Natural Products for Sri Lanka's Future

REPORT OF A WORKSHOP
2-6 JUNE 1975

National Science Council

NATURAL PRODUCTS FOR SRI LANKA'S FUTURE

Report of a Workshop held
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Preface

This report is the product of a Workshop jointly sponsored by the National Science Council of Sri Lanka (NSC) and the National Academy of Sciences of the United States (NAS). The Workshop's purpose was to identify scientifically sound projects that exploit natural products, that are realistic for Sri Lanka, and that can significantly contribute to the nation's economic and scientific development.

Sri Lanka is ideally suited for exploiting plants. It has warm temperature year-round, ample rainfall and sunlight, and a range of climatic zones and altitudes. A century ago, several tropical plants were introduced to the country. Most grew well, but for reasons of colonial policy only tea, rubber, and coconut became major crops. Even cinnamon, one of the country's most important spices, was neglected.

This report, which has resulted from the joint deliberations of the Ceylonese and American Workshop participants, presents a number of suggestions for improvement of ongoing programmes, for marshalling latent resources, and for experimenting with new food and export crops. A companion report "SLICHEM" (Sri Lanka International Chemistry Programme) outlines a major project to expand and upgrade natural products research in Sri Lanka's universities and research institutes.

The suggestions and recommendations in this report have resulted from the pooled knowledge and experience of all participants and are presented in several chapters that reflect the subject matter of the Working Subgroups of the Workshop. Each chapter of the report establishes priorities that are meaningful in the context of available data and reflect the combined judgment of the participants at the time the Workshop took place.

Clearly, to implement all the top priority items simultaneously represents a task that would exceed the skill, manpower, and funds even of a country larger than Sri Lanka. The Workshop participants realize that within the framework of national goals and policies, government officials must select from all these recommendations a small number of <u>their</u> top priority projects.

In 1974 the National Science Council asked the National Academy of Sciences to join in a Workshop to evaluate natural products that could contribute to the country's future economic development. The Academy agreed, and the Workshop was held in Colombo, June 2 - 6, 1975. The opening address was delivered by Mr. T. B. Subasinghe, Minister of Industries and Scientific Affairs. A comprehensive written review of natural products research in progress in Sri Lanka was prepared by the National Science Council,* and during the Workshop the American delegates conducted brief seminars on new crop plants that are being exploited in other parts of the tropics and on plant products in chronic short supply in world markets.

But the crux of the Workshop was three days of joint working sessions by four separate working groups covering: a) Underutilized Food Crops; b) Plant-Derived Industrial Products; c) Essential Oils and Spices; and d) Medicinal Plants and Plant-Derived Pharmaceuticals. The conclusions of each working group were presented to the Workshop plenary sessions for comment and criticism.

This final report is the edited collection of the drafts from the working groups, together with general conclusions developed by the Workshop participants at plenary sessions. The report is written especially for those who will be making decisions for economic development for Sri Lanka. It presents some ideas that, within the wisdom and experience of some sixty Workshop participants, represent sound, practical alternatives or supplements to existing programmes.

The Workshop participants visited the Peradeniya Botanical Gardens; the University of Sri Lanka, Peradeniya Campus; the Medical Research Institute; the Ceylon Institute of Scientific and Industrial Research; and Floralia Ltd. Some members of the American delegation visited the Coconut Research Institute, Lunuwila; The Rubber Research Institute, Agalawatte; the Bandaranaike Memorial Ayurvedic Research Institute; the Fisheries Research Station; a cinnamon plantation; and the University of Sri Lanka, Colombo Campus.

The sponsors wish to thank the Government of Sri Lanka and the U.S. Agency for International Development (Technical Assistance Bureau, Office of Science and Technology) for their financial support. The Workshop participants thank their kind hosts at all institutions visited, U.S. Ambassador H. E. Christopher Van Hollen, the National Science Council, and Floralia Ltd. for evening receptions, and the Ceylon Government Marketing Department, Lever Brothers Ltd., and Mackwoods Ltd. for gifts of samples of their products and mementos to the American delegates.

Recognition and thanks are also due to the many individuals who contributed long hours and dedicated effort to the Workshop, especially to the Workshop Steering Committee and the Workshop Secretariat drawn from the National Science Council of Sri Lanka and the Ceylon Institute of Scientific and Industrial Research.

Workshop Steering Committee

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* See Appendix B, Documentation, Workshop on Natural Products.

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CHAPTER I

INTRODUCTION

Sri Lanka's economy rests mainly on tea, rubber, and coconut. It is a very tenuous foundation. Reliance on a small number of plants carries great risk, for monocultures are vulnerable to catastrophic failure caused by disease, by variations in climate, or by changing world market conditions. In the past, other countries have been plagued by diseases that have totally destroyed coconut and rubber crops. Growing air traffic between Sri Lanka and other nations increases the probability that new diseases will be inadvertently introduced.

Sri Lanka must seek to exploit other plants--for food at home and for markets abroad. Fortunately, because the island has one of the world's best climates for plant growing--warm and sunny year-round and a range of rainfall zones, altitudes, and soils—plant products can continue to be a mainstay of the nation's economy. But diversification must be encouraged.

To help the economy and to feed, clothe, and house a rapidly increasing population, it is time to consider plant species that heretofore have been little known, under-exploited, or neglected in Sri Lanka.

The apparent advantages of the plants that are widely cultivated in Sri Lanka over those that are not, often result only from the disproportionate research attention they have received. Many species that could be important for the country's economy were disregarded during the colonial era, when consumer demands in Great Britian and among local British residents largely determined local agricultural research priorities. The selected crops—such as rubber, coconut, tea--received much research attention. Even after independence, the pattern of concentrating on a few crops changed little. Markets abroad were already established and the country needed foreign exchange.

Because of this, the local potential of many crops has not been fully explored. (A striking case is Dambala, *Psophocarpus tetragonolobus.* This native plant, virtually unstudied in Sri Lanka, promises to be one of the most productive plant-protein sources in the tropics.) There is an urgent need for researchers to become acquainted with Sri Lanka's plant life. Important new products--oils, gums, and waxes; proteins for food and feed; compounds of industrial and medicinal importance; and chemicals for insecticides--are likely to result.

The variety of Sri Lanka's plant species is impressive. There are recorded over 3,300 flowering plant species in about 1,300 genera and 172 families. Contained among them may be a wealth of new products. In deciding upon the potential of each, it is not enough to consider solely traditional needs and markets. New raw materials will be required in the future. Changing conditions are already creating demands for new products from previously underexploited plants; more will be needed as pressures increase for the exploitation of renewable resources.

-- Innovations in transportation have made it feasible to transport perishable products around the world.

-- Affluence in certain parts of the world has increased both the consumer's ability to pay for special items and his desire for new products such as rare spices, fruits, fragrances, cut flowers, and other luxuries.

-- Sri Lanka's burgeoning population and continued poverty are increasing the need for highly productive food plants and for hardy species that can be grown in currently unused marginal land.

-- Improved scientific knowledge has created demands for new specialized plant products, including unsaturated fats, low-calorie sweeteners, and biodegradable pesticides.

-- New industrial processes have stimulated the need for larger supplies of materials such as elastomers, lubricating oils, drug precursors, and waxes.

Plants grown in Sri Lanka could meet many of these demands.

CHAPTER II

RECOMMENDATIONS

Later chapters recommend almost forty plants (or plant-derived products) that, because of their potential for Sri Lanka, warrant greater use or greater attention from researchers. A selection of nine, that in the judgment of the Workshop deserve the highest priority, are summarised in this chapter, along with general recommendations on science for Sri Lanka's future.

PROJECTS FOR IMMEDIATE IMPLEMENTATION

Pastures Under Coconuts

Sri Lanka's pioneering work on intercropping of pastures with coconuts is now being applied elsewhere in Asia, in the Pacific, and in the Caribbean. But it has been little adopted in Sri Lanka itself. Planting pasture in coconut plantations should be greatly increased. It will have major impact on the nation's milk and meat supplies, will increase farm income, and will improve stability in the coconut industry. A network of nurseries to produce and distribute pasture-cuttings to coconut farmers is recommended.

Intercropping Under Coconuts

Using the coconut plantation land to grow a second crop could produce food, increase foreign exchange, and expand employment in rural areas. This intensive agriculture requires careful crop management, but the Coconut Research Institute has completed the necessary trials and has found successful methods. Their procedures should be extended to the whole coconut farming community.

Passion Fruit

There is large demand for passion fruit products in world markets. However, improvements in horticulture and in processing are indispensable if Sri Lanka is to capitalize on this demand.

Floriculture

A number of tropical countries (Colombia, Brazil, Ivory Coast, Israel, and Singapore, for example) are now cashing in on the enormously lucrative export of fresh flowers to Europe, North America, and Japan. The International Bank for Reconstruction and Development (World Bank) has given loans for such ventures. Sri Lanka should explore the potential for large-scale production of saleable flowers for air shipment to Europe, the Middle East, Hong Kong, or Japan.

Kenaf

This quick-growing, tall-stemmed herb produces a very high quality fibre for use in textiles or paper. Recently, its agronomy and the technology for paper production has been worked out by the U.S. Department of Agriculture. A decade ago agronomic trials showed that it grows well in Sri Lanka.

Citronella

Although "Ceylon" citronella is not in high demand, the "Java" type, little grown in Sri Lanka, is highly valued by the international fragrance industry. A task force of researchers and commercial interests is needed to develop jointly this latter type into a marketable product in Sri Lanka. The returns in foreign exchange might be substantial.

Lemongrass Oil

There is a growing demand by industry for citral, the major ingredient of lemongrass oil, a demand that is likely to continue for at least a decade. Increased production could yield important foreign exchange earnings for Sri Lanka.

Patchouli Oil

This oil is a standard component of many fragrances and, although substitutes have often been tried, none have been found satisfactory. Continued demand for this oil appears certain, and it offers a potentially profitable opportunity for Sri Lanka. If a continuing supply of good-quality patchouli oil can be guaranteed, contracts from large-volume users for long-term purchases are likely to be forthcoming.

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 tea or coconut in Sri Lanka. Increased production from such plantations should be fostered.

THE IMPORTANCE OF RESEARCH

Short-term, stop-gap measures are not the answer to the long-term development of Sri Lanka and its quest for economic stability and independence. It is doubtful that any developing country can become strong without a proper balance of scientific research, development of new programmes, and acquisition of technology that will allow it to exist in a highly competitive world. Sri Lanka is no exception.

The Workshop members urge that serious consideration be given to the support of basic and applied scientific research in Sri Lanka, especially as they apply to the area of natural products, on which the country relies so heavily. A number of research projects and research areas are suggested in the body of this report. Proposals like these must not be neglected if Sri Lanka is to prosper and grow.

LIBRARY FACILITIES

The American group was shocked by the deplorable state of library facilities and the lack of up-to-date technical journals and books in Sri Lanka. They were incredulous that no scientific journal subscriptions or purchases of scientific books for research and technical libraries have been authorised since 1973. For all practical purposes, therefore, for the past two years or more the Ceylonese scientific community has been isolated from the rest of the world. This cannot continue much longer without mortal results in science, since a large portion of their knowledge will very rapidly become out of date and they will soon lose touch with the subjects in which they were trained.

The reason for this draconic measure was apparently the desire by the Sri Lanka planning authorities to save foreign currency, but the penalty for such savings is extremely high. Immediate steps must be taken to solve this problem and a permanent solution must be found quickly. The visiting scientists recommend that the key research institutions in Sri Lanka make a list of essential journals and books and that they ask the Government of Sri Lanka to fund subscriptions at once.

If the Government of Sri Lanka cannot afford to subscribe to these journals, the American group suggests that local scientists contact the embassies of the key countries publishing such journals (United States of America, United Kingdom, West Germany, France, Switzerland, Scandinavia, etc.) and provide them with lists of the most useful journals and books published in their countries. The proper Ceylonese authorities should ask these foreign governments to donate the journals to an appropriate library, which would then make them available to all relevant Ceylonese institutions. This would be an appeal to international charity, probably not the most desirable alternative, but an improvement over the present situation, which has already caused damage and will cause irreparable retrogression if allowed to persist.

The Workshop participants were encouraged to learn of one positive step to help the literature situation. A proposal for the establishment of a National Scientific and Technological Information Centre has been submitted to the government. It is hoped that it will be funded.

This Centre will establish a central documentation and information service, which will also link the existing information resources. The benefits of the project should be that all information resources available in the country will be used to the fullest extent. In the long-term, it is hoped that this Centre can cooperate with national documentation centres of other nations.

The Centre initially will operate through the National Science Council. A phased programme of preliminary operations for 1975 - 1978 has been prepared, recruitment of staff is complete, and the work programme has already been initiated.

The Workshop wholeheartedly endorses this project.

CENTRAL LABORATORY FOR SCIENTIFIC INSTRUMENTATION

Sri Lanka's scientists have long felt the need for a Central Laboratory for Scientific Instrumentation. The concept was proposed over a decade ago as a means to: a) increase efficiency of instrument utilization; and b) centralise repair and maintenance facilities. It is proposed then that a centralised instrument facility be designed to serve the needs of all research institutions and universities in the island and be administered through the National Science Council. The Workshop recognises the need for such a facility and understands that the National Science Council has already taken initial steps towards its installation.

High priority <u>must</u> be given to this proposal.

A PROPOSAL FOR A SRI LANKA INTERNATIONAL CHEMISTRY PROGRAMME (SLICHEM)

The international scientific community is increasingly worried by the gap between scientists in the developed and developing world. Sri Lanka is a prime example of the serious consequences resulting from the isolation of scientists from their colleagues, from service facilities, and from the literature. Sri Lanka has highly trained scientists and it has buildings constructed for research and teaching. But both are underutilized. The root cause of this is the difficulty in obtaining foreign exchange. Chemists working in natural products are among the scientists hardest hit. This situation could be corrected by a novel project that proposes organizing chemical societies in a number of countries into a cooperative programme aimed at supporting chemical research in Sri Lanka. In this project each chemical society would provide funds for scientific equipment produced in their countries and would provide travel funds for one of their leading natural-products chemists to work in a continuing collaborative research with Ceylonese chemists in the existing university campus and research institutions like the Ceylon Institute of Scientific and Industrial Research.

Without any expenditure of Sri Lanka's foreign exchange reserves, this programme would help bring to the island the equipment and facilities that the scientific community needs so desperately. It would decrease the isolation Ceylonese scientists now feel, for it would bring in a continuous stream of the world's finest natural-products chemists. Their impact on the Sri Lanka future development is inestimable. Finally, it would perhaps help to hold back the brain-drain pressures that are forcing Ceylonese scientists to seek fulfillment in the better-equipped laboratories abroad.

This proposal is detailed in a companion report.

PRESERVATION OF PLANT GERM PLASM

A massive effort is needed to ensure the survival of endangered plant species throughout Sri Lanka. Wanton destruction of natural vegetation is killing many, but the relentless spread of conventional agriculture displaces and destroys many others. Preservation of endangered and threatened species of plants in their native habitat is the best method of ensuring their survival and should be adopted. Cultivation or artificial propagation of these species should be used only as a last resort when extinction appears certain, and then with the intention of reestablishing the species in its natural habitat.

Habitat preservation must be given the highest priority in all conservation activities, but particularly when dealing with endangered species. Otherwise, potential breeding stocks, clones, and cultivars could become extinct.

To this end, the botanic gardens and field stations must also be preserved. The nation's native flora resources are too vital to its economic development to allow any of the existing collections to be lost.

CHAPTER III

UNDERUTILIZED FOOD CROPS

Several agricultural projects relating to food deserve urgent government attention. The following have been identified as having high priority:

1. Pasture under coconut
2. Intercropping under coconut
3. Passion fruit
4. Limes
5. Manioc
6. Dambala
7. Sweet potato
8. Kidaran
9. Kandala

PASTURE UNDER COCONUT

The unavailability of suitable land is a serious factor that limits food production in Sri Lanka; most of the island's arable land is now used. However, there are approximately 1.2 million acres of coconuts, and using the land between the palms for additional crops would make about 1,000,000 additional acres available for agriculture. If improved pasture and dairy cattle can be introduced to the small coconut holdings, increased production of meat, milk and other foods would result, and much foreign exchange could be saved. Sri Lanka's Coconut Research Institute (CRI) has pioneered the development of pasture under coconut. Through its efforts, world attention has been focused on the potential of coconut lands to produce milk and meat, and increase farm income. CRI also was the first to recognize the importance of the pasture grass *Brachiaria miliiformis* (Cori grass) and to report to the world its potential as a pasture plant. Using the CRI research, coconut-growing countries elsewhere in Asia, in the Pacific islands, and in the Caribbean have grown some Cori grass. But unfortunately the research results have not been widely adopted in Sri Lanka itself.

This situation should not continue. A large percentage of the total cattle population is already raised on unimproved "natural" pastures under the palms. Much greater production could be achieved if CRI's results with pasture intercropping were widely applied.

The ingredients for a programme that can be implemented immediately are at hand: there is a significant cattle population already present; the research work has been done; and Colombo's markets for both milk and meat are close to the Coconut Triangle.

The government's policy of providing subsidies for planting improved pastures is commendable. The need now is to find mechanisms that will accelerate the programme and its adoption. The Workshop recommends the following procedure:

Cori grass nurseries should be established. One acre of nursery should be established for every 200 acres of pasture to be developed. Enough cuttings from the nursery should be made available to farmers (without charge) so that they could plant one acre on their farms. Cori grass grows rapidly and can be grazed six to eight weeks after planting, so there will be little loss of feed during the changeover.

From his first acre, the farmer could harvest his own Cori grass to plant in other areas. The programme must include an extension phase to emphasize to farmers that this improved pasture will produce better feed for their animals and greater income.

The new pastures will require nitrogenous fertilizer; such nitrogen can come from commercial fertilizers, but a better method is to grow a legume that fixes nitrogen from air. The legume of choice for growing in combination with Cori grass is Centro (Centrosema pubescens). Centro reproduces from seed, and the seed is available locally, however, increased seed production may be required. Another possible legume is Leucaena latisiliqua (formerly L. leucocephala or L. glauca), which can fix large amounts of nitrogen. Very productive varieties have now been developed at the University of Hawaii; seed is being exported in large quantities to the Philippines.

The CRI has worked out the techniques for growing high-quality pasture under coconuts. It can provide technical advice on planting and managing the pastures and on obtaining or growing Centro seeds; it can also provide Cori grass planting materials. No foreign technical assistance is required. Except for a possible shortage of Centro seeds and fertilizers, all of the ingredients for this programme are available in Sri Lanka.

This project should be coordinated with the farm demonstration programme on intercropping that is now being conducted by the CRI in the three subzones of the Coconut Triangle. This programme could be rapidly implemented on several hundred thousand acres of coconut lands. However, careful phasing will be needed to keep it manageable. This project should provide much-improved feed, stabilize the livestock industry, and increase production of livestock products. It will bring an increased milk supply for Colombo and the nation; obvious nutritional benefits will result.

In addition, the project will also increase farm income and bring greater stability to the coconut industry. Farm labour utilization will also improve.

INTERCROPPING UNDER COCONUT

An accelerated programme of growing crops other than pastures on coconut lands would also be important for Sri Lanka. For local use or export, food plants, essential oil-bearing plants, medicinal plants, or industrial crops can all be grown on the land between the palms. This is especially important for the following reasons:

1. The CRI, a world leader in growing crops in conjunction with coconuts, has developed methods that can be implemented immediately.
2. Coconut lands have high rainfall, need no irrigation and are close to markets and transportation.
3. Some form of ground cover is needed to control weeds in any case; it may as well be productive.

Many of the plants mentioned in this report can be grown as an intercrop with coconut palms, for example, passion fruit, limes, manioc, vegetables, patchouli, vetiver, spices, and many medicinal plants.

The CRI has much experience with interplanting these and other crops between coconuts. Their research now gives the government a system of intensified agricultural management that capitalizes on the tropical environment of Sri Lanka, that will produce food and export income, that will improve land use, and that will provide increased rural employment.

The government should provide funds to ensure that all available information from the CRI is mobilized and put to use. Little or no technical assistance from other nations should be required.

If funds are required, the International Bank for Reconstruction and Development (World Bank) should be approached for help. Intercropping of coconuts appears a profitable proposition.

This programme should be implemented quickly. It must be coordinated with the previously discussed improved pasture programme. Indeed, the two are complementary. Since intercropped lands will no longer be available for grazing, improved pastures will be needed to support the displaced animals. (However, in some locations a triple cropping system--coconuts, pasture, as well as a food or cash crop--could be profitably implemented.)

Intercropping will require increased use of fertilizer, notably nitrogen, phosphorus, and potassium. Wherever feasible, nitrogen should be obtained by using leguminous plants; phosphorus can be obtained from local rock phosphate deposits.

PASSION FRUIT

Sri Lanka's passion fruit juice export industry has been developed to its present level in only three years; it is now earning approximately Rs. 3,000,000 in foreign exchange annually. But there is increasing demand for more sophisticated equipment and additional products for export markets. A strong impact has already been made by Sri Lanka passion fruit juice in world markets and this may be attributed to the inherent high flavour of Passiflora edulis grown in Sri Lanka and to the thermal processing technology already developed here. It is estimated that an export market of at least Rs. 10,000,000 is available to Sri Lanka from passion fruit. However, the economics of fruit processing depend on the yield of juice per acre. Improved horticulture and processing are essential if the industry is to expand and to compete in foreign markets. With only minor improvements in quality, and with the introduction of new products, (especially those that reduce freight costs), this industry could expect to be a major and stable foreign exchange earner for Sri Lanka.

Horticultural research must be started immediately. The investigations most needed are ones that would:

1. Select stock having desirable agricultural characteristics (such as disease resistance and high yield) and with desirable processing characteristics (such as peel thickness, juice yield, acidity, total solids, carotenoids in the juice, etc.);
2. Improve disease and pest control;
3. Improve agricultural practices (spacings, trellising, etc.).

The high acidity of the natural juice simplifies thermal processing but passion fruit contains free starch that makes processing difficult. Concentrating the juice (by vacuum evaporation and by freeze drying) urgently requires study.

The Horticultural Section of the Department of Agriculture and the Department for Development of Marketing need more technical personnel to help solve the problems facing the passion fruit industry. In particular a horticulturist and a plant pathologist should be put to work on passion fruit full time (perhaps for as many as four years). To improve the processing of passion fruit will require an analytical chemist and a food technologist working on analytical and pilot plant processing. This must be done in close collaboration with the horticulture work. New analytical instruments and pilot plant machinery may be needed. Such equipment need not be used exclusively for passion fruit--it could be useful for investigating other economically promising fruits.

LIMES

Already widely grown on the island, limes appear to be a most promising fruit that can be increasingly exploited with relatively little capital expenditure. A lime industry could earn much foreign exchange (estimated at over Rs. 1,000,000 annually) while benefiting local fruit cultivators and consumers by stabilizing lime prices, which are currently fluctuating.

It is estimated that at least 9,500 acres of lime trees now exist in Sri Lanka and that over 20,000 tons of limes are marketed annually. But the low price realized for the fruit (particularly during the harvest season) means that large quantities of limes remain unharvested.

Nevertheless, this large acreage and sizable home market is a good start toward developing an export industry. To produce limes for export may not initially require new plantations. The fruit can probably be obtained by increasing production from existing orchards through better agricultural practices.

Research investigations conducted in Sri Lanka indicate that limes are free of the diseases that affect other citrus fruit; they store well and could be exported as fresh fruit to overseas markets. To capitalize on this potential, research into horticulture, processing and marketing is needed.

Horticultural work must begin with a survey of lime cultivation in Sri Lanka to ascertain the extent and location of growing areas, and the varietal characteristics of the fruit (per acre yield of fruit and juice, juice quality, as well as the yield and quality of lime oil). The introduction and selection of superior varieties of limes and the establishment of nurseries and extension service can follow.

The many uses of the fresh fruit, juice and peel are schematically illustrated in Figure 1. Investigations are needed to analyse the juice and the lime oil. Pilot plant studies concerned with processing of the juice (by methods such as thermal sterilization, freeze concentration, dehydration, distillation, etc.) can be done after these investigations. Based on the pilot results, factories could be established to produce the lime products warranted. Post-harvest behaviour of fruit, including cold storage and controlled atmosphere storage, should be studied. Finally, if justified, actual trial shipments should be made to prospective markets.

Marketing investigations in Europe, North America, Japan and other countries should be initiated early. Statistics of the trade in lime juice products (straight juice, concentrate, frozen juice and powder) and lime oil products, including prices in the wholesale and retail trade, should be gathered. Other data will also be needed. This will include information about packaging of the products in relation to the prospective markets and on regulations concerning the import and export of the commodities.

MANIOC (CASSAVA)

Manioc is an inexpensive source of food and industrial starch. It is already grown on a wide scale (about 150,000 acres) in Sri Lanka. Manioc yields vary widely but have been measured up to 5 tons per acre in Sri Lanka; experimental plots have yielded up to 10 tons per acre. However, given proper care, good cultivars have yielded 40-50 tons per acre in other countries. More research on cultivars and fertilizers is needed to bring Sri Lanka's average yields up to those in other parts of the world.

If yields can be increased, surpluses can probably be exported. Manioc starch is a major cattle feed in Germany and other European countries, and Thailand already capitalizes extensively on this demand. The Thai experience could provide an important model for Sri Lanka.

Manioc contains a cyanogenic glycoside, which is toxic because it is a source of cyanide. Although the traditional cooking method (boiling the fresh tubers) detoxifies manioc, this method cannot be relied on if the product is to be consumed more extensively, especially if consumption of manioc is high while protein intake is low.

It follows, then, that manioc should be processed to remove the cyanogenic glycoside. Fortunately, the CISIR has developed an inexpensive method for such extraction.* A small drying unit (2,000 lbs of fresh manioc per day) has been designed to be located in the growing area. It uses the sun instead of an oven for most of the drying. This detoxified manioc flour can be incorporated into bread (at least up to 10 percent of the wheat flour), which could help the island reduce its wheat imports. This process should

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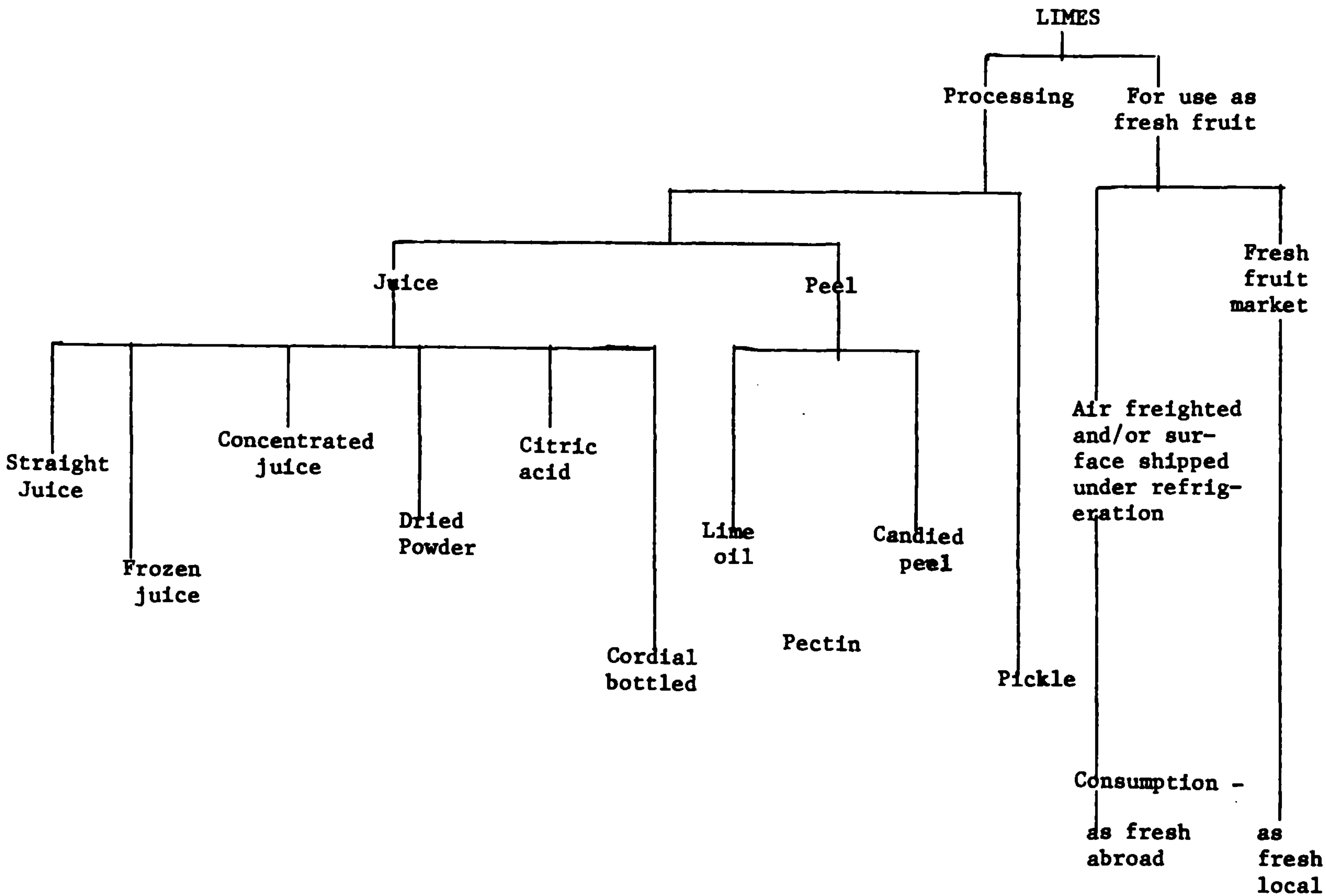
* A Process for Improved Manioc Chip and Flour - available from the Library, CISIR, Price Rs. 1/=

FIGURE 1 Potential Products from limes (information supplied by Mr. L. A. C. Alles).



be adopted and widely implemented by the Department of Small Industries, the Industrial Development Board, and individual District Development Councils.

Fresh manioc tubers can be stored for a few days, but after that they cannot be used for human consumption. This causes great problems for manioc growers. However, the dried chip and flour from the CISIR process can be stored for weeks and for even longer if protected against insects.

Some Uses of Manioc Products Are

Type		Potential demand in Sri Lanka
Industrial grade (Flour or Chip):	Cotton warp sizing	1,000 tons
	Plywood glue filler	300 tons
	Commercial glucose	
	Low-quality adhesives	
Purified flour or Starch:		
Textile finishing		400 tons
Dextrins and adhesives		
Starch:		
Modified starches		
Dextrins and adhesives		
Edible grade (flour):		
Bread		10,000 tons rising to 45,000 tons

DAMBALA

Fifty years ago, soya bean was an Asian crop much used in China, Japan and the Far East but little known elsewhere. Since then, research has made it a principal crop plant of the world. Dambala (Psophocarpus tetragonolobus) seems to have characteristics that could turn into Sri Lanka's own "soya bean."

It has recently been discovered that the composition of Dambala seeds is identical to that of soya beans. They have 17 - 20 percent oil; soya beans have 20 percent. Dambala seeds have 34 - 37 percent protein, the same as soya beans; Dambala seed protein contains the same amino acids as soya bean protein.

Normally, only the seeds of soya beans are eaten or utilized, but the tender pods of Dambala are delicious and are widely consumed in Sri Lanka. The leaves and shoots make a nutritious green vegetable. The stems make a very good animal feed. Even the flowers can be eaten. In Burma, they are used in salads; in Papua New Guinea they are fried and are reported to taste like mushrooms. A most important difference between Dambala and soya bean is that some Dambala varieties produce a fleshy tuber similar to a potato. It tastes like potato but contains 20 percent protein, which is 20 times the protein content of manioc and ten times the protein of potatoes, yams and other edible root crops.

Soya beans contain anti-nutrition factors and therefore must be heated or fermented before they are safe to eat. Dambala seeds also must be thoroughly cooked before eating. But all in all, Dambala is more versatile than soya beans.

A few varieties of Dambala tested give a low yield of tubers (1-2 tons per acre), but the yield of seed have been measured at 2,000 pounds per acre, about the same as the normal yield of soya beans in the tropics. But Dambala must be compared to soya bean of 50 years ago. No research has yet been conducted, but the future promises greatly increased yields.

Sri Lanka is the westernmost limit of the natural range for Dambala, New Guinea is its easternmost limit. In between, it grows in Indonesia, Malaysia, Thailand, Burma, and the Philippines. Papua New Guinea has some varieties that yield two foot long pods. The tuber-producing varieties are found also in Burma.

Dambala is a legume that fixes nitrogen from the air; it requires little or no additional fertilizer. Soya beans, as well as peas and beans, fix nitrogen, but Dambala seems to do it better, because it has a very extensive root system with many more, and much longer nodules. In its nodules, Dambala appears to use the common bacteria associated with cowpeas, ones that are present in almost all tropical soils. No matter where it has been grown, it has not needed bacterial innoculation.

Unlike soya beans, Dambala seeds do not ripen simultaneously. This means that the crop cannot be mechanically harvested, and, also unlike the soya bean, Dambala does not lend itself to large-scale commercial production. But a plant that produces food over several months is ideal for a small land holder, and for homestead gardens.

Another notable difference is that soya beans are free-standing plants that can be grown in large fields, while Dambala has to be grown on stakes, trellises, or wire fences. This is not a serious difficulty for the small farmer, but unless free-standing varieties are found, this will also keep Dambala from becoming a large-scale mechanized commercial crop.

The National Academy of Sciences has recently completed a comprehensive study of Dambala and has concluded that it is one of the most promising food plants for the entire tropics. Copies of this report are available without charge from the National Science Council of Sri Lanka.

For Sri Lanka to take advantage of Dambala, the Agriculture Departments at the Universities, the Central Agricultural Research Institute and the Department of Agriculture should collect the seeds of all varieties now grown in Sri Lanka.

The most promising varieties should be planted in large enough quantity (perhaps 5 acres) to provide enough seeds for experimentation (by the Medical Research Institute and others involved in the country's nutritional problems) and for distribution to farmers through normal agricultural extension channels. The university should contact Professor Tanveer Khan at the University of Papua New Guinea, Port Moresby, Papua New Guinea, to obtain seed of tuber-producing varieties, and of varieties with other important characteristics.

A systematic international effort to investigate and develop Dambala is now beginning. Ceylonese scientists have a chance to play a leading role in this development.

SWEET POTATO

Sweet potato (Ipomoea batatas) is grown extensively in Sri Lanka. During 1974 - 75 it was being cultivated on an estimated 71,000 acres. However there has been little or no research to improve yields and the per-acre production in Sri Lanka is very low. Therefore, farmer income is low and there is less food for the people. The labour needed to grow this crop is low, and diseases are rare. A considerable increase in production could be achieved, and the sweet potato could take a greater role as human and animal food. The leaves could also be dehydrated into a high-protein meal for animal feeding. The tubers can also supply starch and glucose, but the technology has yet to be worked out.

The sweet potato has a place in the cropping systems of most areas of Sri Lanka. It has especial potential in the Coconut Triangle and the dry zone of Sri Lanka. Sweet potatoes inter-crop well with coconut; their drought-resistance makes them an ideal root crop for the dry zone.

To capitalize on the potential that sweet potatoes offer Sri Lanka, an improvement programme must be implemented to:

1. Select superior varieties with
   - High yield
   - High drought resistance
   - Low sweetness
   - Fast maturation
2. Propagate the best varieties and make germ plasm available to farmers at low cost.

The varieties could be imported from abroad or selected from local strains. These tasks should be handled by the Department of Agriculture and by the university. In addition, a government agricultural extension programme is needed to induce farmers to adopt cultivation practices known to produce higher yields.

KIDARAN

Kidaran (Amorphophallus campanulatus), a minor native root crop in Sri Lanka, has potential as a speciality crop to produce mannan for export. Mannan is used in food and pharmaceutical preparations; Kidaran is the only known, non-woody source. The plant should be examined by Ceylonese chemists and agriculturists to determine its potential.

Japan presently uses Kidaran as a food ("konnyaku") as well as in medicinal preparations. The Japanese market might therefore prove attractive for Kidaran products.

A collection of varieties and a survey of the areas where it is now grown is first needed to determine essential information about the crop in Sri Lanka. Chemists should analyze and screen all varieties for mannan. The local products may then be compared with those now sold in Japan. While the chemical studies are progressing, preliminary agronomic trials might be conducted, using the information gained from field surveys and from farmers as the basis for an estimate of the cultural and management practices needed.

KANDALA

Because food is in extremely short supply in Sri Lanka, there is a need to examine more closely those plants already used but that have potential for improvement and increased cultivation.

One such plant is Kandala (Colocasia esculenta). Kandala products have many markets, since the corms can be boiled, baked, fried or used in curries and other foods. In addition, flour, chips and other processed foods can be made from them. Improved and increased production of Kandala could have significant benefits to the country's food supply and land use because the crop can be grown in many types of soil and conditions unfit for most other crops. It is usually hardy and seldom damaged by storms or other disasters. It can grow under flooded or aquatic conditions, much like rice. Some varieties can withstand high salinity in soil or water. It adapts well to difficult water or land conditions and it fits well into inter-cropping systems. In Sri Lanka some varieties are fast-maturing and can provide food throughout the year. Yields can be very high (in Hawaii, yields of flooded Kandala average 10 tons per acre per year).

The plant can have significant nutritional impact for children, because it contains much calcium and phosphorus, both of which are necessary for tooth development. In addition Kandala starch is easily digested and it has non-allergenic proteins that make its products suitable as special foods for infants suffering from protein allergies. In non-acrid varieties, young leaves can be eaten as spinach or in soups: they are a good source of vitamins and minerals, especially iron.

Cultivation of Kandala requires extensive labour at planting and harvesting time and some during weeding, but the crop needs little daily care. Kandala varieties that can be grown under flooding, but that can also withstand salinity, are a very good crop for growing in rice paddies.

To take advantage of Kandala the government should appoint an agronomist, a botanist, an agricultural economist, and a person knowledgeable about village and rural environment to collect Kandala varieties and analyse Kandala cultivation techniques in Sri Lanka. This survey might require one or two months. Local agricultural agents, farmers, and gardeners should be interviewed. Care should be taken to record local names, crop duration, virtues the farmers or growers recognize, special cultural requirements, water requirements, food uses (including uses of corms, cormels, petioles and leaves), food preparation, and recipes. The survey should be adequately supported to ensure complete coverage of the country.

The government should also designate an existing research station to be responsible for propagating and evaluating the varieties collected.

Superior varieties from this collection should be grown under both flooded and rain-fed conditions in order to determine tolerance to flooding. If saline soils or paddy areas are available, a few varieties purported to be saline-tolerant should be grown to evaluate this feature. Corms should be analyzed for mineral and protein content. Botanists should check for the presence or absence of calcium oxalate rephides that cause acridness. Superior or well-adapted varieties should be released to the university, the Central Agricultural Research Institute and other research and development groups for inter-cropping or agronomic experiments. Superior varieties should be released to innovative farmers for trial cultivation on their farms.

It may be desirable to introduce superior varieties from overseas, but this should be done carefully to avoid introducing diseases.

Researchers at the university and the Central Agricultural Research Institute, the Coconut Research Institute, and others, should design a plan for evaluating and studying the varietal collection.

Little foreign technical assistance should be required, except in collecting the literature on Kandala and related root crops. No specialised equipment should be necessary, and this programme would not be costly.

CHAPTER IV

PLANT-DERIVED INDUSTRIAL PRODUCTS

The following are believed to have industrial exploitation possibilities:

1. Floriculture (for foreign exchange)
2. Kenaf (fibre)
3. Wattle (tannin)
4. Manioc (Industrial starch and flour)*
5. Gum Karaya (Sterculia species)

FLORICULTURE

Increasing affluence in many countries has given rise to a new industry: the exportation of flowers and other horticultural products from tropical areas. This industry is already highly developed in Colombia, Hawaii, Singapore, Israel, Ivory Coast, and Kenya.

With its equable tropical climate and geographic situation, Sri Lanka has extensive possibilities for tapping the European, and possibly also even the Japanese, fresh flower market. Some flowers have already been exported to Germany and the success of this small beginning indicates that an increased programme could be feasible and profitable for Sri Lanka. The country also has a sizable group of trained professionals in floriculture, as well as several botanical gardens and commercial establishments dedicated to horticulture. Furthermore, Sri Lanka has the advantage of ample airline service, especially to Europe, including its own line. It is possible that preferential rates might be given for flower export.

The Orchidaceae, Araceae, Musaceae, Bromeliaceae and Zingiberaceae plant families are the ones most likely to yield marketable flowers. The Ministry of Agriculture, the School of Agriculture, the Royal Botanical Gardens at Peradeniya, and commercial firms such as Floralia and the Exotic and Orchids Cooperative Society should be contacted to assist in developing this new export industry.

Plant tissues can be grown in sterile culture to produce complete plants, and this technique is now utilised in commercial floriculture. It is especially useful for rapidly propagating new varieties. This tissue

* This section is treated under manioc in Chapter III.

culture involves taking bud- or other actively growing tissues and growing them on nutrient agar to produce callus tissue, then, from callus, a large number (potentially thousands) of plantlets. Orchids lend themselves to this technique and Sri Lanka has long been world renowned for its orchids. The commercial production of orchids and other plants by this technique in Hawaii should be investigated as an example of what could be achieved by the Ceylonese.

KENAF

The increasing demand for paper everywhere, the worldwide shortage of pulp, and the resulting increase in cost of pulp and paper production have shown that traditional sources of pulp and paper cannot be relied on for future needs. Therefore, great attention has been focused on finding non-conventional sources of fibrous raw materials for the paper industry.

Rice straw is the raw material currently available in Sri Lanka in sufficient quantity to meet the paper industry's requirements. A mill operated by Eastern Paper Mills Corporation at Valaichchenai, and a proposed mill under construction at Embilipitiya, utilize rice straw as the chief raw material. Because of its fibre characteristics, rice straw requires at least 30 - 35 percent long-fibre pulp to provide pulp with the necessary strength to run it on the paper machine. The long-fibre pulp used in Sri Lanka is imported wood pulp. To conserve foreign exchange, steps have been taken to grow conifers, Eucalyptus, and bamboo to replace imported wood pulp. On the basis of mill trials it has been found that kenaf pulp could partly replace imported wood pulp. To make the paper industry self-reliant on home-grown raw materials, kenaf is being considered as a possible long-fibre substitute until woody materials become available to the industry in sufficient quantity.

Apart from its uses as pulp for the paper industry, kenaf is one of the leading substitutes for jute fibre, and could be used in industries manufacturing ropes, nets, sacks, Hessian cloth, carpets, and other goods. It should be remembered that Sri Lanka annually imports over Rs. 10 million in gunny sacks. Kenaf also produces a very nutritious forage and edible fruit.

Kenaf has a wide range of adaptability to soil and climatic conditions. The crop grows successfully on well-drained, reddish-brown earths found in most parts of the unirrigable highlands of the dry zone of Sri Lanka. About 20 to 25 inches of rainfall will be required to raise a successful crop of kenaf; hence it can be grown in Sri Lanka's dry zone during the Maha season as a rain-fed crop.

Of the several local and introduced varieties tested at the Agricultural Research Station, Maha-Illippallama, the local varieties were observed to be equal to introduced varieties in terms of fibre quality. Among promising varieties, Talagama pink (local) and Cuba 2032 (introduced) strains have been recommended for cultivation. The yield of fibre is in the range of 1,200 to 1,500 lbs. per acre, while yield of dry stalks for pulp (oven-dried) ranges from 15,000 to 20,000 lbs. per acre.

Extensive literature and experience in the growing and processing of kenaf are available from the U.S. Department of Agriculture and from the Applied Scientific Research Corporation of Thailand, a Thai government research institution.

The Government of Sri Lanka should carefully evaluate the results obtained in other countries with a view to increasing their level of kenaf cultivation.

WATTLE

Wattle bark extracts are used in tanning hides. They are now imported from South Africa. The same tree (Acacia mollissima) from which the South Africans get their tannin already grows well in Sri Lanka. However, the existing wattle plantations in Sri Lanka are too small to support an extraction mill. The government should consider enlarging the plantations, extracting the tanning agents locally, and abolishing wattle bark imports.

Wattle trees are available in the up-country plantations of the Forest Department. They were originally planted for shade, as windbelts, or as a source of firewood. The species is no longer planted, but that it can grow successfully is already proven. Once established they maintain themselves, but cannot tolerate shade conditions. Many plantations are mixed Eucalyptus/wattle, and under these conditions growth of wattle is considerably reduced.

The bark of local wattle has been found to be comparable with imported wattle. Yield of dry bark per acre would be about 0.5 ton/acre/year. The last estimate on the extent of wattle plantation available (1964) indicated 1,700 acres of mixed Eucalyptus/wattle. It is now probably less. About three years ago, an Indian firm estimated that 5,000 tons of wattle bark for commercial exploitation could be collected in Sri Lanka. In 1969, 15,208 cwt of wattle bark and wattle extract valued at Rs. 966,288 were imported. That amount could be substituted entirely by wattle grown locally. Eventually, wattle extract might even be exported; India, for example, imports tanning materials. Another possible local industry based on wattle would be the manufacture of tannin/formaldehyde adhesives.

To make a wattle extract programme economical, about 2,000 acres should be available annually. Since wattle can be harvested for seven years, the total acreage should be 14,000 acres. The wood left after peeling the bark is an acceptable fuel. Since the demand for wood fuel has increased since the recent fuel crisis, this side benefit is significant.

A pilot-scale wattle extraction plant is planned by the Ceylon Leather Products Corporation. This plant can now make use of existing wattle bark. For the future, however, it is recommended that 14,000 acres of wattle plantings be established at a rate of 2,000 acres per year, to make raw material available for a commercial-scale plant on a continuing basis. The quantity produced would exceed the needs of the Sri Lanka leather industry, but there seems little doubt that the entire surplus can be exported.

The current need of the leather industry amounts to 500 tons of wattle extract per year, which is imported at a cost of Rs. 2,600/- per ton. A proposed 14,000-acre plantation will produce 1,500 tons of wattle extract per year, thus making 1,000 tons per year available for export, which would earn Rs. 2,000,000 per year.

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. Sterculia trees already established in Sri Lanka should be tested for their gum quality and yield. The results may indicate the feasibility of large-scale plantations.

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 colour: red, yellow, and black.

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. It grows wild in local areas in northern Sri Lanka. The tree produces the gum freely as a soft, solid mass when its bark or branches are cut or injured.

Literature is available, especially from India, on recent agronomic research and on properties of the gum. A first step should be to assemble this literature, then initial experimental tapping of the wild trees in Sri Lanka might be undertaken. Planting of the Sterculia tree is a long-term enterprise, but in view of the climate of parts of Sri Lanka 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. The Department of Forestry and the Milk Board, aided by private industry such as Elephant House, should be encouraged to consider this potential natural product for Sri Lanka.

CHAPTER V

ESSENTIAL OILS AND SPICES

Current projections predict that the world's essential oil industry will multiply several times (perhaps up to five times) by the end of the century. Sri Lanka is in an excellent position to improve its balance of trade by taking advantage of this trend. The country could supply the world with fragrance chemicals derived from plant materials.

To capitalize on opportunities in this field, Sri Lanka must produce consistently high-quality products at a constant rate. To ensure quality control, modern analytical instrumentation facilities should be purchased and experts to use them should be trained. Attention must also be directed towards considerable enhancement of the present programme of research by making available all facilities for such work. The present facilities at the CISIR are inadequate for a meaningful research programme and for the further development of the analytical, chemical, and technological expertise in this field that the country will need in the future. A technical sales force will also be needed. The country should certainly put particular emphasis on essential oils containing ingredients that are not likely to be produced synthetically.

The following appear to have the greatest promise:

1. Citronella oil (Java type)
2. Lemongrass oil
3. Patchouli oil
4. Vetiver oil
5. Cinnamon leaf oil
6. Cardamom oil
7. Black pepper
8. Ginger
9. Ambrette seed oil

Each of these has a well-established market. Because they can be produced in large volume, or because they command high prices, they could significantly improve Sri Lanka's economy. Furthermore, they do not suffer competition from synthetic substitutes. The first two are already available on the island and their increased production could bring rapid economic benefits.

Sri Lanka may one day be able to produce processed fragrances, but this production and formulation is becoming so highly sophisticated that it is unlikely that the country can compete in the international market at present.

Nevertheless, where technology exists, it is preferable to produce perfumery materials, rather than raw essential oils, because they should increase foreign exchange earnings and serve the requirements of a home market.

CITRONELLA OIL

At present, Sri Lanka produces citronella oil, mainly of the so-called "Ceylon" type, which contains a relatively low amount of the important component citronellal. This type enjoys a steady though relatively low demand of about 250 tons per year; because of its citronellal content, it will probably continue to be used at this low rate with relatively little annual growth in demand.

Another type of citronella oil, the so-called "Java" type, is much richer in citronellal, sells at a higher price, and is in greater demand than the "Ceylon" type. Citronellal is used in synthesising prized fragrance materials. The fragrance industry buys several thousand tons of this type annually, and the demand for citronellal, and oils containing it, is growing rapidly. Studies are underway to evaluate the possibilities of producing the "Java" type of oil in Sri Lanka. However, it is recommended that a task force of university laboratories, research institutes, and commercial interests be formed to expand the existing programme. The task force should study and evaluate the quality and yield of "Java"-type citronella oil. In addition, it should study and select "Java"-type strains for use in Sri Lanka's growing conditions. This agronomic analysis must be coordinated with chemical analysis of the oil to ensure that the high-citronellal content is retained. This should take two years.

If the results meet expectations, production can be initiated; "Java"-type citronella oil for export could then be available in about one year.

To produce this oil, 20 acres of land per ton is required, or 16,000 acres for about one quarter of the world production. At current market prices, this amount would yield an annual income of about Rs. 25,000,000.

LEMONGRASS OIL

A second essential oil also currently produced in Sri Lanka is "lemongrass oil." This is valuable mainly for its content of citral, used also as a starting agent for valuable fragrance materials. Because of the increasing demand for essential oils, it, too, is expected to be in growing demand, at least over the next decade. To produce about one quarter of the world's need for this oil would require about 16,000 acres of lemongrass plantings. It is recommended that a task force (similar to that suggested for citronella) be established to undertake the research and market development for lemongrass oil. The required time again would be two years for the feasibility study and one year to achieve production. Again, a financial return of about Rs. 25,000,000 per year might be realized. Although both citronella and lemongrass oils have a built-in price ceiling of about Rs. 13/lb. (because their major components are available from other sources), this price assures a good profit.

PATCHOULI OIL

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. Currently the patchouli plant is not grown in Sri Lanka, but it seems certain that it would thrive in the tea- and coconut-growing areas.

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 markets of the future, large-scale production of patchouli oil seems to hold much promise for Sri Lanka's future economic development.

Forty acres devoted to patchouli production could have an annual yield of one ton of oil worth about Rs. 91,000.

Patchouli is intercropped with rubber in Malaysia, which could provide a valuable model for Sri Lanka. If adopted, no new land would have to be brought under cultivation. Supplementation of rubber with patchouli production would be beneficial to both industries. The Workshop recommends that the government make an extra appropriation to the Rubber Research Institute for immediate trials with patchouli as an intercrop. The funds should be sizable enough that the Institute can subcontract with agricultural and horticultural researchers in the universities and Department of Agriculture for help with patchouli cultivation.

In addition, the government or private industry should contact European or American companies that purchase patchouli oil. It is likely that one or more of these companies might guarantee a market (and base price) for Sri Lanka's patchouli oil and, in return, would provide all of the agricultural and processing expertise now lacking here.

Patchouli production could be accelerated by a cooperative effort between Ceylonese agronomists who could produce sample oils from plantings in different parts of the island, and overseas laboratories who could do the physical, chemical, and odour evaluations.

VETIVER OIL

Vetiver oil comes from the roots of a wiry perennial grass Vetiveria zizanioides. Though native to Sri Lanka, vetiver oil is not produced commercially on the island. The principal countries that now exploit the plant are Haiti, Réunion, Madagascar, India, Zaire, Angola, Brazil, and Guatemala.

The grass is propagated by planting sections of root. It can be used to stabilize soils and reduce erosion; it is also used along roadsides and garden borders. Commercial harvest of roots is made 15 - 24 months after planting. Special agricultural techniques are required to produce high root yields. After drying, the roots are crushed and distilled to yield the oil.

The viscous vetiver oil is often used as a fixative for more volatile fragrances, especially in soaps and cosmetics. Vetiver oil, like patchouli oil, is widely used by industry. It contains complex chemicals not likely to be synthesized commercially in the foreseeable future.

Vetiver is being studied in Sri Lanka in far-sighted projects on tea estates, and it is recommended that the Tea Research Institute be given an additional allotment of funds intended for comprehensive trials of vetiver as a tea intercrop. Agricultural help will be needed. Perhaps agronomists and horticulturists at the university or in the Agricultural Research Station could provide assistance. But, as in the case of patchouli oil, Sri Lanka's best course of action may be a contract with a foreign firm already experienced in vetiver production. In return for a guaranteed supply for a given number of years, that company is likely to provide all necessary knowledge and experience.

One hundred and fifty acres planted in vetiver is a good target. It could yield about Rs. 182,000 annually.

CINNAMON LEAF OIL

Cinnamon leaf oil is also being produced in Sri Lanka. It is esteemed because of its high content of eugenol, a chemical of great value as a fragrance in its own right and for conversion into other fragrance materials. By selling both cinnamon bark and cinnamon leaf oil the profit of cinnamon plantations can be increased. It is recommended that the present botanical search for improved strains (that produce a better yield of eugenol in the leaf, in addition to high quality bark) be intensified.

The potential for producing cinnamon leaf oil from existing cinnamon plantations is not being exploited. Production from the present acreage of cinnamon plants could probably be more than doubled. Also, Sri Lanka has not fully exploited export markets. An effort should be made to develop new markets and to utilize excess oil to produce perfumery/flavour materials that will replace imported materials.

CARDAMOM OIL

Cardamom oil also is produced in Sri Lanka; it is valued for its flavour. At present, in international trade, Guatemalan cardamom oil is considered superior to that from other countries. This preference is based solely upon the subjective judgment of aroma experts, and cannot be interpreted in analytical terms. It is recommended that steps be taken to determine whether there is any scientific basis for the superiority of Guatemalan oil. If so, studies should be initiated to achieve quality parity for the Ceylonese product.

BLACK PEPPER

Black pepper is another Ceylonese product sold as the spice and as the oil. This is a lucrative product, but the amount that is sold is only a small fraction of the potential that could be realized if production difficulties were overcome. Black pepper is the spice imported into the United States in greatest quantity. It is recommended tHat a research grant be made to the Faculty of Agriculture, which is qualified to study seed preparation difficulties and deficiencies in the entire process as now practised.

GINGER

In order to develop foreign markets and to increase domestic consumption of ginger itself, the problem of drying must be solved. It is recommended that a study of this be initiated. The study may involve introduction of new hybrids of the present variety with more manageable types.

AMBRETTE SEED OIL

One further oil worthy of special comment is Ambrette seed oil, which commands a steady, though small market. There is, at present, a scarcity of high-quality oil. The amazing price of Rs. 6,500 to Rs. 13,000 per lb. that this oil sells for and the suitability of the island's climatic conditions for producing it, makes research on growing ambrette most worthwhile. To initiate this research it will be necessary to import seeds for experimental plantings and subsequent evaluation.

CHAPTER VI

MEDICINAL PLANTS AND PLANT-DERIVED PHARMACEUTICALS

The worldwide importance of plant-derived pharmaceuticals is undisputed. In 1974, for example, about $3,000 million worth of prescriptions containing drugs derived from plants was sold in the U.S.A. From the 1,500 million prescriptions dispensed in the U.S.A. in that year, about 25 percent contained active principles extracted from plant sources. This percentage has remained constant for 15 years, which clearly indicates the stability of the market for drugs from terrestrial plants.

Data of this type are not available for other countries, though the United Kingdom uses a large percentage of plant-derived pharmaceuticals and it has been estimated that drugs from plants comprise about half of all prescription drugs in West Germany.

In addition to prescription drugs, an important and financially rewarding market for plant-derived pharmaceuticals is the nonprescription market: laxatives, cough and cold preparations, etc. No financial data are available for this market, but in the United States the value of plant-derived materials probably approaches that in the prescription products.

The major plants that are used in drugs are listed in Table I. Some already grow in Sri Lanka; most could be grown on the island.

THE NEED FOR RESEARCH

The size of world markets for plant-derived pharmaceuticals and Sri Lanka's ability to grow many of them argues that research in this field should be encouraged and strongly supported by the government. Sri Lanka's abundant flora already contain many drug plants. Also there are some plants (both native and exotic) that could be cultivated in Sri Lanka to yield materials that, after chemical modification, produce pharmaceuticals. An organized research effort could make Sri Lanka a major supplier of some of these natural resources.

By exporting natural raw materials and active principles, Sri Lanka can increase its foreign currency reserves. Some important plant-derived pharmaceuticals are in short supply in international markets. For example, there is a critical worldwide shortage of quinine and quinidine and the price of these drugs is now very high. Sri Lanka already grows the *Cinchona* plant from which they are obtained.

TABLE I Important Plant Drugs and Their Relation to the Economics of Sri Lanka*

Plant and/or Active Principle	Growing in Sri Lanka	Possibility of Cultivation in Sri Lanka
Dioscorea species diosgenin (starting material for synthesis of steroids Rs. 300 - 600 per kilogram)	Yes (Studies must be conducted to determine economic feasibility.)	Doubtful if cultivated plants would give adequate amount of diosgenin
Rauvolfia serpentina reserpine rescinnamine deserpidine	Yes	Yes - Introduction of appropriate additional species might be considered
Digitalis purpurea digitoxin	No	Cultivation could be profitable
Digitalis lanata digoxin	No	Cultivation could be profitable
Papaver somniferum opium morphine codeine	No	Doubtful if desirable, but thought should be given to cultivation of high thebaine-yielding Papaver species, from which morphine and codeine can be prepared without difficulty
Atropa belladonna atropine hyoscyamine scopolamine	No	Could be cultivated
Datura species scopolamine	Yes (Economics of collection and extraction would have to be studied)	-
Catharanthus roseus vincristine vinblastine	Yes	Yes
Cinchona species quinine quinidine	Yes	Yes - Work should be expanded

* Only drugs of widespread use and great economic importance are listed here. Other possibilities are discussed later in the report.

TABLE II   Some Plants Available or Easily Cultivable in Sri Lanka, But Which are Imported*

	Local Name	Botanical Name	Family	Quantity	Est. Price
1.	Amukkara (seeds) (Aswaganda)	Withania somnifera	Solanaceae	20 tons	Rs. 8,140/ton
2.	Bodi seeds	Psoralea corylifolia	Leguminosae	10 cwt.	Rs. 1,060/ton
3.	Geta aralu	Terminalia chebula	Combretaceae	11.2 tons	Rs. 1,430/ton
4.	Iramusu	Hemidesmus indicus	Asclepiadaceae	15 tons	Rs. 1,730/ton
5.	Kohomba (oil)	Azadirachta indica	Meliaceae	12 tons	Rs. 3,040/ton
6.	Kumburu (seeds)	Caesalpinia bonducella	Leguminosae	12 tons	Rs. 3,150/ton
7.	Katuwel batu	Solanum jacquini	Solanaceae	50 tons	Rs. 2,240/ton
8.	Malithamal	Woodfordia fruticosa	Lythraceae	20 tons	Rs. 2,250/ton
9.	Nelli	Phyllanthus emblica	Euphorbiaceae	60 tons	Rs. 1,140/ton
10.	Namal (stems)	Mesua ferrea (stamens)	Guttiferae	10 cwt.	Rs. 8,313/ton
11.	Rathnitual	Plumbago indica	Plumbaginaceae	2 tons	Rs. 19,950/ton
12.	Rathkihiri	Acacia catechu	Leguminosae	2 tons	Rs. 4,480/ton
13.	Sarana tubers	Boerhaavia diffusa	Nyctaginaceae	10 tons	Rs. 1,580/ton
14.	Savendara roots	Vetiveria zizanoides	Gramineae	5 tons	Rs. 2,660/ton
15.	Thippilli (pods)	Piper longum	Piperaceae	15 tons	Rs. 23,080/ton
	Thippilli (roots)	Piper longum	Piperaceae	6 tons	Rs. 2,744/ton
16.	Inguru	Zingiber officinale	Zingiberaceae	20 tons	Rs. 5,429/ton
17.	Kaha	Curcuma domestica	Zingiberaceae	2 tons	Rs. 7,980/ton

* Information supplied by S. Ponnuchamy

In addition, a number of plant species are prime candidates for sources of new drugs not yet known elsewhere. Sri Lanka should initiate a long-term programme to investigate its flora for new medicinal plants and plant-derived pharmaceuticals. One approach--that is uniquely Ceylonese--would be to investigate plant materials used in Ayurvedic medicine.

PLANT MATERIALS NOW IMPORTED EVEN THOUGH THEY GROW LOCALLY

The Workshop was surprised to discover that 18 different plant materials are now imported by Sri Lanka, even though they are available in the natural state or are easily cultivated in Sri Lanka. A list of these plants is presented in Table II. It is estimated that these imports cost Sri Lanka about Rs. 1 million in foreign exchange each year.

The apparent reason for importing plants that are already available on the island is that they grow in remote areas and it is less expensive to import them than to collect and transport them within Sri Lanka itself. It is strongly suggested that studies be made to determine whether or not transportation difficulties can be overcome so that Sri Lanka can conserve its foreign currency and provide its farmers with employment.

Quinine and Quinidine

The Cinchona trees (*Cinchona pubescens*, *Cinchona officinalis*, and their variants), native to the Andean highlands of South America, produce the remarkable antimalarial drug quinine as well as quinidine, which is widely used to treat heart disease (especially as a cardiac depressant).

Cheap synthetic substitutes for quinine have been available for 30 years; however some strains of plasmodium, the malaria parasite, are resistant to them all. Surprisingly, quinine is still lethal to these strains. There appear to be potential markets for quinine in regions that have the resistant plesmodium strains--such as Southeast Asia. The People's Republic of China is a very likely market as well. However, Sri Lanka should conduct a careful market survey before there is any increase in Cinchona production. A cartel of companies in European countries control and monopolise most of the world's markets.

At the present time quinidine is in short supply. The wild stands of Cinchona in South America and the plantations elsewhere in the tropics are insufficient to supply world demand. This demand is increasing and quinidine sells at six times its price of five years ago.

Cinchona prefers cool, tropical, hill country (above 1,000 feet) with a year-round rainfall. In a story that strangely parallels that of rubber, Cinchona seeds were smuggled from South America for planting in Asia. They came to Sri Lanka in the 1860s and the Hakgala Botanic Gardens were created as a Cinchona nursery.

It is not possible to produce quinine and quinidine economically on a small scale. Considerable investment in Cinchona plantations and an extraction plant are needed.

Anticancer Drugs

The National Cancer Institute (U.S.A.) has a large programme for screening plants for anti-cancer activity. So far they have checked over 50,000 plants collected throughout the world. They are still interested in new plants and Sri Lanka should contact them regarding a collaborative project.* The Institute pays for the material collected--although the amount of money involved is modest it could provide Ceylonese science with some foreign exchange.

If some of the specimes prove active against cancers, a research grant proposal could be submitted to the National Institutes of Health (U.S.A.), or similar agencies in other countries, requesting funds to isolate and characterise the active principles. Similarly, pharmaceutical firms in various countries might be receptive to research proposals, should the area of pharmacological activity be of interest to the firm. Rights to discoveries under such agreements would be subject to negotiation.

From the 50,000 plants screened so far, a dozen or so with anti-cancer activity are promising candidates for new drugs. These are now moving through a series of clinical trials. Of these, one Heliotropoum indicum already grows in Sri Lanka. Two others have close relatives growing on the island, they are: Caesalpinia gilliesii (Ceylonese relatives: C. coriaria, C. crista, C. major, C. pulcherrim and C. sappan) and Brucea antidisinterica (Ceylonese relatives: B. javanica and B. sumatrana). These would be good plant materials to initiate collaboration with the National Cancer Institute.

In laboratory animals acronycine, which is extracted from the woody plant Achronychia baueri, has the broadest anti-cancer spectrum of any known antitumour drug. It is currently in clinical trials in the U.S.A.; if it proves effective, it will be required in large quantities. A synthesis has been reported for acronycine, but getting it from plants might well compete economically. Since Sri Lanka has a related species, Acronychia pedunculata, a study to determine whether acronycine is present in adequate concentration to warrant its exploitation is needed.

Dioscorea

Commonly called yams, some species of Dioscoreas are sources of a starting material (diosgenin) which is widely used in the pharmaceutical industry. Diosgenin is now obtained largely from wild yams growing in Mexico, the People's Republic of China, Africa, and India. It is in chronic short supply throughout the world. Because the Mexican yams grow slowly under natural conditions, they are overexploited and cannot meet the current demand.

The time is fast approaching when yams that yield useful quantities of diosgenin will have to be cultivated and managed in a systematic agricultural manner. Previous attempts to do this, notably in Guatemala and Mexico, have not been too successful, apparently because of agricultural difficulties.

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* Contact Dr. John Douros, Acting Director, Natural Products Section, Drug Research and Development Division of Cancer Treatment, National Cancer Institute, Bethesda, Maryland 20014, United States of America.

Sri Lanka grows edible yams extensively and has several indigenous varieties. Yam cultivation methods are known and the climate and soil seem suited to growing the specific Central American varieties that have high diosgenin content. Diosgenin production, if it can be made successful, could bring substantial foreign exchange to Sri Lanka. Diosgenin is a material that is easily shipped, even to distant markets in the United States and Europe. It sells for the enormous price of Rs. 300,000 - 600,000 per ton.

To begin production, contact should be made with a corporation such as Schering AG, Berlin (Federal Republic of Germany) which has extensive experience in attempting to cultivate the plant in Mexico and Guatemala, the corporation is seeking sources of diosgenin and is likely to be receptive to a proposal from Sri Lanka. Such a company is likely to welcome a cooperative project in which it provides technical support in exchange for a contract to buy the product from Sri Lanka for a given number of years. A contract of that kind could bring major benefits to both parties.

Catharanthus Roseus

Native to Sri Lanka, *Catharanthus roseus* contains pharmaceuticals that are in demand both in Europe and the United States. At one time it was found in weedy abundance on the island, but collectors have wantonly exported so many roots and leaves that they have decimated the native stands. A survey of the remaining *Catharanthus roseus* should be made and methods to preserve them effected. Also the potential of cultivating the plant should be determined by Ceylonese horticultural researchers. It responds well to cultivation and it is likely that four crops of leaves could be harvested annually.

The plant's roots produce ajmalicine, a drug that is widely used in Europe as an ingredient in pharmaceuticals for treating heart disease. Because of the rapacious destruction of ajmalacine-containing plants throughout their native habitats, many European importers are desperate for new supplies. (Other Ceylonese plants containing ajmalacine are *Rauvolfia serpentine* and *Cartharanthus pusillus.* They too need to be analysed.)

The stems and leaves of *Catharanthus roseus* contain leurocristine (also known as vincristine or VCR). It is the most effective drug for treating acute leukemia in children and now sells for the incredible price of Rs. 1 million per pound. The annual demand for VCR is small--only 10 lbs by the United States, for example. The purchase price is so high because VCR is found in very small amounts in *Catharanthus roseus.* (Only 1 ounce is obtained from 15 tons of leaves.)

It is likely that the price of VCR will soon drop dramatically because a Hungarian research team recently developed a technique for producing it from vincaleucoblastine (also known as vinblastine or VLB), which occurs in much greater concentrations in *Catharanthus roseus* (70 lbs from 15 tons of leaves). With VLB available from this Ceylonese weed, its conversion to VCR provides a highly promising, but very challenging, research area for local chemists. If a new or improved conversion of VLB to VCR can be developed, the patent covering it would be of great significance; then the exploitation of *Catharanthus roseus* could earn Sri Lanka much foreign exchange.

Bromelain

There is a worldwide shortage of bromelain, an enzyme that is isolated from pineapple by-products, particularly from the stump that is left in the ground after the fruit is harvested. Bromelain is an anti-inflamatory pharmaceutical, used to treat injuries, sprains, and contusions. There are only two sources for the enzyme: a large pineapple company in Hawaii and pineapple producers in Taiwan.

To extract any enzyme from natural products is difficult; incorrect handling quickly denatures it and destroys its medicinal activity. In particular, bromelain extraction will probably need a costly freeze-drying plant.

Other by-products with potential economic value are pineapple peels, which are currently discarded in Sri Lanka, but which can be processed to yield sugar and citric acid; and the dried residue of the pineapple plant after harvest (pineapple hay), which is valuable for animal feed.

OTHER RESEARCH TOPICS

Cardiac glycosides

In Europe, cardiac glycosides derived from species of *Urginea* and *Scilla*, bulbous plants of the lily family, are used to control heart disease. Sri Lanka has *Scilla hyacinthina* and *Urginea rupicola*; neither appears to have been evaluated chemically or pharmacologically. Studies on both species could prove interesting.

Vincamine

Vincamine is obtained in good yield from *Vinca minor*, a plant available in Sri Lanka. Vincamine has been known for a number of years, but current interest in this alkaloid, especially in France, is very high because preliminary reports indicate that it may delay senility by increasing oxygen supply to brain cells. Vincamine is currently being studied by pharmaceutical firms as a likely candidate for introduction into the U.S.A. as a new drug. Current supplies are being met through plants under cultivation in Hungary. But *Vinca minor* could be cultivated in Sri Lanka with little difficulty. Should vincamine eventually become widely used, Sri Lanka might compete as a world supplier.

Sennosides A + B

Sennosides A + B, used widely as laxatives, are in short supply; new sources are being sought by U.S. importers. They are commercially prepared from the leaves and/or fruits of *Cassia acutifolia* and/or *C. angustifolia.* Sri Lanka has several *Cassia* species growing that might be good sources for these substances. Thus, it may be profitable to carry out a survey of all species of *Cassia* in Sri Lanka for sennosides A + B.

Rotenone

Rotenone is a valuable insecticide that could possibly be produced from Sri Lanka plants. This compound is present in virtually every species of Tephrosia and Derris yet tested. A study is needed to determine whether rotenone is present in the ten or so species of Tephrosia and in the six species of Derris that grow in Sri Lanka. There is a world market for rotenone.

Picrotoxin

Picrotoxin is extracted from Anamirta cocculus and is used throughout the world as an analeptic (stimulant to the nervous system) and antidote for barbiturate intoxication. The plant grows in Sri Lanka. A market survey and some simple analyses of local specimens might show that picrotoxin is a candidate for export by Sri Lanka.

L-Dopa

L-Dopa is an important drug used throughout the world for the treatment of Parkinson's Disease. Much of the L-Dopa used today is extracted from the seeds of leguminous plants. In certain legume seeds it is present in up to 5 percent concentration.

Seeds of Ceylonese leguminous plants should be assayed for L-Dopa content. The best candidates are Mucuna species (for example Mucuna atropurpurea and Mucuna prurita) and Leucaena latisiliqua.

THE PRODUCTION OF DRUGS BY UNIVERSITY STUDENTS

Students at Peking University in the People's Republic of China are assigned syntheses of low-volume, high-cost drugs in place of laboratory exercises in their courses. A small pilot plant has been constructed at the university grounds and the students produce drugs for use largely within the People's Republic of China. In this unique educational programme the student gains valuable practical experience as part of his university training. The programme has contributed to China's self-sufficiency in drug production and has even allowed them to export many drugs.

It would be interesting to see if a similar programme could be initiated in Sri Lanka. In this respect, the advice of representatives of the People's Republic of China might be requested.

APPENDIX A

WORKSHOP PARTICIPANTS

CEYLONESE PARTICIPANTS

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DJERASSI, Prof. Carl - Professor of Chemistry, Stanford University and Chairman of the Board of Science and Technology, National Academy of Sciences (Chairman of the American Participants)
FARNSWORTH, Prof. Norman - Professor of Pharmacognosy, University of Illinois at the Medical Center, Chicago, Illinois
PLUCKNETT, Prof. Donald L. - Department of Agronomy and Plant Science, University of Hawaii, Hawaii
SCHEUER, Prof. Paul - Professor of Chemistry, University of Hawaii, Hawaii
SCHULTES, Prof. Richard E. - Director, Botanical Museum, and Mangelsdorf Professor of Natural Sciences, Harvard University, Cambridge, Massachusetts
THEIMER, Dr. Ernst - Former Vice President, Research and Development, International Flavours and Fragrances Inc.

VIETMEYER, Dr. Noel - Professional Associate, Board on Science and Technology for International Development, National Academy of Sciences (Staff Study Director)

APPENDIX B

CONTENTS OF DOCUMENTATION: WORKSHOP ON NATURAL PRODUCTS

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   A Survey of the Economic Plants of Sri Lanka

2. B. A. Abeywickrema -
   List of Fascular Plants of Sri Lanka which are of Economic Importance as Food, Drugs, etc.

3. K. Mahadeva -
   On the Trail of the Elusive Herb

4. A. E. K. Tisseverasinghe -
   The Forest Resources of Sri Lanka and their Utilisation

5. E. E. Jeya Raj -
   An Outline of the Research done at CISIR with particular reference to Products from Palm Saps and Fibres.

6. E. R. Jansz and Nirmala Pieris -
   Utilisation of Manioc

7. A. S. B. Rajaguru -
   Studies on some of the lesser known Natural and Agricultural Products as Protein and Energy Supplements for Animal Feeding

8. S. Sentheshanmuganathan -
   Plant Proteins for Human Consumption

9. K. Sachithananthan, A. Sivapalan and M. Mahendran -
   Antibacterial Properties of some Marine Algae of Sri Lanka

10. R. O. B. Wijesekera, A. L. Jayewardene and R. A. S. Chandraratna -
    Current Status of Research on Essential Oils and Spices Carried out by the Natural Products Group of the CISIR

11. S. Ponnuchamy -
    Studies on the Chemotypes of Citronella Grass Cultivated in Sri Lanka

12. H. M. W. Herath -
Some Studies on Lemon Grass and Citronella carried out at the Faculty of Agriculture, Peradeniya

13. L. B. de Silva -
Chemical Investigation of Medicinal Plants

14. G. P. Wannigama -
Natural Product Chemistry at the Department of Chemistry, University of Sri Lanka (Peradeniya Campus)

15. C. Satkumananthan -
Extraction of Cannabinoids with Milk

16. R. G. Panabokke and S. N. Arseculeratne -
Further Observations on the Chronic Toxic Effect of Palmyrah (Borassus flabellifer) flour on rats

17. K. T. D. de Silva -
Biogenetic Precursors of Terpenoid Indole Alkaloids

18. S. P. Gunasekera -
The Chemical Constituents of some Medicinally Important Plant Species of the Family Flacouritiaceae

19. R. O. B. Wijesekera -
A Case for an Asian International Centre of Natural Product Research

20. Grants awarded since the inception of the National Science Council for Projects relevant to topics under discussion at the Workshop.

21. Research in Natural Products carried out in Sri Lanka in the period 1970 - 1973.

APPENDIX C

MARINE NATURAL PRODUCTS

Paul Scheuer

Sri Lanka is not unique in its underutilization of the sea as a source of food and raw materials. Virtually all countries bordering on the ocean share this neglect. In order to improve this situation, a suitable organization, presumably CISIR should immediately prepare an inventory of available resources in manpower trained in all facets of marine science, in facilities (e.g. stations, boats, ponds, etc.), and in library resources. Dr. M. Mahendran of the Colombo Campus, University of Sri Lanka, has begun a research programme in marine natural products and should be a consultant in this initial, as well as subsequent, phases of this development.

Short-term upgrading of skilled manpower may be underwritten by various UN agencies (FAO, WHO), by the East-West Center in Honolulu, or by the International Center for Living Aquatic Resources Management (ICLARM).*

Long-range manpower and facilities development should be planned as part of natural products development in general, following completion of the inventory.

Since algae are photosynthetic plants and primary producers in the food chain of the sea, they should be considered first. Unicellular algae are an excellent protein source and have been grown in experimental outdoor culture (Nature, 254, 594. 1975). To my knowledge, no large-scale production facility is in operation, but marine scientists should follow the pertinent literature for new developments.

Red and brown macroscopic algae (green, brown, and red are the major divisions) have long been used in various parts of the world as food, fodder, fertilizer, or as a source of potash and iodine. Most of their uses are highly localized and not readily transferable to other cultures, except for

* ICLARM is the activity initiated January 1, 1975, by the Rockefeller Foundation of New York, which aims at a major improvement of the aquatic resources for the people of the Pacific and of Southeast Asia. It is currently headquartered in Honolulu. Its director Dr. Philip Helfrich, has indicated to me that they do not feel strictly limited to the Pacific area. Requests by Sri Lanka for aid with training or requests for a particular knowledge and experience in the marine area would be given the same consideration as similar requests from a Pacific country. (P.O.Box 3830, Honolulu, Hawaii 96812, USA)

the use of fertilizer, which is on the increase. Annual production in western countries is about 40,000 metric tons, of which 35 percent is produced in Norway.

Red and brown algae are no longer an industrial source of potash or iodine, but they have become an important raw material for the extraction of alga polysaccharides. These so called phycocolloids have no nutritive value, but they are valuable in the food industry as thickening, stabilizing, suspending, and gelling agents. The current annual harvest is approximately 17,000,000 metric tons with a market value of Rs. 2,275,000,000. Virtually all of this is harvested by fishermen, divers, specially built boats, or simply gathered after storms, none of it mechanically. Attempts are underway to culture the red alga genus Euchema in the Philippines for production of carrageenan, which is a widely used gum, particularly in milk products. Current price of carrageenan is about Rs. 20 per pound.

Marine algae have so far found no significant medical applications, with the exception of algin (one of the polysaccharides) as a laxative, for making dental impressions, and as a medium for laboratory culture. Kainic acid is an anthelmintic (Digenin, Helminal), produced by the red alga Digenea simplex, first isolated and studied by Japanese workers.

Only one marine invertebrate serves currently as the source of a biomedical raw material. A gorgonian from the Caribbean elaborates a prostaglandin, which can be transformed in the laboratory into a physiologically active substance. Another marine natural product of an annelid, nereistoxin, served as the template for a valuable insecticide, which is marketed in Japan under the trade name Padan, with an annual production in 1972 of 1,500,000 kg.

Mariculture of invertebrates for food or pearls is highly successful in various parts of the world. Many more organizations are experimenting with additional crops. Developments in this area should be followed by the fisheries staff. A very simple kind of mariculture, of the brine shrimp Artemia, which is in great demand as a food source in mariculture, can be carried out in brackish ponds, with virtually no other investment.

Similarly, culturing of fish is highly successful in many areas and additional species of fish are currently under study. To commence such a programme Sri Lanka will constitute a major long-range commitment.

Pertinent Literature

"Marine Science Contents Tables," a monthly literature alerting service, is available without charge from FAO, Via delle Terme di Caracalla, 00100 Rome, Italy.

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APPENDIX D

THREATENED OR ENDANGERED PLANTS OF SRI LANKA

Edward S. Ayensu

The selection is based on A Revised Handbook tō the Flora of Ceylon I (1):1973 and manuscripts available as of May 8, 1975, which were prepared for the Revised Handbook. Trimen's Handbook to the Flora of Ceylon (1893 - 1900) was partially based on collections by Thwaites, and species not collected since the time of Thwaites may be considered endangered, due to probably modification of their habitat by human activities in the intervening years.

Numbers after the family name refer to page numbers in the Revised Handbook or in the relevant manuscripts.

Alchemilla indica var. sibthorpiodes - Rosaceae - 63 - endemic - not coll. since 1911.
Anodendron manubriatum - Apocynaceae - 26 - endemic - not coll. since Thwaites
Anodendron rhinosporum - Apocynaceae - 26 - endemic - not coll. since Thwaites
Ceropegia elegans var. gardneri - Asclepiadaceae - 55 - endemic - not coll. in wild since 1800; perhaps extinct in wild; in Europe cultivated in greenhouses
Ceropegia thwaitesii - Asclepiadaceae - 54 - also in Deccan - not coll. since Thwaites
Cleghornia acuminata - Apocynaceae - 25 - endemic has become rare this century
Cyathula ceylanica - Amaranthaceae - 38 - endemic - not coll. since Thwaites
Croton zeylanicus - Euphorbiaceae - endemic - not coll. since Thwaites
Didymocarpus floccosus - Gesneriaceae - 92 - endemic - coll. once recently since Thwaites
Dischidia nummularia - Asclepiadaceae - 51 - also in Asia - not coll. since Thwaites
Ellipanthus unifoliatus - Connaraceae - 13 - endemic - not coll. since 1888, probably due to clearing and deforestation
Helicia ceylanica - Proteaceae - endemic - not coll. 1946 since the 1800's; probably due to development

Helixanthera ensifolia - Loranthaceae - 75 - endemic - not coll. since Trimen, Thwaites
Hunteria zeylanica - Apocynaceae - 10 - also in Asia - disappearing rapidly via forest destruction
Hypolytrum longirostre - Cyperaceae - endemic - not coll. since Thwaites
Lindernia viscosa - Scrophulariaceae - 32 - also in Asia - becoming rarer since Trimen
Mapania immersa - Cyperaceae - endemic - not coll. since Thwaites
Petchia ceylanica - Apocynaceae - 16 - endemic - much in danger of extinction via rain forest destruction
Peucedanum ceylanicum - Apiaceae - 45 - endemic - not coll. since 1846 (Gardner)
Phyllanthus hakgalensis - Euphorbiaceae - endemic - type coll. only
Phyllanthus oreophilus - Euphorbiaceae - endemic - not coll. since Thwaites
Prunus ceylanica var. ceylanica - Rosaceae - 72 - endemic - not coll. since early 1900's, probably due to rapid deforestation
Sanguisorba indicum - Rosaceae - 60 - endemic - not coll. since 1886
Tolypanthus gardneri - Loranthaceae - 69 - endemic - reported 1960; most original localities destroyed by agricultural activities
Tylophora fasciculata - Asclepiadaceae - 43 - also in India - not coll. since 1864
Tylophora multiflora - Asclepiadaceae - 43 - also in India - not coll. since Thwaites
Tylophora zeylanica - Asclepiadaceae - 44 - perhaps also in India - not coll. since Thwaites; may not exist at all now
Vernonia gardneri var. brevior - Asteraceae - 23 - endemic - not coll. since Thwaites
Willughbeia cirrhifera - Apocynaceae - 8 - endemic - now rare via forest destruction
Wrightia puberula - Apocynaceae - 24 - endemic - not coll. since Thwaites

APPENDIX E

SOME EXOTIC PLANTS THAT SHOULD BE INTRODUCED TO SRI LANKA FOR TESTING AS NEW CROPS

Richard E. Schultes and Noel D. Vietmeyer

Caryocar species. The British botanist who initiated rubber growing in this part of the world promoted oil from *Caryocar* as much as he did the rubber tree. But *Caryocar* remain a group of little-known trees growing wild in the Amazon region. They bear large quantities of oily seeds resembling Brazil nuts. Test plantings and studies in Sri Lanka are warranted.

Jessenia polycarpa. Native to the Amazon regions, this palm bears extraordinarily large bunches of fruit with an oil similar to olive oil in appearance, content, and quality. It is sold as an edible oil in Bogota, Colombia, but is virtually unknown to the rest of the world. With the skyrocketing cost of olive oil, the time for *Jessenia* domestication is fast approaching.

Jojoba (*Simmondsia chinensis*). This subtropical, North American desert plant is unique in the vegetable kingdom: it secretes liquid wax in its seeds instead of the glyceride oils secreted by other plants. Liquid waxes are important in industry. They are difficult to synthesize, and the only other source is the sperm whale. Development of jojoba as a crop might provide important economic benefits to the dry zone of Sri Lanka. Test plantings are warranted. (A National Academy of Sciences report, "Products from Jojoba: A Promising New Crop for Arid Lands," describing the commercial importance of jojoba can be obtained, without charge, from the National Science Council of Sri Lanka or from Dr. Noel Vietmeyer, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, U.S.A.)

Naranjilla (*Solanum quitoense*). Related to, but wholly unlike, tomatoes, this dessert fruit is highly esteemed in Peru, Colombia, Ecuador, and Guatemala, but is unknown in Sri Lanka. Its delicious, refreshing juice could become popular in Sri Lanka, where the plant could easily flourish at proper altitudes.

Other Solanum species. In northwestern South America, there are three large tomato-like, tropical-lowland fruits that might be appropriate for Sri Lanka. They are Solanum topiro, Solanum georgicum, and Solanum alibile. They are high in vitamin and mineral content. Vitamin-rich iced drinks and jams are prepared from these, especially from Solanum topiro, which is now being commercially cultivated in Colombia for the preparation of jellies. It is recommended only for local markets in Sri Lanka, as it is not easily transported over long distances, and is easily grown in home gardens and on small farms. Material and information are available from the Campania Fruco, Cali, Colombia.

Pejibaye (Guilielma gasipaes). The chestnut-flavoured fruit of this palm is probably the best nutritionally balanced of tropical foods. It contains carbohydrates, protein, oil, minerals, and vitamins. Suited to the wet tropics, the trees, once established, require little care and yield well. They grow widely in the Central and South American tropics. Test plantings should definitely be made in Sri Lanka.

Leucaena latisiliqua. New varieties of this nitrogen-fixing leguminous plant developed at the University of Hawaii have tremendous growth rates and productivity. Trees attain 50 feet in 7 years. The Philippines is now beginning to exploit these varieties on a very large scale as energy plantations to fuel steam-powered electric generators.

Hawaiian Supersweet Corn. Special varieties of corn suitable for growing in the tropics and with extremely high sugar contents have been developed. They could become a popular snack, sweet, or even food in Sri Lanka.

Caryodendron orinocense (Euphorbiaceae). 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 Departmento de Botanica, Universidad de Narino, Pasto, Colombia; planting material may be solicited from the Agricultural Experiment Station at Palmira, Colombia.

Passiflora mollissima. The fruits of several little-known highland (5,500 - 8,500 ft.) species of passion fruits, especially Passiflora mollissima, provide a favourite and exquisite fruit in Colombia and Ecuador, where they are known as curuba.

The fruit are elongate-ovoid, measuring 7 by 3 inches. Yellow when ripe, they contain an orange jelly with many embedded seeds. The pulp is pressed through a sieve to separate the jelly from the seeds. The jelly is made into jams, candies and sorbetes (mixed with milk as a delicious drink), with a flavour that can be described as a mixture of strawberries, pineapple, and bananas but with a slight suggestion of almonds.

Most of the fruit comes from wild plants, but recently some selection work and several small plantations have been initiated in Bogota. A vine, *Passiflora mollissima*, is grown in rows on simple wire trellises.

Sri Lanka already has much experience with passion fruit products, but *Passiflora mollissima* is a highland species, the source of a new taste for fruit juices, ice cream, jams, jellies, and concentrated pulp.

Information and plant material may be solicited from the Agricultural School of Tibaitata, Colombia, and from certain commercial firms, especially Compania Fruco, Cali, Colombia.

Arracacia esculenta (Umbelliferae). A new starchy root for local food consumption could be *Arracacia esculenta*, employed in the Andean countries in soups, purees, etc. Its mineral content, though not high, is better than that of cassava and most other roots and tubers. This plant can be cultivated in equatorial regions from 5,000 - 9,000 feet and has numerous agronomic varieties, some of which might be adaptable to Sri Lanka. It is a crop admirably appropriate for small home gardens, although it might also be produced commercially in larger holdings.

APPENDIX F

THE PRODUCTION OF FERTILIZER FROM AQUATIC WEEDS

Victor E. Dalpadado

Developing countries are generally short of foreign exchange for development and lack raw materials for the production of conventional industrial goods. However, they invariably have almost unlimited amounts of unskilled and semi-skilled manpower resources.

Aquatic weeds like Salvinia and water hyacinth are widespread in Sri Lanka's lakes and waterways. Several costly attempts have been made from time to time to eradicate them using agrochemicals and manpower, all ending in failure. The question arises: "Should these aquatic weeds be continued to proliferate and spread unchecked? or Is it not better to consider whether these aquatics can be converted to useful products, needed by the country."

Artificial fertilizers are in short supply and ever since the energy crisis, prices have soared. The use of the abundance of aquatic weed growth appears to offer a solution to this problem. For by using new methods and simple technology, it can be made into rich compost manure.

Through the judicious collection of weeds for composting operations, utilizing our large unemployed manpower resources, the present unchecked growth of these weeds could be soon brought under a reasonable degree of control, thus avoiding the dangers generally attributed to their dense growth and spread.

It has been successfully demonstrated that these weeds and organic city garbage (Colombo has 400 - 500 tons a day) make a very rich compost. This compost not only supplies the nitrogen, potassium, and phosphorous of artificial fertilizers, but also generally supplies the other primary elements like sulphur, calcium, magnesium and micronutrient elements such as boron, zinc, molybdenum, manganese, copper, cobalt, and iodine.

A number of seminars, training programmes on the new method of compost-making from organic garbage and weeds, have been conducted this year at the Plant Supply Nursery, Torrington Place, Colombo. The customary Indoor Method of composting, which takes 90 days to complete, has been cut to 14 days, using the "work-studied" method called the "Dalpadado Method."

The conversion of urban organic garbage and aquatic weed into rich compost manures where they are used obviously solves a number of problems. It checks the present uncontrolled spread of the weed, while providing gainful employment to unemployed at centres close to their own homes.

The large scale use of compost manures at comparatively inexpensive prices will give a tremendous boost to the food drive efforts of the Government, and cushion the effects of the population/food collision.

The implementation of an aquatic weeds collection and composting programme does not require much capital, especially foreign exchange. But when the programme gathers momentum, low-cost mechanization measures might be introduced.

The following steps are proposed for setting up a programme almost immediately:

(i) Organization of pools of unemployed labour for this work.

(ii) Conduct of training programmes for collection and composting.

(iii) Posting such trained employees to selected Pilot Centres for compost manufacture.

(iv) Organization of marketing facilities for manufactured products.

APPENDIX G

COLLABORATIVE POSSIBILITIES

Norman R. Farnsworth

Until more suitable arrangements can be made, it appears that, in the area of chemistry, Ceylonese scientists must rely on foreign scientists for sophisticated spectral data. While not desirable, the delays encountered by this procedure are not impossible to work with, especially during the initial stages of submission of the proposal, where for the most part, only compounds of known structure will be encountered. Ceylonese chemists are very knowledgeable concerning the location of scientists willing to cooperate in this respect.

With regard to collaborative programmes in the area of pharmacologic testing, I will agree to act as a resource person, on request, when various types of pharmacological testing are required. A number of pharmacologists in my department would be willing to collaborate, especially in the cardiovascular, analgesic, CNS, anti-inflammatory, autonomic nervous system, and antifertility areas, where we have on-going programmes.

It may also be possible to support one post-doctoral natural products chemist from Sri Lanka every two years (each for a two-year period) to work in Chicago on the isolation and structure-elucidation of anti-tumor agents from plants. (Support for post-doctoral people could not begin before March of 1977, since all available positions are filled up to that time.) Further, it would be interesting to explore the possibility of sending graduate students from the University of Illinois to Sri Lanka for combined field work and laboratory experience. Financial support for some graduate students from Sri Lanka who meet the entrance requirements of the Graduate College of the University of Illinois could be expected.

In addition, I will be willing, on request, to act as a resource person for advice on institutions in the U.S.A., where support might be available for graduate students and/or post-doctoral scientists in the U.S.A., depending on individual interests. Information concerning the availability of support for graduate students and post-doctoral scientists can also be given for countries other than the U.S.A., should such information be available at the time of inquiry.

Finally, if requested by Ceylonese scientists, I will be willing to bring the matter of collaboration on specific projects, need for journal subscription gifts, etc., to the attention of the Executive Committee of the American Society of Pharmacognosy (ASP) if specific needs and details can be provided. There is already some support to scientists having problems with foreign currency by members of the ASP, and perhaps an organised effort in this direction will be beneficial.