what if we do find something interesting? Is there a market for anything new? Indeed, what is the present market situation? Examine the data in a pharmaceutical environment--the United States--where sales of natural products are probably artificially low.

In 1973, which is the last year for which good data are available, 1.532 billion prescriptions were dispensed in community pharmacies in the United States. Of these, 41.2% contained products from natural sources; 25.2%, products from higher plants. That is nearly twice the number of products from microbial sources. For plant products alone, this amounts, at $4.13 a prescription, to $1.59 billion. Assuming a 7% inflation rate for pharmaceutical products between 1973 and 1979, this could now well be in the region of $2.4 billion products this year. But remember, this is only in community pharmacies.

What about hospitals and federal and state establishments? Conservative estimates would place the total value of prescription products containing higher plants or their products at $4 billion, and this is for the United States prescription market alone! The other major prescription markets in the world, such as Europe and the Far East, and the non-prescription drugs have not been considered.

What are these products which command such an important position in the marketplace? The twelve most common of these are shown in Table 1, and only two of these, ephedrine and pseudoephedrine, are produced by synthesis.

Fantastic efforts have been put into steroid synthesis in the past twenty-five years, yet 95% of the total requirements for the steroidal nucleus are produced from diosgenin isolated from Dioscorea species. Even a relatively difficult natural product to obtain such as reserpine, the main hypotensive alkaloid of Rauvolfia serpentina, costs twice as much to produce synthetically as it does to isolate.

Yet there is even another aspect to be considered, for so far, we have discussed only pure compounds; in 1973, there were 38.3 million prescriptions (2.5% of total) in the U.S. containing 99 different crude plant products, and the eight major ones are shown in Table 2.

The previous paragraphs have emphasized the pharmaceutical and economic significance of drug natural products from higher plants, but we should not forget that natural products may also be important as pharmacologic tools because of the incredible range of activity displayed by these compounds. As an illustration, let us ponder a group of about 5,000 known compounds, the alkaloids. Table 3 shows just some of the vast range of physiologic and pharmacologic responses produced by this group of compounds.

Remember, though, we are not always looking for the development of the natural product into a commercially viable entity. There is the possibility of stimulating the development of new synthetic entities which have modified pharmacologic responses. The development of procaine and related anesthetics based on cocaine are of course a classic example.

With this rather extensive background as a prelude, let us consider the problem of how meaningful and significant projects may be developed in the area of Medicinal and Toxic Plant Products.

The magnitude of world markets for pharmaceuticals derived from natural products affords a unique opportunity for many developing countries to

become providers of these precious compounds either as crude extracts or as partially purified extracts. Such efforts in the pharmaceutical marketplace of the world should be actively encouraged by the governments concerned for there seems little doubt that foreign currency reserves can be increased by exporting these products. Provision of pharmaceutical products from a home-based industry will undoubtedly make these compounds more readily available and also reduce foreign currency losses. As crude oil prices have risen, however, so has the cost of all commodities from it, including many prescription products. The wheel has turned full circle and plants are again being regarded as a viable source of new drug products by the more enlightened pharmaceutical manufacturers.

Recently, the WHO has begun to look at the problems of health care delivery to the third world countries and has recommended among otherthings the development of small-scale drug manufacturing industries and full scale screening and utilization of medicinal plants. With this in mind, let us turn our attention to the Caribbean region, where a three point program is suggested to develop natural products as pharmaceutical entities in the region.

A. Development of a program to study the flora of the region for potentially useful, new pharmaceutical entities.

B. Development of plants for established pharmaceutical entities.

C. Development of training programs and fellowships.

A. <u>Development of a program to study the flora of the region for potentially useful, new pharmaceutical entities</u>.

Peoples of the Caribbean have used their indigenous plants as providers of health care for many years. Indeed, it is estimated that 70% of the population still uses these so called "bush teas." The reasons for this are

manyfold, but two important contributing factors are the failure of the modern drugs to treat a disease state, whereas the herbal remedy will, and the exceptionally high cost of health care for physician visits and imported prescription products.

It is therefore absolutely clear that sections of both the rural and urban populations of the Caribbean have to and will continue to rely on the herbalist and his bush teas for their primary health care. Under these conditions, it is essential that the population be protected from any danger due to undue toxicity.

The Caribbean region is replete with information pertaining to the use of medicinal plants. However, at the present time, the data are very dispersed and consequently an initial objective should be to collect, collate and publish this information to the scientific and lay communities. The latter publications will serve to educate the rural community as to the nature and uses of the products available to them. Personal interviews should also be conducted with herbalists before these practitioners disappear from the community. The available data should also be compared with the current body of knowledge on medicinal plants. For there is a need to establish whether prior work has revealed toxicity or an established, isolated active principle. As an absolute minimum, toxicity testing should be carried out. It cannot be assumed that because a bush tea is currently used, that it is non-toxic.

This should illuminate several plants which are likely to be health hazards rather than of potential therapeutic benefit. As this information becomes available, so it should be passed on to the community through publications and bulletins warning that certain plants should not, on any account, be used for medicinal purposes. The aim is preventive health care for the rural and urban communities.

Clearly though, this should be just the beginning of an extensive programme which must be aimed at an examination of the most active medicinal plants for their active principles. Such work requires taxonomic, chemical and pharmacologic collaboration in a team effort, where the long-term goal is to develop new pharmaceutical products not just for the Caribbean, but for the whole world.

The next phase should be to develop selected drugs thought to be most efficacious through botanical quality control, cultivation where appropriate, and marketing. It has been already indicated that "bush teas" are unlikley to be eliminated from the health care delivery system and consequently some controls must be developed to assure that an appropriately identified, unadulterated product be available for the consumer. It is recognized that prevailing local laws will have to be taken into account. It must be emphasized that this is a temporary solution to a health care problem and will rely on appropriate medicinal diagnosis if it is to be effective. This does not imply scientific endorsement of the efficacy of any of the products.

Concurrently with this program, work should begin on the isolation, structure elucidation and pharmacologic evaluation of the active principles of the selected plants. Efforts in other areas, particularly in the discovery of new anti-cancer agents, have indicated that all isolation and separation steps should be monitored by an appropriate biological model system.

Those active compounds which appear, based on preliminary pharmacologic testing, to have the most promising activity compared with existing market products should be considered for more extensive pharmacologic and toxicologic testing. Extensive successful work in this area could eventually lead to a sponsored pharmaceutical industry, which could substantially reduce the import costs of prescription products and bring cheaper, improved health care to rural communities.

B. Development of plants for established pharmaceutical entities.

The vast worldwide market for plant-derived pharmaceuticals and the ability of Caribbean nations to grow many of them suggest the CARICOM region should begin an active research program in this area. Exportation of raw plant materials and active principles could greatly increase foreign currency reserves in the region. Some important plants and their potential are shown in Table 4.

TABLE 1

Most Commonly-Encountered Pure Compounds
From Higher Plants Used as Drugs in 1973 in the U.S.A.

Active plant principle	Total number of Rxs[a]	Per cent of Total Rxs
Steroids (95% from diosgenin)	225,050,000	14.69
Codeine	31,090,000	2.03
Atropine	22,980,000	1.50
Reserpine	22,214,000	1.45
Pseudoephedrine[b]	13,788,000	0.90
Ephedrine[b]	11,796,000	0.77
Hyoscyamine	11,490,000	0.75
Digoxin	11,184,000	0.73
Scopolamine	10,111,000	0.66
Digitoxin	5,056,000	0.33
Pilocarpine	3,983,000	0.26
Quinidine	2,758,000	0.18

[a]Total number of Rxs in 1973 was 1.532 billion

[b]Produced commercially by synthesis, all others by extraction from plants

TABLE 2

Most Commonly Encountered Higher Plant Extracts Used in Prescriptions in 1973[a]

Crude Botanical or Extract	Total number of Rxs[b]	Per cent of Total Rxs
Belladonna (*Atropa belladonna*)	10,418,000	0.45%
Ipecac (*Cephaelis ipecacuanha*)	7,047,000	0.46%
Opium (*Papaver somniferum*)	6,894,000	0.45%
Rauwolfia (*Rauvolfia serpentina*)	5,822,000	0.38%
Cascara (*Rhamnus purshiana*)	2,451,000	0.16%
Digitalis (*Digitalis purpurea*)	2,451,000	0.16%
Citrus Biflavonoids (*Citrus spp.*)	1,379,000	0.09%
Veratrum (*Veratrum viride*)	1,072,000	0.07%

[a]Compounded prescriptions represented less than 2.0% of total prescriptions and were excluded from the survey data.

[b]Total Rx volume in 1973 was 1.532 billion prescriptions.

TABLE 3

SOME ALKALOIDS AND THEIR BIOLOGICAL ACTIVITIES

ALKALOID	ACTION OR FIELD OF USE
Morphine	analgesic, narcotic
Codeine	analgesic, antitussive
Atropine	mydriatic, antispasmodic
Scopolamine	sedative
Reserpine	antihypertensive, tranquilizer
Deserpidine	antihypertensive, tranquilizer
Quinidine	cardiac depressant, antiarrythmic
Quinine	antimalarial
Caffeine	CNS stimulant
Ephedrine	bronchodilator
Colchicine	gout suppressant
Vinblastine	generalized Hodgkins disease
Vincristine	childhood leukemia
Pilocarpine	treatment of glaucoma
Vincamine	improved circulation

TABLE 4

SOME IMPORTANT PLANT DRUGS AND THEIR POTENTIAL FOR THE ECONOMY OF THE CARIBBEAN

PLANT ACTIVE COMPOUND	POSSIBILITY OF CULTIVATION
Atropa belladonna atropine hyoscyamine scopolamine	Potential for cultivation should be studied
Datura species scopolamine	as above
Catharanthus roseus vinblastine vincristine ajmalicine	Cultivation and extraction could be profitable
Vinca minor vincamine	Cultivation and extraction should be studied
Discorea species diosgenin	Would cultivated plants give adequate diosgenin
Digitalis purpurea digitoxin	Cultivation and extraction could be profitable
Digitalis lanata digoxin	Cultivation and extraction could be profitable
Rauvolfia species reserpine rescinnamine deserpidine	Introduce appropriate species?
Papaver species morphine codeine	Cultivation of high thebaine-yielding species should be studied

APPENDIX VIII

UNDERUTILIZED SOUTHEAST ASIAN PLANTS WITH PROMISE FOR THE CARIBBEAN*

SOURCES OF CARBOHYDRATES

The breadfruit, Artocarpus altilis has become established throughout Central America as a village tree providing an alternative source of carbohydrates (the seeds are boiled, baked or fried). It demands fertile soil, but it is a useful cover for steep land liable to erosion. There are some 30 species of Artocarpus in the Far East. Others cultivated there include A. incisus (terap), A. heterophyllus (Nangka jack) and A. integer (champedak). The latter two are smaller trees than the breadfruit, bearing their large oblong fruit with scented pulp surrounding very large seeds on the trunk. Nangka is a major carbohydrate source in densely populated parts of West Java where it is grown in suburban gardens or small orchards; it produces fruit almost continuously throughout the year and grows well in mixture with other taller fruit tree species including the breadfruit. It is little cultivated in the American tropics.

*This Appendix is contributed by Peter Ashton.

The sago palm, Metroxylon species, grows in periodically flooded alluvium, including brackish sites. It produces supine branching stems and erect unbranching leafy stems which ultimately individually flower and die. As these erect stems grow, they accumulate insoluble starch in the pith. When 3-6 m tall, the apical meristem develops into an enormous terminal inflorescence. As this expands, the huge starch store, then at its maximum, is converted into soluble sugars and these rush into the inflorescence. The secret is to fell the stem as soon as the florescence begins to form. The starch is rasped out, washed and dried. A growing technology exists for processing it, fermenting it, etc.

Various aroids, including Colocasia and Amorphophallus, bear tubers and are important starch sources.

SOURCES OF SUGAR

Of the several Asian palms whose young cut inflorescences yield sugar, including Arenga saccharifera and Caryota urens, the most productive is the arid zone species, Borassus flabellifer. It may only be a native in Southern India and the extreme north of Ceylon, but is now widely grown in Indochina and the lesser Sunda Islands, often in pure stands. There is a southern Indian text on the 801 uses of this palm. The syrup is copiously produced, can be concentrated into sugar, fermented or fed to livestock. The leaves are used for thatch, utensils, even burned as fertilizer. The stem is used for construction and coffins. The palm produces syrup during the dry season at a time of low agricultural activity, allowing cultivators to grow other crops as well. An excellent account has been given of the Rotinese and their sugar palm culture (Fox, Harvest of the Palm, Belknap Press).

SOURCES OF FATS*

Several Asian trees in the families Sapotaceae and Burseraceae have fat-bearing seeds, but the most promising for cultivation would appear to be certain Shorea species (Dipterocarpacea) mainly growing in Borneo. There are some 12 species of which the most important are S. macrophylla and S. splendida which are large trees of moist sites, and the smaller S. macrantha and S. stenoptera which grow on peats and podsols. The long-chain fats produced are yellow, but otherwise closely resemble cocoa butter which they can replace in chocolate manufacture. They are also used for a variety of purposes, including lipstick and gramophone records. Methods of collecting and storing this fruit have been developed: soaking in water increases their fat content. Their great advantage would appear to be their ability to grow on poor soils in the humid tropics, unlike the demanding Theobroma cacao. Serious disadvantages include difficulties of propagation and their unpredictable flowering; of these, the former could probably be overcome by research while the latter may not apply were the trees grown in a climate with a regular short dry season.

FRUITS

In the last decade, many new cultivars of tree fruit, in particular, citrus, mangos, rambutans and durains have been developed in the Far East. These include high yielding mangos for small gardens in humid climates, seed-

*Reference: J.A.R. Anderson, S.E. Asian Plant Genetic Resources, ed. J.T. Williams et al, pp. 217-230. Source of further information: P.S. Ashton, Arnold Arboretum, Harvard University.

less rambutans which could be tested for canning, and sweet scented durians. None of these seem to have been introduced to the American tropics, but the proximity of the Caribbean to American markets and the tourist industry would suggest they should be tried.

Still unexplored is the possibility of introduction of the several wild species, especially of durian (c. 6 edible species) and rambutans (c. 10 edible species) into cultivation and their hybridizations. In particular, the well established Durio zibethinus and Nephelim lappaceum and their cultivars require soils of moderate to high fertility whereas the wild Durio graveolens and several Nephelium spp. notably N. subferrugineum are grown in nature on podsols. Their possibilites for introduction in Guyana should be investigated.

In the Far East, fruit are grown in mixture in small orchards, usually surrounding dwellings and on land unsuitable for permanent herbaceous agriculture. There is much traditional knowledge concerning the compatibility of different species when planted together. The result is a high productivity tree crop yielding a wide variety of products and at all times of the year. It is thus a valuable cushion to fall back on when staple or commercial crops fail or fetch inadequate prices, and forms a vital part of village economics. The trees may be underplanted by shade-tolerant herbaceous crops, such as gingers.

Gingers - The Zingiberaceae - yield condiments: Curcuma (turmeric), Ellateria and Amomum (cardamom), Kaempferia (galangal), etc., and fine cut flowers, including the torch ginger. Phoemeria and Alpinia - many grow well in partial shade in mixed herbaceous and tree crops; cardamoms, for instance, are grown under a natural forest canopy at 1,000-3,000 ft. altitude.

RATTAN

Increasing world demand for rattan furniture is being met by injudicious exploitation of wild Bornean stock as a non-renewable source. Only in one area of southern Borneo are rattans grown commercially on any scale. One reason is that the stout, structural rotan manua (Calamus caesius) only grows in seasonal swamps. But rattan for weaving can be obtained from several species besides the best known rotan sega. Calamus spp. sprout from the base, and can therefore be harvested continuously. They need to scramble over trees; being shade loving, they can be planted in fruit orchards, tree plantations, unproductive secondary jungles and protection forests.*

FIREWOOD

The genus Casuarina (including the unpublished Gymnostoma Johnson) deserves greater attention as a firewood source, as besides being fast growing, it has several subsidiary advantages, e.g., it bears root nodules, thus enabling it to fix nitrogen. In New Guinea, one mountain species is planted as a woody fallow by the highlanders.

It has a diffuse open crown of feathery photosynthesizing twigs, resembling a pine. This permits inter- or under-planting with broad-leaved species such as fruit trees. The very large surface area to volume ratio, enhanced by the fibrous bark which attracts a rich epiphyte flora, bestows on mountain species an exceptional ability to "comb" water from passing clouds during the dry season, enabling streams to persist even when there

*Source of Information: Dr. J. Dransfield, Royal Botanic Gardens, Kew.

is six months without rain. Curiously, eucalypts and pines lack this property, of vital importance in areas where two crops of rice have traditionally been grown as in Bali, the Mountain Province of Luzon and Sri Lanka.

APPENDIX IX

THE UTILIZATION OF LOWLAND TROPICAL PODSOLS*

Work at San Carlos de Rio Negro, Venezuela has shown that mineral ions are almost entirely held in the organic horizons of tropical podsols, or in the living forest above. So efficient are these forests at retaining what nutrients exist in these impoverished and excessively draining soils that the streams draining podsol areas are found to be poorer in nutrients than the rainwater falling on the forest. This efficiency is largely attributable to the absence of deciduous species so that continuous metabolic activity is maintained to the dense and extensive root mat in the thick layer of raw humus which, unlike in other rainforests, can greatly exceed aboveground biomass; to the well developed ectotrophic mycorrhizae whose have been found to penetrate the stomata of fallen leaves, extracting soluble ions even before they have been leached; and to the physico-chemical characteristics (leathery, rich in phenolics) of the litter of the podsol flora, which impedes rapid leaching.

Measurements for over 15 years in Borneo have shown that trees in virgin forests on lowland podsols in humid tropical climates do not grow

*This Appendix is contributed by Peter Ashton

significantly more slowly than those on the most fertile soils, and that primary production is comparable. As a much higher proportion of the nutrients in this system are removed, though, when this forest on podsols is harvested, this productivity is not maintained in secondary succession.

The secret of utilization of lowland tropical podsols, if they have to be used, lies in growing trees that simulate the original forest in terms of their nutrient cycle, maintaining dense rooting and ectotrophic mycorrhizae and a closed canopy preventing oxidation of the humus; and producing a crop that can be harvested without major canopy opening or soil disturbance. This can best be attained by mixed crops of tall growing monopodial, narrow or diffuse crowned timber or firewood species underplanted with shorter desne-canopied fruit trees which remain after timber extraction. Far Eastern species include:

Timber Species	Fruit Trees
Agathis damarra ssp. *borneensis*	*Durio carinatus*
Gymnostoma nobile ('*Casuarina Sumatrana*')	*Nephelium subferrugineum*
Ploiarium alternifolium	*N. maingayi*
Tristania pentandra	*N. melonomiscum*
Shorea scabrida	*Mangifera havilandii*
S. balangeran	*Canarium pentanerium*
Combretocarpus rotandatus	*Shorea stenoptera* (illipe)
Calphyllum inonphylloide	*Baccaurea* spp.

With the exception of the illipe, *S. Stenoptera*, the fruit tree species are unlikely to become commercial fruit trees in their own right, but, being adapted to podsols, are promising either as roots tocks upon which congeneric cultivars might be grafted, or for hydridization.

Sources of information on nutrient cycling on tropical podsols:

Dr. Raphael Herrera
IVIC
Caracas, Venezuela

Dr. Hans Klinge
Max Planck Institut für Limnologie
Plon, West Germany

Dr. Carl Jordan
Institute of Ecology
University of Georgia
Athens, Georgia

And on the trees:

Dr. Peter Ashton
Arnold Arboretum
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Boston, Massachusetts