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C O N T E N T S

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A SURVEY OF THE ECONOMIC PLANTS OF SRI LANKA

Paper Prepared by :

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Sri Lanka, because of its geographical position and its physical features, has a relatively wide range of climatic regions and a correspondingly rich and varied flora. This flora remained more or less undisturbed by man up to about 500 B.C. From then onwards various crop plants eg. rice, millets, sugar-cane and sesamum along with mango, tamarind, jak and certain other trees, and settled agriculture were introduced to the island from the Indian sub-continent. Further from very early times Sri Lanka served as a trading centre between the East and the West and traders from different countries seem to have brought here a number of plants. More recently, during the last three or four centuries, several hundred plant species - many of them from the New World - have been introduced to the island. A large number of these alien plants have now become naturalised in Sri Lanka and are among the commonest plants seen along roadsides, waste ground, and as weeds of cultivated land. In this paper I shall not deal with the latter group of plants and shall confine attention to the indigenous species and some of the very early introductions.

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Even though our vegetation has been much disturbed for almost 2500 years and the original forests are now restricted to a very few small areas we still have a rich flora with nearly 300 indigenous species of which about 850 are endemic to the island. No complete survey has yet been made of the useful products that could be obtained from these plants. What we now know about them comes mainly from the accumulated traditional knowledge which again is based on empirical observations. According to the information available about 700 of the indigenous flowering plants and nearly 70 of the early introdeuctions could be used as sources of food or of phytochemicals of economic importance. A list of these plants are given at the end of this paper.

Food Plants -

The number of indigenous plants that could be used in various ways as sources of f od is about 200. Over half of them are used as vegetables or pot-herbs. The parts used range from roots and tender shoots to flowers and young fruits. They are mostly collected from wild or semi-wild plants. A very few are cultivated on a small scale. Among these are Alternanthera sessilis (Mukunuwenna), Basella rubra (Niviti), Centella asiatica (Gotukola), Ipomoea aquatica (Kan-kun), and Lasia spinosa (Kohila). Some of these local vegetables are said to be good sources of nitrogen, minerals and vitamins. According to Pirie (1971) leaves of Ipomoea aquatica have 4.6 to

5.8 per cent Nitrogen in the dry matter and the annual yield could be as high as 80,000 Kg/ha.

Very few of the local legumes are edible and even these are of little importance except as gene reservoirs for breeding purposes. Over 80 species produce fruits or seeds that could be eaten in the fresh condition or after roasting. A few of them, eg. Feronia limonia (Divul), Flacourtia indica (Uguressa), Elaeocarpus serratus (Veralu), Carissa carandas (Karanda), Zizyphus mauritiana (Mahadebara), and Aberia gardneri (Ketambilla, Ceylon Gooseberry) are sometimes cultivated in home gardens. In most species, however, the fruits are collected from wild or semi-wild plants. Some of the fruits are suitable for the preparation of fruit-drinks, jams and jellies. It is also said that good quality wines could be produced from some of them.

The starch producing plants number about 30. They are mainly grasses, palms, aroids and Dioscorea yams. Flour could also be extracted from some of the larger seeds like those of Cycas and Vateria copallifera (Hal). Our starch producing plants are of relatively little importance. Tubers of many wild aroids, some of which are plentiful along waterways, are never used locally because of the irritant action of the rhaphides present in them. If satisfactory methods to remove them are devised it should be possible to use these tubers at least as animal feed.

The local sugar producing plants are **Madhuca** longifolia (Mi) and certain palms. Madhuca flowers are said to contain 50 to 70 percent of their dry weight as sugars. These do not seem to be used now in Sri Lanka but in India many thousands of tons are used annually in the fermentation industry. Locally sugar is extracted from Borassus flabellifer (Palmyrah), Caryota urens (Kitul), and Cocusnucifera (Coconut). Very recently tapping of Nypa fruiticans (Gin-pol) has been started in the island. Nypa is considered to be the cheapest source of sugar - one acre producing up to $1\frac{1}{2}$ tons sugar without any cultivation (Macmillan, 1943).

Non-drying oils could be obtained from over 20 local species but very few of them are suitable for use as food. Oil from coconut and from Sesamum (Gingelly) are the only ones now used as food in the country. Madhuca (Mi) oil was used in the past. This is still an important item of food in India.

Before the introduction of tea to the island infusions of the dried flowers of Cassia auriculata (Ranawara), and Aegle marmelos (Beli) were much used as beverages and are still used to some extent. Accoording to Brown (1950) infusions of the leaves of Streblus asper (Moraceae) and those of Carmona microphylla (Boraginaceae) are used as tea in some countries. Sap from palm inflorescences, either fresh or after fermentation, is also much used as a beverage.

Spices and Flavourings -

Sri Lanka has been well known for its spices from time immemorial and a considerable number of local plants are used as spices. The most important of these are Cardamom and Cinnamon. In addition to these and the other better known ones, leaves of Premna serratifolia, P. latifolia, and P. procumbens (Verbenaceae) are sometimes used as flavourings.

Masticatories -

The most widely used masticatories, Piper betle (Betel) and Aerca catechu (Arecanut) are both very early introductions to the island. Among others used locally are the seeds of the endemic palms, Areca concinna (Lenateri) and Loxococcus rupicola (Dotalu) and the seeds of the Zingiberaceous plant Amomum masticatorium which is also endemic to Sri Lanka. In some parts of the island Callicarpa tomentosa (Verbenaceae) is said to be used for chewing.

Medicinal Plants -

Nearly 700 indigenous plant species are used in medicine either here or in some of our neighbouring countries. Out of our native plants which are common to Sri Lanka and India, about 30 percent are considered to be of medicinal use. As against this, only

about 3 or 4 per cent of the endemics are so considered. We still seem to be using the same plants as in India with only a very few additions from the local flora even though the ayurvedic system of medicine has been used here for well over 200 years.

Some of our local drug plants are reputed to have bactericidal properties. In studies carried out in India many of these have been found to be ineffective or only partially effective but Glycosmis pentaphylla (Rutaceae), Hiptage benghalensis (Malphigiaceae), and Phyla (Lippia nodiflora (Verbenaceae) are reported to have inhibited completely the growth of nine different types of bacteria for which tests were carried out (Puri, 1962).

Poisons, Insecticides and Insect Repellants -

About 47 species are recorded as being poisonous; nearly 30 species are used as fish poisons and 19 are reputed to be active as insecticides or insect repellants.

Nettles and Skin Irritants -

Of the plants listed under this group those belonging to the Urticaceae and Tragia involucrata (Euphobiaceae) are true nettles with stringing hairs. One of them, (Laportea crenulata (Maussa,

devil-nettle or fever-nettle) stings severely producing distressing effects which may last for several days. The ripe fruits of Caryota urens (Kitul) and the tissues of certain aroids, if rubbed against the skin, cause irritations due to the presence of raphides in them.

Essential Oils and Perfumes -

The species producing essential oils and perfumes number about 30, but of them only Cymbopogon spp. (Citronellas and Lemon grass), Cinnamomum zeylanicum (Cinnamon), and Elettaria spp. (Cardamoms) are cultivated for commercial purposes. Many of the plants producing essential oils are the same as those used as spices.

Dyes and Tanning -

Before the synthetic dyes became freely available vegetable dyes were much in use in the country. Some of these were considered to be "softer" and more permanent than the synthetics, but this industry died down as it could not compete with the cheaper imports. With the present expansion of various industries and the shortage of imported dyes, local vegetable dyes should have a ready market if a regular supply could be made available.

Tannin extraction still continues but with the deforestation that is now going on the numbers of the tannin producing trees are rapidly dwindling.

Gums, Resins etc. -

Good grade gums, resins, etc., are produced by many of our local trees especially the Dipterocarps. Doona zeylanica (Dun), for example, produces a good grade gum resin; Shorea oblongifolia (Dumala) gives a clear resin suitable for varnishes; and Vateria copallifera (Hal) gives a clear yellowish resin said to be equal to the best dammars. All three of these are endemic to the island.

GENERAL OBSERVATIONS :

Out of the several hundred indigenous plants listed, Coconut is the only major crop plant and is now grown over an area of about a million acres. Cinnamon, Citronella and Cardamom are minor export crops and they cover about 36,000 acres, 15,000 acres, and 9,500 acres respectively. None of the others are grown to any large scale. A few of the food plants and some of the medicinal plants are grown in small plots or in home gardens. Attempts are now being made to grow certain medicinal plants on a larger scale. From the vast majority of the species listed however the various

products are collected from wild or semi-wild plants growing on waste ground or in forests, and with the progressive clearing up of the forests these plants are becoming less and less available for exploitation.

Except for the research on Coconut and, perhaps, also on Citronella, little or no work has been done on the selection and the improvement of any of the indigenous economic plants. In fact as far as some of them are concerned selection may be working against improvement due to the fact that plants or parts of plants with any desirable characteristics are often uprooted or removed for use by man leaving only those with the less desirable characteristics to mature and reproduce.

Cultivation and selection would undoubtedly improve many of our economic plants. In some of them various strains are recognised and some are regarded as superior to others. In these selection for quality and high yields is desirable. In Cinnamon, for example, such slection and vegetative propagation of clonal material could ensure uniform and high quality products.

Untapped phytochemical products may still remain hidden in some of our local species, especially the endemic ones. A full and comprehensive survey of these is urgently needed but at the rate exploitation of forests and deforestation is now going on many endemics

may become extinct long before any such survey is complete. Early action should therefore be taken to protect and even cultivate any endangered species and to preserve representative samples of vegetation types as Strict Natural Reserves so as to protect the flora for studies and use even at a later date.

LIST OF VASCULAR PLANTS OF SRI LANKA OF ECONOMIC IMPORTANCE AS FOOD, DRUGS, ETC.

by

B.A. Abeywickrema

This list has been prepared after a preliminary survey of the literature on the useful plants of Sri Lanka and some of the neighbouring countries. A full list of the literature consulted is given at the end. Only plants indigenous to the island and those considered to have been introduced to Sri Lanka at a very early date are given in this list. The names of those introduced are underlined. Names of plants brought here during the last few centuries from the New World and elsewhere have not been included. Further only plants used as food, drugs, etc. or as sources of useful chemical products are listed. Those providing timber, fibres etc. are not included.

The plant names are arranged under families in the same order as in the author's Check list of the Flowering Plants of Ceylon(Abeywickrema 1959). References to descriptions of the plants may be obtained from this work. Against each name the nature of the use or the product is indicated by a figure. These figures are arranged in two columns. Those under column A refers to uses as food etc. and those under column B to drugs etc. as follows:-

Column A	Column B
1. Starch	1. Medicinal drugs
2. Sugar	2. Poisons
3. Non-drying oils	3. Fish poisons
4. Vegetables and Potherbs	4. Nettles and skin irritants
5. Legumes	5. Pesticides and Insect repellants
6. Edible fruits and seeds	6. Perfumes and essential oils
7. Beverages	7. Dyes and Tannins
8. Spices and Flavourings	8. Gums and mucilages
9. Masticatories	9. Cements and Resins

For example,

	A	B
Areca catechu L	9	1;7
and Cinnamomum zeylanicum Bl.	88	1,6

mean that the first named plant is an introduced one, as the name is underlined, and that it provides a masticatory (A9), medicinal drug (B1) and also a dye or tannin (B7), and that the second is an indigenous plant used as a spice or flavouring (A8), and provides a medicinal drug (B1) and an essential oil (B6).

I wish to record here my sincere thanks to Professor R.N. de Fonseka and to Miss. L.H. Chang for assistance in checking references.

PTERIDOPHYTES

	A	B
Lycopodiaceae		
Lycopodium phlegmaria L.		1
Pteridaceae		
Acrostichum aureum L.	4	1
Parkeriaceae		
Ceratopteris thalictroides (L.) Brongn.	4	1
Aspidiaceae		
Diplazium esculentum (Retz.) Sw.	4	1
Polypodiaceae		
Drynaria quercifolia (L.) J.Sm.	4	1

GYMNOSPERMS

Cycadaceae		
Cycas circinalis L.	1,4,6	1,2

MONOCOTYLEDONS

	A	B
Typhaceae		
Typha angustifolia L.	1	
Pandanaceae		
Pandanus tectorius Soland. ex Park.	6	1,6
Aponogetonaceae		
Aponogeton natans (L.) Engl.&Krause	1,4	
A. crispus Thunb.	1,4.	
Hydrocharitaceae		
Enhalus acoroides (L.f.) Rich. ex Steud.	6	
Ottelia alismoides (L.) Pers.	4,6	1
Gramineae		
Lophatherum gracile Brongn.		1
Phalaris arundinacea L.		2
Eleusine indica (L.) Gaertn.		1,2
E. coracana (L.) Gaertn.	1	1
Dactyloctenium aegyptium (L.) Beauv.		1,2
Cynodon dactylon (L.) Pers.	1.	1, 2
Oryza sativa L.	1.	1

	A	B
Hygroryza aristata (Retz.) Nees		1
Panicum repens L.		1
P. miliaceum L.	1	1
P. psilopodium Trin.		1
P. miliare Lam.	1	1
P. antidotale Retz.		1,2
Echinochloa colonum (L.) Link.	1,4	
E. frumentacea Link.	1	1,2
E. crus-galli (L.) Beauv.	1,4	1
E. stagnina (Retz.) Beauv.)		1
Paspalum scrobiculatum L.	1	1,2
Setaria plicata (Lam.) Cooke		1
S. italica (L.) Beauv.	1	1
Pennisetum glaucum (L.) R.Br.	1	1
Imperata cylindrica var. major (Nees) C.E.Hubb		1
Saccharum spontaneum L.		1
S. officinarum L.	2	1
Hackelochloa granularis (L.) Kuntze		1
Sorghum halepense (L.) Pers.		1,2
S. bicolor (L.) Moench.	1	
Vetiveria zizanioides (L.) Nash		1,6
Chrysopogon aciculatus (Retz.) Trin.		1
Cymbopogon winteranus Jowitt		1,6
C. nardus (L.) Rendle		1,6
C. citratus (DC) Stapf	8	1,6
Themeda triandra Forsk.		1,2
Heteropogon contortus (L.) Beauv.		1
Chionachne koenigii (Spreng.) Thw.		1
Coix gigantea Koen.	1	
C. lachryma-jobi L.	1	1
Bambusa bambos (L.) Druce	4,6	1
B. vulgaris Schrad	4	1
Cyperaceae		
Cyperus iria L.		1
C. diffusus Vahl	4	
C. rotundus L.		1,3,6
C. stoloniferus Retz.		1
C. platypodyllus Roem. & Schult.		1
C. triceps (Rottb.) Endl.		1
C. Brevifolius (Rottb.) Endl.		1
Scirpus articulatus L.		1
S. grossus L.f		1
Remirea maritima Aubl.		1
Scleria pergracilis (Nees) Kunth		5
Palmae		
Areca catechu L.	9	1,7
A. concinna Thw.	9	1
Loxococcus rupicola (Thw.) Wendl.&Drude	9	
Caryota urens L.	1,2,7	1,4
Nypa fruticans Wurmb.	2,6,7	
Phoenix zeylanica Trim.	6	
P. pusilla Gaertn.	1	1
Corypha umbraculifera L.	1	3
Calamus rotang L.		1
Borassus flabellifer L.	1,2,6,7,	1
Cocos nucifera L.	2,3,6,7	1,6

	A	B
Araceae		
Pothos scandens L.	6	1
Acorus calamus L.	8	1,5,6,7
Rhaphidophora laciniata (Burm.f.) Merr.		1
Lasia spinosa (L.) Thw.	4	1
Amorphophallus campanulatus (Roxb.) Bl.	1,4	1
A. sylvaticus (Roxb.) Kunth.		1
Remusatia vivipara (Roxb.) Schott		1
Colocasia esculenta (L.) Schott	1,4	1
Alocasia cucullata (Lour.) Schott	1	
A. macrorrhiza (L.) Schott	1	1,4
A. indica (Roxb.) Schott	1	1
Typhonium trilobatum (L.) Schott		1
Arisaema leschenaultii Bl.		1
Lagenandra lancifolia (Schott) Thw.		1
L.ovata (L.) Thw.		1,2
Cryptocoryne spiralis (Retz.)Fischer		1
Pistia stratiotes L.		1,4
Flagellariaceae		
Flagellaria indica L.		1
Xyridaceae		
Xyris indica L.		1
Eriocaulaceae		
Eriocaulon sexangulare L.		1
Commelinaceae		
Cyanotis tuberosa Schultes f.		1
C. axillaris (L.) J.A. & J.H.Schult		1
Murdannia spirata (L.) Brueckn	4	
M. nudiflora (L.) Brenan	4	1
Floscopa scandens Lour.		1
Commelina benghalensis L.	4	1
C. clavata C.B.Clarke	4	
Pontederiaceae		
Monochoria hastata (L.) Solms	4	1
M. vaginalis (Burm.f.) Kunth	4	1
Liliaceae		
Gloriosa superba L.		1,2
Aloe barbadensis Mill.		1,8
Sansevieria zeylanica (L.) Willd.		1
Asparagus racemosus Willd.		1
A. falcatus L.	4	
A. gonoclados Baker		1
Smilacaceae		
Smilax aspera L.		1
Amaryllidaceae		
Allium cepa L.	4,8	1
Crinum asiaticum L.		1
C. defixum Ker.-Gawl.		1
C. latifolium L.		1
C. zeylanicum L.		1
Hypoxidaceae		
Curculigo orchioides Gaertn.		1
Dioscoreaceae		
Dioscorea esculenta (Lour.) Burkill	1	1
D. pentaphylla L.	1,4	1
D. bulbifera L.	1,4	1,2
D. oppositifolia L.	1	1
D. alata L.	1,4	1

	A	B
Musaceae		
Musa acuminata Colla	4,6	1
M. balbisiana Colla	4,6	1
M. x paradisiaca L. cvs	4,6	1
Zingiberaceae		
Kaempferia rotunda L.		1
K. galanga L.	8,9	1
Boesenbergia pandurata (Roxb.)Schlecht.		1
Curcuma aromatica Salisb.		1,6
C. zedoaria (Berg.) Roscoe	1,8	1,6,7
C. domestica Valeton	8	1,5,7
Z. zerumbet (L.) Sm.		1
Z. officinale Roscoe	1,8	1,6
Amomum masticatorium Thw.	9	
Elettaria repens (Sonner.) Baill.	8,9	1,6
E. ensal (Gaertn.) Abeywick.	8,9	1,6
Languas chinensis Koen.		1
L. galanga (L.) Stuntz		1,7
Costus speciosus (Koen.) Sm.	1,4	1
Cannaceae		
Canna indica L.	1	1,7
Orchidaceae		
Dendrobium macraei Lindl.		1
D. crumenatum Sw.		1
Eulophia epidendraea (Retz.) C.E.C. Fischer		1
E. nuda Lindl.		1
Cymbidium aloifolium (L.) Sw.		1
Rhynchostylis retusa (L.) Bl.		1
Luisia tenuifolia (L.) Bl.		1
Vanda tessellata (Roxb.) Led.		1
V. spathulata (L.) Spreng.		1
Acampe praemorsa Blatter & McCann		1
Anoectochilus regalis Bl.		1
Zeuxine strateumatica (L.) Schlecht.		1

DICOTYLEDONS

Piperaceae		
Piper longum L.		1
P. betle L.	9	1
P. thwaitesii C.DC.	8	
P. nigrum L.	8	1
P. umbellatum L.	8	
Chloranthaceae		
Chloranthus glaber (Thunb.) Makino		1
Ulmaceae		
Holoptelea integrifolia (Roxb.) Planch.		1
Celtis cinnamomea Lindl.		1
Trema orientale (L.) Bl.		1,7
Moraceae		
Streblus asper (Retz.) Lour.	7	1
Artocarpus nobilis Thw.	1,6	7
A. lakoocha Roxb.	6	1,7
A. heterophyllus Lam.	1,6	1,7

	A	B
Antiaris toxicaria (Pers.) Leschen.		1,2
Ficus parasitica Koen.		1
F. benghalensis L.		1
F. mysorensis Heyne ex Roth		1
F. altissima var. fergusonii King		1
F. trimenii King		1
F. nervosa Heyne ex Roth		1
F. arnottiana (Miq.)Miq.		1
F. religiosa L.		1
F. tsjakela Burm.f.		1
F. tsiela Roxb.		1
F. virens Ait.		1
F. callosa Willd.		1
F. heterophylla L. f.		1
F. asperrima Roxb.		1
F. hispida L. f.		1
F. racemosa L.	6	1
Urticaceae		
Laportea terminalis Wight		4
L. crenulata (Roxb.) Gaudich.ex Wedd.		1;2,4
Fleurya interrupta (L.) Wight		1,4
Girardinia zeylanica Decne.		1,4
Pouzolzia zeylanica (L.) Benn.		1
Olacaceae		
Ximenia americana L.	6	1
Olax scandens Roxb.		1
O. zeylanica L.	4	1
Opiliaceae		
Cansjera rheedii Gmelin		2
Loranthaceae		
Dendrophthoe falcata (L.f.) Ianser		1
Viscum orientale Willd.		1
V. monoicum Roxb.		1,2
Aristolochiaceae		
Apama siliquosa Lam.		1,3
Aristolochia bracteolata Lam.		1
A. indica L.		1
Polygonaceae		
Polygonum glabrum Willd.		1
P. barbatum L.		1
P. chinense L.		1
P. plebejum R. Br.		1
Chenopodiaceae		
Atriplex repens Roth	4	
Arthrocnemum indicum (Willd.) Moq.		1
Salicornia brachiata Roxb.		1
Suaeda monoica Forsk. ex J.F.Gmel.		1
Amaranthaceae		
Celosia argentea L.	4	1
Allmania nodiflora (L.) R.Br.	4	
Amaranthus spinosus L.	4	1
A. tricolor L.	4	1
A. viridis L.	4	1
Digera muricata (L.) Mart.		1
Cyathula prostrata (L.) Bl.		1
Aerva lanata (L.) Juss.	4	1

	A	B
Achyranthes aspera L.	4	1
A. bidentata Bl.		1
Alternanthera sessilis (L.) R.Br.	4	1
Nyctaginaceae		
Boerhaavia diffusa L.	4	1
Pisonia aculeata L.		1
P. grandis R. Br.	4	1
Aizoaceae		
Gisekia pharnacioides L.	4	1
Glinus lotoides L.		1
G. oppositifolius (L.) A.DC.	4	1
Mollugo pentaphylla L.	4	1
M. cerviana (L.) Ser.		1
M. nudicaulis Lam.		1
Sesuvium portulacastrum (L.) L.	4	
Trianthema portulacastrum L.	4	1
T. triquetra Rottl.	4	
T. decandra L.		1
Portulacaceae		
Portulaca oleracea L.	4	1
P. quadrifida L.	4	1
P. tuberosa Roxb.		1
Basellaceae		
Basella alba L.	4	1,7
Caryophyllaceae		
Polycarpaea corymbosa (L.) Lam.		1
Nymphaeaceae		
Nelumbo nucifera Gaertn.	1,4,6	1
Nymphaea lotus L.	1,4,6	1
N. stellata Willd.	1,4,6	1
Ceratophyllaceae		
Ceratophyllum demersum L.		1
Ranunculaceae		
Clematis smilacifolia Wall.		1
C. gouriana Roxb.		1,2
Berberidaceae		
Berberis tinctoria Leschen.		1,7
B. wightiana Schneider		1,7
B. ceylanica Schneider		1,7
Menispermaceae		
Tiliacora acuminata (Lam.)Miers		1
Anamirta cocculus (L.) Wight & Arn.		1,2,3
Coscinium fenestratum (Gaertn.)Colebr.		1,7
Tinospora malabarica (Lam.) Miers		1
T. glabra (Burm.f.) Merr.		1
T. cordifolia (Willd.) Miers		1
Hyserpa nitida Miers		1
Diploclisia glaucescens (Bl.) Diels		1
Cocculus hirsutus (L.) Diels		1
Pachygone ovata (Poir.) Miers		3
Stephania japonica (Thunb.) Miers		1
Cissampelos pareira L.		1
Cyclea burmanni (DC) Miers		1
Magnoliaceae		
Michelia champaca L.		1,6,7

	A	B
Annonaceae		
Uvaria narum (Dunal.) Wall.		1
Polyalthia longifolia (Sonner.) Thw.		1
Lauraceae		
Cinnamomum zeylanicum Bl.	8	1,6
C. iners Reinw.	8	1
Machilus macrantha Nees		1
Neolitsea cassia (L.) Kostern.		8
Litsea glutinosa (Lour.) C.B.Rob.		1,8
Cryptocarya wightiana Thw.		1
Cassytha filiformis L.		1,5
Hernandiaceae		
Hernandia ovigera L.		1
Capparidaceae		
Crataeva religiosa Forst.f.		1
Capparis zeylanica L.	6	1
C. horrida L.f.	6	1
Cadaba trifoliata (Roxb.) Wight & Arn.		1
Maerua arenaria (DC)Hook.f.& Thoms.		1
Cleome monophylla L.		1
C. chelidonii L.f.		1
C. viscosa L.		1
Gynandropsis gynandra (L.) Briq.	4	1
Cruciferae		
Brassica juncea (L.) Coss.	3,8	1
Moringaceae		
Moringa oleifera Lam.	3,4,8	1
Nepenthaceae		
Nepenthes distillatoria L.		1
Droseraceae		
Drosera burmanni Vahl		1
D. indica L.		1
D. peltata J.E.Sm.		1
Crassulaceae		
Kalanchoe laciniata (L.) Pers.		1
Rosaceae		
Rubus ellipticus Sm.	6	
R. niveus Thunb.	6	
Connaraceae		
Connarus monocarpos L.		1
Leguminosae		
Crotalaria prostrata Rottl. ex Wblld.		1
C. albida Heyne ex Roth		1
C. retusa L.		1
C. verrucosa L.		1
C. juncea L.		1,2
C. medicaginea Lam.		1
C. mucronata Desv.		2
C. laburnifolia L.		1
Indigofera linifolia (L.f.) Retz.		1
I. enneaphylla L.		1
I. aspalathoides Vahl		1
I. glabra L.		1
I. trita L.f.		1
I. oblongifolia Forsk.		1

	A	B
I. tinctoria L.		1,7
I. galegoides DC.		2
[illegible]ea corylifolia L.		1
Mundulea sericea (Willd.) A. Chev.		1,2,3
Tephrosia spinosa (L.) Pers.		1 [illegible]7
T. purpurea (L.) Pers.		1,3,7
T. villosa (L.) Pers.		1
Sesbania sesban (L.) Merr.		1
S. grandiflora (L.) Pers.	4	1,8
Zornia diphylla (L.) Pers.		1
Smithia sensitiva Ait.		1
S. conferta Sm.		1
Pseudarthria viscida (L.) Wight & Arn.		1
Uraria picta (Jacq.) DC.		1
Alyssicarpus vaginalis (L.) DC.		1
A. longifolius (Rottl.) Wight & Arn.		1
Desmodium pulchellum (L.) Benth.		1
D. triquetrum (L.) DC.		1
D. heterocarpum (L.) DC.		1
D. triflorum (L.) DC.		1
D. heterophyllum (Willd.) DC.		1
D. gyroides DC.		1
Abrus precatorius L.		1,2
Glycine javanica L.	5	
Teramnus labialis (L.f.) Spreng.		1
Mucuna monosperma D.C.		1
M. gigantea (Willd.) DC..		1,2
M. prurita Hook.		1
Erythrina variegata L.	4	1,7
Butea monosperma Taub.		1,5,7,8
Canavalia gladiata (Jacq.) DC.	5	
Phaseolus adenanthus G.F.W.Mey.		1
P. trilobus L.	5	1
P. aconitifolius Jacq.	5	1
P. aureus Roxb.	5	1
P. mungo L.	4,5	1
P. radiatus L.		1
P. calcaratus Roxb.	4,5	
Clitoria ternatea L.	4	1,7
Lablab niger Medic.	5	1,2
Dolichos biflorus L.		1
D. uniflorus Lam.	5	
D. falcatus Klein.		1
Rhynchosia minima (L.) DC.		1
Moghania strobilifera (L.) J.St.Hil.		1
M. macrophylla (Willd.) Kuntze		1
Dalbergia lanceolaria L.f.		1
Pterocarpus marsupium Roxb.		1,8
Pongamia pinnata (L.) Pierre	3	1,3,5
Derris scandens (Roxb.) Benth.		3
D. uliginosa (Willd.) Benth.		1,3
D. benthamii (Thw.) Thv.		3
Sophora tomentosa L.		1,2
Caesalpinia bonduc (L.) Roxb.		1

	A	B
C. crista L.		1
C. digyna Rottl.		1
C. sappan L.		1,7
Cassia fistula L.		1,7
C. occidentalis L.	4	1
C. sophera L.		1
C. Tora L.	4	1,7
C. auricoulata L.	7	1,7
C. italica (Mill.) Lam.		1
C. siamea Lam.		2
C. absus L.		1
C. mimosoides L.		1
Cynometra ramiflora L.		1
Dialium Ovoideum Thw.	6	
Saraca indica L.	[illegible]	1
Tamarindus indica L.	1,3,4,6,8	1,7,9
Bauhinia tomentosa L.	4	1
B. racemosa Lam.		1
Neptunia oleracea Lour.		1
Entada phaseoloides (L.) Merr.		1,2,3
Adenanthera pavonina L.		1,7,8,9
Dichrostachys cinerea (L.) Wight & Arn.		1
Acacia nilotica var. adansonii (Guill.&Perr.) Kuntze		7,8
A. leucophloea (Roxb.) Willd.		1,7,8
A. ferruginea DC.		1
A. concinna (Willd.) DC.		1,5,7
A. pennata (L.) Willd.)		1,3,7
Albizia lebbeck (L.) Benth.		1,7
A. odoratissima (L.f.) Benth.		1
A. chinensis (Osb.) Merr.		1
A. amara (Roxb.) Boiv.		1
Geraniaceae		
Geranium nepalense Sweet		1
Oxalidaceae		
Oxalis corniculata L.	4	1
Linaceae		
Hugonia mystax L.		1
Erythroxylaceae		
Erythroxylum monogynum Roxb.		1
Zygophyllaceae		
Tribulus terrestris L.		1
Rutaceae		
Euodia lunu-ankenda (Gaertn.) Merr.		1
Ruta graveolens L.		1
Chloroxylon swietenia DC.		1
Toddalia asiatica (L.) Lam.	8	1,2
Acronychia pedunculata (L.)Miq.	4	1,3
Glycosmis pentaphylla (Retz.) Corr.		1
Murraya paniculata (L.) Jacq.		1,6,8
M. koenigii (L.) Spreng.	8	1
Clausena dentata (Willd.) M.Roem.	6	
Atalantia monophylla DC.	6	
Paramignya monophylla Wight		1
Citrus aurantifolia (Christ.) Swingle	6,8	1
C. sinensis (L.) Osb.	6	1

	A	B
C. reticulata Blanco	6	1
Aegle marmelos (L.) Corr.	6	1,6,7,8,9
Feronia limonia (L.) Swingle	6	1,8
Simaroubaceae		
Samadera indica Gaertn.		1
Burseraceae		
Canarium zeylanicum (Retz.)Bl.	6	3,8
Meliaceae		
Chukrassia tabularis A. Juss.		1,7
Xylocarpus granatum Koen.		1
X. moluccensis (Lam.) M.Roem.		1
Melia dúbia Cav.		1
Azadiracta indica A. Juss.	3	1,5,6
Walsura piscidia Roxb.	6	1,3
Amoora rohituka (Roxb.) Wight & Arn.	3	1
Aglaia roxburghiana (Wight & Arn.) Mig.	6	1
Malphigiaceae		
Hiptage benghalensis (L.) Kurz.		1,5
Polygalaceae		
Polygala chinensis L.		1
P. sibirica var. macrolophos (Hassk.) Benn.		1
P. telephoides Willd.		1
Euphorbiaceae		
Aporosa cardiosperma (Gaertn.) Merr.	6	
A. lindleyana (Wight) Baill.	4,6	1
A. lanceolata (Thw.) Thw.	6	
Antidesma ghaesembilla Gaertn.	4,6	1
A. alexiteria L.		1
A. bunius (L.) Spreng.	4,6	1,2
Glochidion zeylanicum (Gaertn.) A. Juss.		1
Putranjiva roxburghii Wall.		1
Securinega leucopyros (Willd.) Muell. Arg.		1,3
Phyllanthus reticulatus Poir.		1,7,8
P. emblica L.	6	1
P. urinaria L.		1
P. maderaspatensis L.		1
P. debilis Klein ex Willd.		1
Drypetes sepiaria (Wight & Arn.) Pax & Hoffm.	6	
Cleistanthus collinus (Roxb.) Hook.f.		1,2,3
Bridelia retusa (L.) Spreng.		1
Croton oblongifolius Roxb.		1
C. aromaticus L.		1,9
Chrozophora rottleri (Geisel.) A. Juss.		1,2
Aleurites moluccana (L.) Willd.	3	1,6,7
Trewia nudiflora L.		1
Mallotus philippensis (Lam.)Muell. Arg.		1,7
Macaranga indica Wight		1,8
M. peltata (Roxb.) Muell. Arg.		1,8
Acalypha fruticosa Forsk.		1
A. indica L.	4	1
Tragia involucrata L.		1,4
Homonoia riparia Lour.		1
Ricinus communis L.	3	1
Dalechampia indica Wight		4
Jatropha glandulifera Roxb.		1,7

	A	B
J. curcas L.		1,3
Sebastiana chamaelea (L.) Muell. Arg.		1
Excoecaria agallocha L.		1,2,7
Sapium indicum Willd.		2,3
S. insigne (Royle) Trim.		1
Euphorbia antiquorum L.		1
E. tirucalli L.		1,2,7
E. atota Forst.f.		1
E. rosea Retz.		1
E. hirta L.		1
E. thymifolia L.		1
E. rothiana Spreng.		1
Anacardiaceae		
Mangifera zeylanica (Blanco.)Hook.f.	6	
M. indica L.	6	1,6,7
Lannea coromandelica (Houtt.) Merr.		7,8
Semecarpus marginata Thw.	6	
S. gardneri Thw.		9
Spondias pinnata (L.) Kurz	6	1
Celastraceae		
Celastrus paniculatus Willd.		1
Kurrimia ceylanica Arn.	6	
Kokoona zeylanica Thw.		1
Elaeodendron glaucum (Rottb.) Pers.		1,7
Hippocrateaceae		
Hippocratea indica Willd.		1
Salacia prinoides (Willd.) DC.		1
S. reticulata Wight	6	1
S. oblonga Wall.		1
Salvadoraceae		
Azima tetracantha Lam.		1
Salvadora persica L.		1
Sapindaceae		
Cardiospermum halicacabum L.		1
Allophyllus cobbe (L.) Bl.	6	1
Sapindus trifoliatus L.		1,3
S. emarginatus Vahl.	3	
Schleichera oleosa (Lour.) Oken.	3,6	1
Euphoria Longana Lam.	6	1
Dodonaea viscosa Jacq.		1,3
Harpullia arborea (Blanco) Radlk.		1,3
Balsaminaceae		
Impatiens balsamina L.		1
Rhamnaceae		
Rhamnus wightii Wight & Arn.		1
Colubrina asiatica (L.) Brongn.		1,3
Zizyphus mauritiana Lam.	6	1,7
Z. oenoplia (L.) Mill.		1
Z. rugosa Lam.		1
Ventilago maderaspatana Gaertn.		1,7
Vitaceae		
Cissus setosa Roxb.		1
C. quadrangularis L.		1
C. pallida (Wight & Arn.) Planch.		1

	A	B
Cayratia trifolia (L.) Domin.		1
C. pedata (Lam.) Juss.		1
Leeaceae		
Leea indica (Burm.f.)Merr.		1
Elaeocarpaceae		
Elaeocarpus serratus L.	6	1
Tiliaceae		
Grewia asiatica L.	6	1
G. tiliifolia Vahl	6	1
G. hirsuta Vahl		1
G. microcos L.	6	1
G. tenax (Forsk.) Fiori	6	1
Triumfetta rhomboidea Jacq.		1
Corchorus capsularis L.		1
C. olitorius L.	4	1
C. fascicularis Lam.		1
C. aestuans L.		1
Malvaceae		
Sida veronicifolia Lam.		1
S. acuta Burm.f.		1
S. rhombifolia L.		1
S. cordifolia L.		1
Abutilon asiaticum (L.) G. Don		1
A. indicum (L.) G.Don		1
A. hirtum (Lam.) Sweet		1
Urena lobata L.		1
Pavonia zeylanica Cav.		1
P. odorata Willd.		1
Hibiscus surattensis L.	8	1
H. furcatus Willd.		1
H. micranthus L.f.		1
H. vitifolius L.		1
H. abelmoschus L.		1,6
H. tiliaceus L.		1
H. esculentus L.	4	1
H. rosa-sinensis L.		1,7
Thespesia lampas (Cav.) Dalz. & Gibbs.		1,7
T. populnea (L.) Soland.		1
Gossypium arboreum L.	3	1
Bombacaceae		
Adansonia digitata L.	4,6,7,8	1,5
Salmalia malabarica (DC.)Schott & Endl.	3	1,7,8
Ceiba pentandra (L.) Gaertn.	3	1
Sterculiaceae		
Sterculia foetida L.	6	1
S. urens Roxb.		1
S. balanghas L.		1
Helicteres isora L.		1
Pentapetes phoenicea L.		1
Melochia corchorifolia L.		1
Waltheria indica L.		1
Dilleniaceae		
Dillenia indica L.	6	1
Ochnaceae		
Ochna squarrosa L.		1

	A	B
Theaceae		
Ternstroemia japonica (Thunb.) Thunb.	9	1
Guttiferae		
Hypericum japonicum Thunb.		1
Mesua ferrea L.	6	1,6
Calophyllum inophyllum L.	3	1
C. tomentosum Wight	3	1
Garcinia cambogia (Gaertn.) Desr.	6	1,9
G. morella Desr.	3	1,7
G. echinocarpa Thw.	3	
G. spicata (Wight & Arn.) Hook.f.		7
Dipterocarpaceae		
Dipterocarpus hispidus Thw.		9
D. zeylanicus Thw.		9
D. glangulosus Thw.		6
Doona zeylanica Thw.		9
D. trapezifolia Thw.	1	
D. cordifolia Thw.	6	9
D. ovalifolia Thw.		9
D. macrophylla Thw.		9
Vatica obscura Trim.		9
Vateria copallifera (Retz.) Alst.	1	7,9
Shorea oblongifolia Thw.		9
Tamaricaceae		
Tamarix gallica L.		1
Cochlospermaceae		
Cochlospermum religiosum (L.) Alst.		1,6,8
Violaceae		
Hybanthus enneaspermus (L.) F. Muell.		1
Viola serpens Wall.		1
Flacourtiaceae		
Hydnocarpus venenata Gaertn.		1,3
H. octandra Thw.		1
Trichadenia zeylanica Thw.		1
Flacourtia indica (Burm.f.) Merr.	6	1
Dovyalis hebecarpa (Gardn.) Warb.	6	
Passifloraceae		
Adenia wightiana (Wall.)Engl.		2
A. palmata (Lam.) Engl.		1,2
Thymelaeaceae		
Gnidia eriocephala Meisn.		1,3
Lythraceae		
Ammania baccifera L.		1
Woodfordia fruticosa (L.) Kurz		1,7,8
Lawsonia inermis L.		1,6,7
Lagerstroemia speciosa (L.) Pers.		1,7
Sonneratiaceae		
Sonneratia caseolaris (L.) Engl.	6	1
Lecythidaceae		
Barringtonia asiatica (L.) Kurz		1,3
B. racemosa (L.) Bl.		1
B. zeylanica (Miers.) Gardn.		1
B. acutangula (L.) Gaertn.		1,3,7
Careya arborea Roxb.		1

	A	B
Rhizophoraceae		
Rhizophora mucronata Lam.		1,7
R. apiculata Bl.		7
Ceriops tagal (Perr.) C.B.Rob.		1,7
Bruguiera gymnorhiza (L.) Lam.		7
B. sexangula (Lour.) Poir.		7
B. cylindrica (L.) Bl.		7
Carallia brachiata (Lour.)Merr.		1
Alangiaceae		
Alangium salviifolium (L.f.) Wangerin		1
Combretaceae		
Terminalia bellirica (Gaertn.) Roxb.	6	1,7
T. chebula Retz.		1,7
T. arjuna (Roxb.) Wight & Arn.		1
Anogeissus latifolia (Roxb.) Wall.		1,7,8
Lumnitzera racemosa Willd.		1
Myrtaceae		
Syzygium aqueum (Burm.f.) Alst.	6	
S. jambos (L.) Alston	6	1
S. hemisphericum (Wight) Alst.		1
S. zeylanicum (L.) DC.		1
S. operoulatum (Roxb.) Nied.	6	1
S. cumini (L.) Skeels	6	1,7
S. makul Gaertn.	6	
Melastomataceae		
Osbeckia cupularis D.Don		1
Melastoma malabathrica L.	4,6	1
Memecylon grande Retz.	4	
M. umbellatum Burm.f.		1,7
M. capitellatum L.		7
M. angustifolium Wight		1
Trapaceae		
Trapa bispinosa Roxb.	6	1
Umbelliferae		
Hydrocotyle javanica Thunb.	4	1,3
H. sibthorpioides Lam.	4	
Centella asiatica (L.) Urb.	4	1
Pimpinella heyneana Wall.		1
Cornaceae		
Mastixia tetrandra (Wight) C.B.Clarke		9
Ericaceae		
Gaultheria rudis Stapf		1,5,6
Myrsinaceae		
Aegiceras corniculatum (L.) Blanco		3
Ardisia humilis Vahl		1
Embelia ribes Burm.f.	4	1
Plumbaginaceae		
Plumbago zeylanica L.		1
Sapotaceae		
Chrysophyllum roxburghii G.Don	6	
Madhuca longifolia (L.) J.F.McBr.	2,3,6	1,5,6,7
Palaquium grande (Thw.) Engl.	3	
Mimusops elengi L.	3,6	1,6,7
Manilkara hexandra (Roxb.) Dubard.	6	

	A	B
Ebenaceae		
Maba buxifolia (Rottb.) Pers.	6	
Diospyros montana Roxb.		1,2,3
D. malabarica (Lam.)Kostel.		1,5,7,8
D. atrata (Thw.) Alst.		7
D. albiflora Alst.		7
D. ebenum Koen.		1,3
D. melanaxylon Roxb.		1,7
Symplocaceae		
Symplocos loha Buch.-Ham.		1,7
Oleaceae		
Jasminum angustifolium (L.) Willd.		1
J. auriculatum Vahl		1
J. flexile Vahl		1
J. humile L.		1
Olea glandulifera Desf.		1
Loganiaceae		
Strychnos colubrina L.		1
S. cinnamomifolia Thw.		1,2
S. nux-vomica L.		1,2
S. potatorum L.f.		1
Gentianaceae		
Exacum pedunculatum L.		1
Canscora diffusa (Vahl) R.Br.		1
Enicostema verticillare (Retz.) Baill.		1
Nymphoides indicum (L.) Kuntze		1
Apocynaceae		
Carissa carandas L.	6	1,7
C. spinarum L.	6	1
Rauvolfia serpentina (L.) Benth.		1
Petchia ceylanica (Wight) Livera		1
Cerbera manghas L.		1,2,3
Catharanthus pusillus (Murr.) G.Don		1,2
C. roseus (L.) G.Don		1
Holarrhena mitis (Vahl) R.Br.		1
Rejouva dichotoma (Roxb.) Gamble		1,2
Ervatamia divaricata)L.) Burkill		1
Alstonia scholaris (L.) R.Br.		1
Vallaris solanacea (Vahl) Kuntze		1
Wrightia tomentosa Roem. & Schult.		1,7
W. antidysenterica (L.) R.Br.		1
Ichnocarpus frutescens (L.) Ait.f.		1
Nerium oleander L.		4,2
Asclepiadaceae		
Hemidesmus indicus (.L.) Ait.f.		1
Cryptolepsis buchananii Roem. & Schult.		1
Secamone emetica (Retz.) R.Br.		1
Oxystelma esculentum (L.f.) R.Br.		1
Calotropis gigantea (L.) Ait.f.		1,5,7
Pentatropis microphylla (Heyne) Wight & Arn.		1
Pergularia daemia (Forsk.) Chiov.		1
Holostemma annulare (Roth)K.Schum.		1
Sarcostemma brunonianum Wight & Arn.		1
Gymnema sylvestra (Retz.) R.Br.		1

	A	B
Marsdenia tenacissima (Roxb.) Moon		1
Tylophora fasciculata Buch.-Ham.		1,2
T. indica (L.) Merr.		1
Cosmostigma racemosum Wight		1
Dregea volubilis (L.f.) Hook.f.	4	1
Leptadenia reticulata (Retz.) Wight & Arn.		1
Convolvulaceae		
Cuscuta reflexa Roxb.		1
C. chinensis Lam.		1,7
Cressa cretica L.		1
Evolvulus alsinoides (L.) L.		1
Ericybe paniculata Roxb.		1
Rivea ornata (Roxb.) Choisy	4	1
Merremia tridentata (L.) Hallier f.		1
M. emarginata (Burm.f.) Hallier f.		1
M. umbellata (L.) Hallier f.		1
M. vitifolia (Burm.f.) Hallier f.		1
Operculina turpethum (L.) Manso		1
Ipomoea mauritiana Jacq.		1
I. muricata (L.) Jacq.	4	1
I. pes-tigridis L.		1
I. eriocarpa R.Br.		1
I. obscura (L.) Ker.-Gawl.		1
I. pes-caprae (L.) R.Br.		1
I. aquatica Forsk.	4	
Argyreia populifolia Choisy	4	
Hydrophyllaceae		
Hydrolea zeylanica (L.) Vahl	4	1
Boraginaceae		
Cordia dichotoma Forst.f.		1,8
Carmona microphylla (Lam.) G.Don	7	1
Coldenia procumbens L.		1
Rotula aquatica Lour.		1
Heliotropium indicum L.		1
Trichodesma indicum (L.) R.Br.		1
T. zeylanicum (Burm.f.) R.Br.		1
Verbenaceae		
Lantana indica Roxb.		1
Phyla nodiflora (L.) Greene	4	1
Callicarpa tomentosa (L.) Murr.	9	1
Premna serratifolia L.	4,3	1
P. tomentosa Willd.		1
P. latifolia Roxb.	8	1
P. procumbens Moon	8	
Gmelina arborea Roxb.		1
G. asiatica L.	6	1
Vitex trifolia L.f.		1
V. negundo L.		1,5,7
V. pinnata L.		7
V. leucoxylon L.f.		1
Clerodendrum inerme (L.) Gaertn.		1
C. phlomidis L.f.		1
C. serratum (L.) Moon	4	1
C. infortunatum L.		1

	A	B
Avicenniaceae		
Avicennia officinalis L.		1,7
A. marina (Forsl.) Vierh.		7
Labiatae		
Ocimum americanum L.		1
O. sanctum L.		1,6
O. gratissimum L.		1
Coleus rotundifolius (Poir.) A.Chev.& Perr.	1,4	
C. aromaticus Lour.	4	1
Anisochilus carnosus (L.) Wall. ex Benth.		1
Pogostemon heyneanus Benth.		1,5,6
Dysophylla auricularia (L.) Bl.		1
Anisomeles indica (L.) Kuntze		1
A. malabarica (L.) R.Br.		1,6
Leucas zeylanica (L.) Benth.	4	1
Leonotis nepetifolia (L.) Ait.f.		1
Solanaceae		
Solanum nigrum L.		1
S. verbascifolium L.		1
S. ferox L.	4	1
S. ficifolium Ort.	4	1
S. indicum L.	4	1
S. melongena L.	4	1
S. xanthocarpum Schrad.	4	1
S. trilobatum L.	4	1
Physalis minima L.		1
Withania somnifera (L.) Dunal.		1
Datura metel L.		1,2
Schrophulariaceae		
Limnophila indica (L.) Druce		1
Bacopa monniera (L.) Wettst.		1
Striga gesnerioides (Willd.) Vatke		1
Sopubia delphinifolia (L.) G.Don		1
Centranthera indica (L.) Gamble		1
Bignoniaceae		
Oroxylum indicum (L.) Vent.		1
Dolichandrone spathacea (L.f.) K.Schum.		1
Stereospermum personatum (Hassk.) Chatt.		1
S. suaveolens (Roxb.) DC.		1
Pedaliaceae		
Pedalium murex L.		1
Sesamum indicum L.	3,4	1
S. radiatum Schumach.	3	
Lentibulariaceae		
Utricularia bifida L.		1
Acanthaceae		
Asteracantha longifolia (L.) Nees		1
Acanthus ilicifolius L.		1
Barleria prionitis L.		1,7
B. mysorensis Roth		7
B. cristata L.		1
Crossandra infundibuliformis (L.) Nees		1
Asystasia gangetica (L.) T. Anders.		1
Andrographis paniculata (Burm.f.)Nees		1

	A	B
A. echioides (L.) Nees		1
Justicia betonica L.		1
J. gendarussa Burm.f.		1
J. procumbens L.		1
Adhatoda vasica Nees		1,5,7
Rhinacanthus nasutus (L.) Kuntze		1
Eebolium viride (Forsk.) Alst.		1
Rungia parviflora (Retz.) Nees		1
R. repens (L.) Nees		1
Rubiaceae		
Nauclea orientalis (L.) L.		1
Anthocephalus cadamba (Roxb.) Miq.	6	1,6
Oldenlandia corymbosa L.		1
O. diffusa (Willd.) Roxb.		1
O. herbacea (L.) Roxb.		1
O. umbellata L.		1,7
O. biflora L.		1
Hedyotis auricularia L.		1
H. nitida Wight & Arn.	4	
Ophiorrhiza mungos L.		1
Mussaenda frondosa L.	4	1
M. glabrata (Hook.f.) Hutch.		1
Tarenna asiatica (L.) Alst.		1
Randia uliginosa (Retz.) DC.	6	1
R. dumetorum Lam.		1,3,5
Gardenia latifolia Ait.		9
G. turgida Roxb.		1
Dichilanthe zeylanica Thw.		9
Canthium dicoccum (Gaertn.) Merr.		1,2
C. coromandelicum (Burm.f.) Alst.		1
Ixora coccinea L.		1
Pavetta indica L.		1
Morinda tinctoria Roxb.		1,7
M. citrifolia L.		1,7
M. umbellata L.		1
Borreria hispida (L.) K.Schum.		1
Rubia cordifolia L.		1,7
Cucurbitaceae		
Trichosanthes nervifolia L.		1
T. cucumerina L.	4	1
T. anguina L.	4	1
Gymnopetalum wightii Arn.	8	
G. tubiflorum (Wight & Arn.) Cogn.	8	
Lagenaria siceraria (Molina) Standl.	4	1
Coccinia grandis (L.) J.O. Voigt	4	1
Momordica charantia L.	4,8	1
M. dioica Roxb.	4	1
Cucumis melo var. agrestis Naud.	4,6	1
C. sativus L.	4	1
Luffa aegyptiaca Mill	4	1
L. acutangula (L.) Roxb.	4	1
Colocynthis vulgaris Schrad.	4	1
C.citrullus (L.) Kuntze	6	1
Bryonopsis laciniosa (L.) Naud.		1

	A	B
Melothria maderaspatana (L.) Cogn.		1
M. perpusilla (Bl.) Cogn.		1
M. heterophylla (Lour.) Cogn.		1
Kedrostis rostrata (Rottl.) Cogn.		1
Corallocarpus epigaeus (Rottl.) C.B. Clarke		1
Ctenolepis garcini (L.) C.B. Clarke		1
Benincasa hispida (Thunb.) Cogn.	4	1
Zanonia indica L.		1
Campanulaceae		
Lobelia nicotianifolia Heyne		1
Goodeniaceae		
Scaevola sericea Vahl		1
Compositae		
Vernonia cinerea (L.) Less.	4	1
V. anthelmintica (L.) Willd.		1
V. zeylanica (L.) Less.		1
Elephantopus scaber L.		1
Adenostemma lavenia (L.) Kuntze.		1
Grangea maderaspatana (L.) Poir.		1
Erigeron astercides Roxb.		1
Laggera alata (D.Don) Schultz-Bip.		1
Epaltes divaricata (L.) Cass.		1
Sphaeranthus indicus L.		1
S. africanus L.		1
Xanthium strumarium L.		1
Siegesbeckia orientalis L.		1
Eclipta prostrata (L.) L.		1
Wedelia chinensis (Osb.) Merr.		1
W. biflora (L.) DC.		1
Spilanthes paniculata Wall.		1
Centipeda minima (L.) A.Br. & Aschers.		1
Emilia sonchifolia (L.) DC.	4	1
Notonia grandiflora DC.		1
Lactuca runcinata (L.) DC.		1
Launaea sarmentosa (L.) Alston		1

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ON THE TRAIL OF THE ELUSIVE HERB ....

Paper Prepared by :

K. Mahadeva*

From time immemorial this pearl drop of an isle in the Indian ocean has been the source of attraction to foreign invaders as well as to those with goodwill. There was thus a good deal of cross fertilisation of foreign cultures, ideas and practices with those prevailing here resulting in a medical structure which is a good combination of what is best in the East as well as in the West.

We have therefore here in Sri Lanka the practice of Allopathic Medicine from the West taught at two University campuses and Ayurvedic Medicine from North India taught at the Ayurvedic Medical College. The latter is a very wide term and includes generally in its fold, Siddha medicine from South India, Unani from Arabia and Desiya Chikisa, which is actually the real indigenous medical practice. Nearly 80% of the people of Sri Lanka are rural and speak a language of illness which is only understood by the Ayurvedic physician. In time of illness the first line of action is the time honoured home remedy. These home remedies have been built into folklore and handed down on talipot manuscripts from father to son for generations

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and in some cases are jealously guarded heirlooms, which are a means of their livelihood. Failing these home remedies their next approach is the Ayurvedic Physician.

Briefly Ayurveda means the Science of Life and is said to be of divine origin according to mythology going back to the dim past. This knowledge was first said to have been imparted by the gods in the form of verses and memorized by the ancient sages. The doyen of Ayurvedic Medicine-Caraka- had it systematised in print 2500 years ago. In the Ayurvedic concept of medicine the human being is generally conceived as a whole and is based on the theory that the biological regulators, which are three in number, are present in the cell in definite proportions. A person is said to be in good health if the regulators conform to the normal proportions. Any upset in the proportion of these factors due to the everchanging environment affects firstly the cell, next the tissues and finally the whole body and consequently the person is ill. These imbalances may be quantitative or qualitative in character and suitable antidotes or drugs are prepared to combat these effects. Ayurvedic medicine is as yet in the era where all the preparations are in the crude form, consisting of chips of roots, barks, flowers and leaves. The percolated fluid extract is yet very much in vogue. At most time it is bitter, unattractive and savours of a pungent flavour.

The Bandaranaike Memorial Ayurvedic Research Institute is situated a a few miles out of Colombo on a wooden hillock. It has most of the attributes needed for research viz. seclusion, privacy, convenience and backgrou nd. Housed in a picturesque building it has 48 beds, a modest laboratory and a pharmacy. The only handicap is that the staff and equipment are absolutely inadequate. Any technical assis-

tance like radiology, bacteriologye etc. is freely available from neighbouring institutions like the Hospitals, Medical Research Institute, the University etc. for which we are grateful.

There is always a satisfactory and promising dialogue between the Ayurvedic public and the Institute. At the moment quite a number of research studies have been initiated. Some are conducted conjointly with the other Institutions mentioned above. These studies assess the efficacy of Ayurvedic drugs prescribed in old talipot manuscripts on the following diseases:- Asthma, Arthritis, Renal calculi, Leucoderma, Psoriasis, Eczema and Anaemia.

Drug Evaluation :

A. Western approach : In the West drug firms spend large sums of money on research. Due to lack of tropical plants, which are said to possess compounds of the therapeutic value, drug evaluation is a very tedious process. Firstly the plants have to be obtained from the tropics and during the course of transport the natural texture is lost and they may get dried or suffer biodeterioration. This may cause alterations in therapeutic properties. Acids, alkalies, water, and sunlight also decompose a vegetable matter. A further difficulty is the diversity in botanical characters. Hence, during botanical collection the following are noted viz. family, genus, species, seasons, soil and climate. The process of drug evaluation is purely a fundamental biochemical approach. The basic sequence is as follows : the botanicals are ground, percolated, extracted, freeze dried and separated according to different solubilities and thin layer chromatography is next carried out. The chemical "finger prints" of the various compounds are shown up and could be identified with known ones. The pharmacological action and toxicity are next evaluated on bacteria, small animals and large animals in turn. At least

5 pounds of botanicals are needed bofore the drug company can do screening. Lastly clinical trials are carried out on human volunteers and if successful in combating disease these drugs are then marketed. This process may take as long as five to seven years.

B. Our approach. Unlike the Western one ours is more advantageous and safe and in a way looks the reverse of the Western approach. Here, we have at our very doorstep a very large armamentarium of indigenous botanical remedies built up over the centuries by a process of trial and error. These prescriptions which have been tried out on humans are made up of complete extractions of plants and are by experience known to be non-toxic. It has the advantage of using full extracts and possessing all the compounds in the plant material. Some of these may augment one another and have a synergistic action thereby potentiating its value. Amongst 80% of the world's people crude drugs still constitute the basis of prevailing medicine. Break down of this information is important. Scientific interpretation of folklore will give a clue to medico-botanical knowledge. These prescriptions are studied by us and controlled clinical trials carried out in this Institution in the following sequence of research viz. literary, botanical, clinical, chemical and pharmacological. Like many other research establishments the world over we have our drawbacks which are chiefly the lack of up to date technical equipment and trained personnel.

Although our progress is slow and our results are not promising at present, we hope that in the not too distant future, we will be able to get a break through which will be beneficial to humanity. I believe our civilisation's survival depends on our ability to sieve these age old folklores embodying human ingenuity and wisdom down the ages in talipot manuscripts and combine it with our 20th century scientific knowledge.

Addendum

Procedure, Research Activities, Assistance Received and Publications at the Bandaranaike Memorial Ayurvedid Research Institute

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1. Procedure :

One of the first steps needed was to teach the staff the keeping of correct records. This has been done but, the staff is as yet inadequate. Our next step was chiefly exploratory. As such we carried out pilot controlled clinical trials. At present drug evaluation of one or more drugs, can be compared on a small number of patients and the significance measured by the technique of sequential analysis in which a trial is stopped as soon as a result unlikely to have happened by chance, has been obtained. Its value is in enabling reliable conclusions to be wrung from a minimum of data. In this therapeutic drama the five actors cnncerned are viz : the physician, the pharmacist, the patient, the nursing staff and the referee. The physician and the patient are strongly motivated towards obtaining a positive result for quite different reasons, the former to be successful and the latter to be cured. The referees part in this game is a very trying one and an unenviable one. It is not always an easy one. He has to be impartial and without bias.

A Trial sequence -

There is a thrill and an air of expectancy at the beginning of a trial. After a hectic period of planning and preparation the blue print is ready and the trial starts and we hlpe for a dovetailed sequence of happy events. It is not always so. Even the best planned trial may go awry for the most abstruse reason. A sudden dearth of red onions in the market or the arrival of a batch of adulterated honey upsets the sequence.

Ethics

Codes of ethics have been laid down both in Ayurveda as well as in modern medicine. There is the Nuremberg rules, the Declaration of Helsinki by the World Medical Association (1964) and those laid down in Ayurveda. As concepts differ there are bound to be variances. The only real safeguard in human experimentation is the intolerance of the profession to do anything which offends.

2. Research Activities and assistance received

A. Literary

(1) Concept of heating and cooling

(2) Mandhams - Malnutrition

(3) Mootra asmari-renal calculi.

(4) Pruritus - Kandu -

(5) Amavata - Arthritis

(6) Hypertension

B. Clinical

(1) Guide Lines

(a) Kushta-dermatitis

(b) Ama Vata - Arthritis

(c) Asthma

(d) Hypertension

(2) Ward - Assess efficiancy of Ayurvedic drugs :-

(a) Asthma - 1974 - August 18th Trial

(b) Studied aetiology of 100 cases of Asthma.

(c) Ama Vata - Arthritis

(d) Psoriasis - Kitibhari as specific

(e) Leudoderma - Vacuchi as specific

(f) Eczema

(g) Renal stone with Dr. G.H. Perera G.H.C.

(h) Eosinophelia - Haridra Massi roasted saffron as specific

(i) Anaemia - Punarnava Mandura

(j) Mild hypertension (1974)

(3) Laboratory -

(a) Estimated flourine content of drinking water of the whole island.

(b) Histamine in normal and in eczemations and asthmati patients.

(c) P.E.F. in normal adults - Male and female.

(d) Assess the mucolytic action of Ayurveda drugs with modified viscometer.

(e) Isolation of alkaloid: from Ayurvedic herbs viz. Punarava and Heen nidikumbe.

(f) Determine normal range of mean arterial pressure (Mc Iver) 1974.

C. Other Acrivities and Assistances -

(1) Ayurvedic Interns are trained on the methods of research for periods 3-6 months.

(2) Obtained grant of Rs. 10,000/- for purchasing equipment necessary for laboratory work from the National Science Council 1971.

(3) Arranged for necessary assistance from the following establishments

(a) M.R.I. Medical Research Institute

(b) Radiological Department 1. G.H.C.
2. Colombo South Hospital

(c) C.I.S.I.R.

(d) University of Sri Lanka 1. Colombo
2. Peradeniya

(e) T.R.I. Tea Research Institute

(4) Initiated the publication of Ayurveda Pradeepika in all three languages in 1970. This also contained all the research activities of the Institute.

(5) Appointed Chairman of a sub-committee to submit a White Paper on Ayurvedic Research by the Ayurvedic Medical Council 11th November, 1970. submitted 16.7.1971.

(6) Seminar held at the Institute. Feb. 1973. Papers read on the work done.

(7) Lecture on Statistics by Dr. Stern, Colombo Campus to the staff.

(8) Selection of scholar O.M.S.F. April 1974.
For a two year period with allowance of Rs. 600/- p.m. study efficiency of Ayurvedic drugs in Hypertension.

3. Publications

(1) Guide for appraisal of state of Rheumatoid Arthritis using the criteria laid down by the Medical clincs of North America (1968).
K. Mahadeva (1969) Vol 1 No. 1 page 91.

(2) Fluoridation of water supplies as a preventinn of dental caries.
E. Karunanayake, K.D. Dharmasena and K. Mahadeva (1969) Vol. 1 No. 2 pg. 54.

(3) Scope of Research on Medical Plants.
K. Karunanayake (1969) Vol 1 No. 2 pg. 60.

(4) Protection and Propagation of Ayurvedic Medicinal Herbs.
W. Nawagamuwa (1969) Vol 1 No. 3 p. 65.

(5) Study of allergy amongst Asthmatic patients.
K.D. Dharmasena and K. Mahadeva (1969) Vol 1 No. 3 p. 73.

(6) Can we and to what extent incorporate modern clinical investigation
S. Arunachalam (1970) Vol. 2 No. 1 p. 7.

(7) The concept of Pitta in Ayurveda and Enzymes.
E. Karunanayake (1970) Vol 2 No. 2 p. 3.

(8) Concept of heating and cooling in Ayurvedic Medicine
K.D. Dharmasena and K. Mahadeva (1970) Vol 2. No.2 p. 10.

(9) Mandama . H. Jayatillaka, S.A. Gunaratnam, K.D. Dharmasena, D.H. Rajapaksa and K. Mahadeva (1970) Vol 2 No. 3 pg 7

(10) Leucoderma (Vitiligs)
K.D. Dharmasena (1970) Vol 2 No. 3 pg. 14.

(11) Pilot study to assess the effect of Haridra (Turmeric) on Asthma and absolute eosinophil count by
S. Arunachalam, S. Gunatillaka, S. Sivasamy and N. Perera (1971), Vol 2, No. 4 p. 25.

(12) Application of thin layer chromatography for quality control of Seetharama Pill
E.H. Karunanayake, S.N. Weerakoon, J. Thillainathan, S. Arunachalam and S. Sivasamy (1971) Vol 3 No. 1 pg. 15.

(13)) Mootrasmari - Renal Calculi
S. Arunachalam, S. Sivasamy and N. Perera (1971).
Vol 3 No. 1 p. 22.

(14) Arthropathy in Ayurveda
S. Sivasamy (1971) Vol 3 No. 2 p. 11.

(15) Use of Chromatography for the characterisation of a herbal mixture
L. Andrady and R.K. Sirimanna

(16) Guide lines for evaluating the efficacy of Ayurvedic treatment in anaemia (Pandu)
K. Mahadeva, S. Arunachalam, K.D. Dharmasena and K. Balasupramaniam (1971) Vol 3 No. 3 p. 10.

(17) Suggestion for effecting quality control of Ayurveda drugs.
N. Scott (1971), Vol 3 No. 4 p. 6.

4. Articles related to Ayurveda

(1) Presidential Address Section A - CAAS 1972 "Ayurvedic Research geared to modern scientific techniques".

(2) Personal View British Medical Journal - 17th October, 1973.

Papers Read at Sec. A - CAAS 1973

(1) Pilot study of evaluating the efficacy of Ayurvedic drugs on Bronchial Asthma.

(2) Pilot study of evaluating the efficacy of Punarnava Mandura on Anaemia.

(3) Pilot study of evaluating the efficacy of Psorales corylifolia on Leucoderma.

ABSTRACT

Dr. K. Mahadeva of the Banadaranaike Medical Ayurvedic Research Institute, Nawinna in his address "On the trail of the elusive herb..." focuses attention on the wealth of medical folkore which have been built up by a process of trial and error throughout the centuries and made available in talipot manuscripts.

He discusses the different modes of approach made by the West and Sri Lanka as regards assessing the efficacy of herbal remedies in the treatment of specific diseases. The progress made at the Institute is painfully slow due to lack of up-to-date equipment and trained personnel.

He believes our civilisation's survival depends on our ability to sieve these age-old folklores embodying human ingenuity and wisdom down the ages and combine it with our 20th century scientific knowledge.

THE FOREST RESOURCES OF SRI LANKA AND THEIR UTILISATION

Paper Prepared by :

A.E.K. Tisseverasinghe*

Climatically the island may be considered as falling into the following Zones :

The Arid Zone with less than 50" rainfall per year.
The Dry Zone with 50 - 75" rainfall per year mostly falling in one season.
The Intermediate Zone with 75 - 100" rainfall per year and
The Wet Zone with a well distributed rainfall of more than 100" per year.

From the forestry point of view the Wet Zone may be conveniently divided into a Montane Zone of over 3500' elevation and a low country Wet Zone.

The Arid Zone is small in extent and is of no forestry interest and will thus not be considered any further.

The Dry Zone was historically the most important for forestry

* Forest Department, Colombo Sri Lanka.

because the species of timber then most sought after came from the Dry Zone forests eg. Satin (Chloroxylon swietenia), Ebony (Diospyros ebenum) and Milla (Vitex pinnata).

The forests of the Dry Zone are generally considered as secondary in that they grow on land cleared of its original forests. As a result of this they are difficult to regenerate. Many decades of research efforts were spent on trying various techniques to encourage regeneration and we have now given up the attempt.

The latest estimate of the area of Dry Zone forests (including those in the Arid Zone) is 5,280,000 acres (1). However this does not take forest type differences into account and the area of actual high forest is probably only a fraction of this. Within the high forest area the most abundant species (forming nearly 40% of the timber volume) is Wira (Drypetes sepiarai) which, due to its extremely poor form is used at present only as firewood. A better use for this species of timber cannot be envisaged in the foreseable future. Due to this and also due to the spares distribution of trees of valuable species, the yield of useful timber on exploitation of the Dry Zone forest may be only about 50-100 cubic feet per acre which is pitifully low.

This picture of the Dry Zone forests is admittedly very depressing. Scientific management of such a forest is virtually impossible. The present policy of the Forest Department is there-

fore to treat these forests as a wasting asset and replace them by plantations which are much more productive. The principal species used for reforsstation in the Dry Zone is Teak (Tectona grandis). Not only is the per acre productivity greater in a Teak plantation but its value per cubic foot is also much greater than that of any of the natural Dry Zone species. This value is likely to be always high because of certain unique properties of the wood. Up to the end of 1974 around 135,000 acres of Teak Plantations have been established and 10,000 acres are added to this each year. It is expected that from the year 2020 the annual production of Teak timber will be 20,000,000 cubic feet (as compared to the 2,000,000 cubic feet presently yielded from a very much larger extent of natural forest in this Zone).

Teak was introduced on a plantation scale to the Dry Zone about a hundred years ago and till about twenty years ago continued to be the only species planted. This was because Teak was a very easy species to raise and it is also very hardy and able to tolerate the harsh climatic conditions in the Dry Zone. The dangers of extensive monoculture were realised but no other species as hardy as Teak was available. In 1955 another species Et-demata (Gmelina arborea) was introduced and this was found to be as hardy as Teak although the timber is much less valuable. However it also belongs to the same family as Teak, the venbenacear and cannot therefore be considered as a completely satisfactory species from the silvicultural point of view. A few years after the introduction of

Et-demata it was found that Eucalyptus camaldulensis would also tolerate the conditions prevailing in our Dry Zone. Presently therefore, it is Eucalyptus camaldulensis and not Et-demata which is used to break the monotony of Teak. About 1000 acres of this species are planted annually.

The forest area of the Intermediate Zone was estimated in 1970 to be 283,900 acres (1). Here, more than in the Dry Zone, there is hardly any high forest left. The only feature in this area of forestry interest is the 12000 or so acres on mixed Jak (Artocarpus heterophyllus) and Mahogany (Swietenia macrophylla) plantations. These plantations were established between 60 and 20 years ago and since no further land is available for forestry in this Zone, no additions will be made to them. This mixture of species is of silvicultural interest. Jak is a light demanding species and does well only in open conditions. Mahogany is almost unique among tree species in that it is shade demanding in its early stages. If planted in the open it is almost invariably attacked by shoot boring insects. Jak regenerates with difficulty while Mahogany regenerates profusely. Over a period of time therefore the composition of the forest alters in favour of Mahogany and in time it will be pure Mahogany which because of its case of regeneration will be managed on the Selection System without clear-felling. In this case also, certain other species which establish themselves naturally, such as Wana Sapu (Cananga Odorata) and Alstonia macrophylla are encouraged so as to have some degree of mixture.

The low-country Wet-Zone forests were virtually ignored as a source of timber until World War II created a great demand for virtually any variety of timber. The Wet Zone forests contained only two species of timber which were considered the equals of the best Dry Zone species. The first of these is Calamander (Diospyros quarsita) (which was almost totally removed from the forest where it was found during the period of Dutch rule in Ceylon and is therefore very rare at present) and the other is Nedun (Periocopsis mooniana) which maintains its popularity as a furniture timber up to the present day. Most of the species of the Wet Zone forests were not utilised for various reasons, the principal one being that they were not very durable.

A significant change took place with the establishment of a Plywood Factory in the nineteen forties. Species of timber which were considered non-durable in their natural state could be manufactured into plywood and used. Over the years the Plywood Factory has been widening the range of species considered acceptable and at present about 40 different species of the Wet Zone forest are being used for plywood. These forests have thus come to be our most valuable natural forest resource.

The total area of the Wet Zone forest (including Montane Forest) was estimated in 1970 to be 334,953 acres which is a bare 9% of the land area in this Zone (2). The well stocked forests in this

Zone are managed on the Selection System (without clear-folling), the degraded areas are enriched by line planting with Mahogany while the very poor and bare areas are reforested mostly with Pinus caribaea. Other species which have been tried out on an experimental or small scale are Albizzia moluccana, Eucalyptus deglupta and Araucaria. cunninghamii. All these species are exotics as reforestation using indigenous species has been found to be difficult.

The Montane Zone forests are a curiosity. None of the species in this forest can be considered really suited to the climatic conditions in this Zone, so much so that even large trees suffer injury in years of severe (by our standards) Many of the species have close relations in the low-country Wet Zone forests so that one could almost imagine that the Montane forests is an uplifted Wet Zone forest still trying to come to terms with its environment. One or two species in this forest yield valuable timber but regeneration in this forest is even more difficult than in the Dry Zone so that one cannot even entertain the notion of attempting to manage it on a sustained yield basis.

This was realised by foresters years ago and when it was found that many species of Eucalyptus grew exceedingly well in this Zone, It was a natural step to convert these forests to plantations. It would be true to say that the only productive forests in this Zone are the plantations. Plantations were also created

where no forests but only unproductive grassland existed before. The species used were Eucalyptus and Acacia mollissima. About 20 years ago Pinus caribaea was introduced into this country for the purpose of grassland afforestation. Today it is the most important of the species being planted. In the higher, wetter areas, Pinus patula is planted instead.

Thus the forestry programme in all of Sri Lanka other than the Wet Zone is strongly committed to plantations - all the species used being exotics. Increasing the productivity of Forest land by creating plantations has the same effect as increasing the land area.

Another way of increasing the productivity of forest land is by enhancing the durability of wood in use. For instance, before the nineteen fifties all the Railway Sleepers used in Sri Lanka were of very valuable species such as Satin (Chloroxylon swietenia) Palu (Manilkara hexandra), Milla (Vitex pinnata) and so on. After a timber impregnation plant was set up, the position rapidly changed and now, the majority of Railway Sleepers are of a Wet Zone forest species, Hora (Dipterocarpus zeylanicus) which was virtually unknown before. Similarly, all the wooden transmission poles used in this country are treated.

Recently a new resource has begun to be developed. The rubber plantations in the Wet Zone of the Country had only been regarded as a source of rubber. The timber produced in these plantations

could not be used except as firewood due to its extreme perishability. An inexpensive method of preservations using salts of Boron has been developed making it possible to use rubber wood for high grade purposes such as furniture, panelling and flooring. Since the acreage of rubber plantaions is greater than the acreage of all the forests inthe Wet Zone, this must be considered as a very valuable addition tothe timber resources of this country.

Nothing has been said so far in this paper onforest products other than timber because, unlike in other countries of this region, hardly any collection of these materials is being done. Limited quantities of Kadol (Rhizophora mucromata) and Ranawara (Cassia amiculata) barks are collected for tanning leather. Limited quantities of medicinal herbs are also collected and this has been increasing recently. The tendency in the past had been to import the medicinal herbs used in this country. Large numbers of people in Sri Lanka are treated according to the Ayurvedic systems of medicine, so that the collection of processing of medicinal herbs can give rise to an important industry.

Distillation of essential oils from forest plant materials is also a very recent industry. It started with the distillation of Eucalyptus oil from Eucalyptus globulus and now various other leaf materials such as Cypress (Cupressus macrocarpa) are used to obtain oils suitable for perfumery.

Gums and resins are collected only on a very small scale and not on any organised basis. All in all it is abundantly clear that much remains to be done in the field of forest products other than timber.

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AN OUTLINE OF THE RESEARCH DONE AT CISIR WITH PARTICULAR REFERENCE TO PRODUCTS FROM PALM SAPS & FIBRES

Paper prepared by :

E.E. JeyaRaj *

The plants chiefly involved are:

Borassus flabellifer Linn	-	Palmyrah
Caryota urens Linn.	-	Kitul;
Cocos mucifera Linn.	-	Coconut
Corypha umbraculifera Linn.	-	Talipot
Hibiscus cannabinus Linn.	-	Kenaf

Palm Sap : Sweet Toddy:

Yields: The sugar content and yield of fresh sap from the tapped spadices is affected by ambient temperature and by the method of tapping.

Palmyrah: Our results at Kankesanturai over a period of one complete year using 25 trees[1] indicated that total yields were affected by the method of tapping, the chief variant being the period of yield. Average daily yields were from 2 to 6 litres with maximum over 9 litres, over a period of 5 to 10 weeks (average). Sugar content varied from 9 to 18% sucrose, there being a broad correlation with seasonal temperatures.

It should be possible to obtain similar data for other palms whose average yield has been reported as follows:

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	Kitul	Coconut	Nipah
Average daily yield: litres:	4 – 7	1½	½
Sugar content : %	14	17	17

Preservation and Flavour: (Coconut sweet toddy)

Methods of sterilisation have been worked out. Further work is proceeding on conservation of natural flavour, prevention of darkening and development of objectionable flavours, and the use of additives.

Similar work has also been done on preservation and bottling of the liquid endosperm[2], where it was also found necessary to prevent the formation of a melanin intermediate.

Improved jaggery and sugar:

Processes were worked out for the manufacture of improved jaggery, treacle and white sugar from palmyrah and coconut toddy[3]. Twenty four centres for improved jaggery have been set up by the Industrial Development Board in the Jaffna District.

Fermented Toddy:

Preservation: Satisfactory methods have been worked out for arresting the fermentation at any selected stage in the fermentation[4].

Colour: Methods were found to prevent the development of dark colours, which are particularly evident in the product from which cloudiness has been removed.

Flavour of coconut toddy: Among the flavour problems investigated was the formation of H_2S and sulphides in toddy, levels of which can be as high as 5 mg/l.

The source of the sulphide was found to be the sulpho-amino acids in the toddy. Methods were developed to prevent its formation or for its removal[5]. Different yeast strains differed in their ability to form sulphides in toddy. Differences were also noted between individual trees.

Efficiency of alcohol formation: This was found to depend chiefly on the strains of yeast employed.

The results are also being tested in the field, and their application to the improvement of distillates (arrack) is projected. This will also include collaborative work on arrack essence.

The work on coconut toddy also needs to be repeated with the other palm saps.

F i b r e s:

Fibres from various parts of the palmyrah palm have been investigated at the C.I.S.I.R. and possible uses found for them[5]. Fibres which are likely to regain importance in commerce are bassine (from palmyrah leaf base) suitable for brushes and brooms, and kitul fibre (from the leaf sheath) consisting of fibres up to 3 mm in diameter.

The microbiology of retting with special reference to coir has been investigated. A method of assessing completion of a ret has also been developed[6]. Further work is projected on the microbiology and mechanism of retting of coir and other fibres.

Cultivation studies and assessment of the harvested fibre established kenaf as an excellent jute substitute, in a joint project between the C.I.S.I.R. and the Dry Zone Research Station at Maha Illuppallama. Recently the Eastern Paper Mills have also reported that the fibre is suitable for paper manufacture.

Leaf:

Chemical preservation of ola and preservation of the pliability of palm leaf for woven baskets and mats have been worked out[5].

Constraints:

Among constraints experienced has been the shortage of chemicals and other materials. The availability of an amino acid analyser and similar apparatus would greatly accelerate some of these investigations.

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UTILIZATION OF MANIOC

Paper Prepared by :

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Nirmala Pieris

1. Summary of Research.

Research has been done on two main lines:

A. Investigations into the Cyanogenic glucoside content of manioc and the chemistry of the linamarin-linamarase reaction.

B. Work directed at the more effective utilization of manioc carbohydrate by microbial and other methods.

A. Cyanogenic glucosides of manioc

Manioc contains the cyanogenic glucosides linamarin and lotaustralin (bound cyanide) which, on interaction with the enzyme linamarase results in the liberation of HCN (which together with heat labile cyanohydrins is termed free cyanide).

(i) Assay: Most of the data on bound cyanide in manioc and its products reported in the literature had been obtained either by acid hydrolysis or autolysis. However, these methods, when subjected to detailed investigations, were found to be inadequate as the bound cyanide content was nearly always underestimated. A detailed study of the linamarin-linamarase reaction has enabled us to develop a reliable assay for bound cyanide in manioc.

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(ii) Application of assay. The assay has been used to determine the bound (and total) cyanide content of processed and unprocessed manioc including fried and boiled manioc, manioc starch and flour (prepared under various conditions) and also the fate of bound cyanide when flour containing cyanogenic glucosides is used to make products such as bread, 'roti' and 'pittu'.

These studies have also led to a method of detoxifying manioc chips and flour as well as to an intimate knowledge of the factors governing cyanide release from manioc and its products.

(iii) Cyanide releasing factors in vegetable juices. Studies have also been conducted into the effect of vegetable juices on bound cyanide. Cyanide releasing factors have been detected in Zingiber officinale Rosc., Alternanthera sessilis. Br. and Ipomea aquatica Forsc. It has also been found that a leaf extract of Psidium guajava L. contains a potent inhibitor of manioc linamarase.

	Product	Loss of total cyanide on preparation (%)
1.	Fresh manioc (cyanide content 20–200p.p.m. most frequently 50–100p.p.m.)	-
2.	Boiled manioc	40–60
3.	Fried manioc chips	0–10
4.	Manioc flour (dried quickly)	0–20
5.	Manioc flour (dried slow)	30–50
6.	Manioc starch	95
7.	Bread from manioc flour	40–60
8.	Roti from manioc flour **	50–75
9.	Pittu from manioc flour	0–20

** contains a significant amount of free cyanide

3. Assistance needed.

The constraints met with are mainly the lack of specialized chemicals and equipment. Material for microbial and biochemical research is often in short supply. Materials such as ion exchange resins, dialysis tubing, chromatographic standards and detection reagents are difficult to obtain. Equipment for Electrophoresis and gel filtration are not available. Equipment for chromatography (paper, tanks, driers and solvents etc.) are inadequate. At the moment no scintillation counter is available in the country. A significant amount of the literature needed is also not available. Another pressing requirement is a low temperature room for basic biochemical work.

For details on experimental work see:

1. Manioc selected Topics (1973) J. Natn. Sci. Council(Sri Lanka) 1, 83-96.

2. Cyanide liberation from linamarin (1974) ibid 2, 57-65.

3. Cyanogenic glucoside content of manioc. I An enzymic method of assay applied to processed manioc (1974) ibid 2, 67-76. II. Detoxification of manioc chips and flour (1974) ibid 2,(2)

4. Production of the starch hydrolysing enzyme glucoamylase. (1973) Proc. 2nd annual sessions of the Institute of Chemistry Ceylon 29. June 1973. 27-36.

B. Utilization of manioc carbohydrate.

(i) Direct uses of manioc starch and flour. A purified flour from manioc that is much cheaper than manioc starch and more effective for the sizing of yarn has been prepared. Studies have also been made into the use of manioc starch and purified flour for the preparation of modified starches.

(ii) Conversion of manioc starch to glucose. A successful project has been completed on the laboratory scale conversion of manioc starch to glucose. The process involved the isolation of a fungus and its growth on a suitable medium to produce large quantities of the starch hydrolysing enzyme glucoamylase. The enzyme has been used to convert manioc starch to glucose at more than 90% yield.

(iii) Microbial utilization of manioc wastes. Investigations have been made into the use of manioc starch pulp-waste hydrolysates for fermentation to ethyl alcohol, the use of manioc starch wash water and manioc chip steep water as a source of nutrients for yeast growth and the detoxification of manioc rind which could be used for animal feed.

2. Lines of future research

A. A more detailed study on the linamarin-linamarase reaction including the purification of linamarase and the study of its kinetics and inhibitors.

B. An investigation into the factors responsible for linamarase inhibition (in Psidium guajava) and cyanide release (in Zingiber Officinale.)

C. Use of manioc carbohydrate for microbial fermentations such as the citric acid fermentation.

D. Preparation of modified starches from manioc.

E. Radioisotope studies on the fate of cyanogenic glucosides on ingestion. In collaboration with the Radio-Isotope Centre, Sri Lanka and Dept. of Animal Husbandry, University of Sri Lanka, Peradeniya, Campus.

F. Studies on cultivars of manioc. Collaboration with Agriculturists.

G. Further studies on the use of manioc in food products in collaboration with Food Technologists.

STUDIES ON SOME OF THE LESSER-KNOWN NATURAL AND AGRICULTURAL PRODUCTS AS PROTEIN AND ENERGY SUPPLEMENTS FOR ANIMAL FEEDING

Paper Prepared by :

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INTRODUCTION :

The products studied under this research project were Rubber seed meal, Gingelly meal and Manioc fiber and leaves.

(1) Protein supplements:

Rubber seed meal (RSM)

The effects of rubber seed meal on growing chicken depends on the quality of animal protein supplement used in the ration. It was found that the RSM could be successfully used upto 10% level with imported meat meal and 20% with the imported fish meal in the rations. If these diets are supplemented with lysine and methionine optimum growth response could be obtained in growing chicken upto 25% RSM. Thus it is evident that the main problem with RSM is an amino acid imbalance. However pullets have the capacity to overcome the adverse effects caused by higher levels of RSM in diets as they mature, and are able to maintain a normal body weight and performance upto 40% level of RSM. The batches of RSM used in the study contained about 35 mg of hydrocyanic acid per 100 grams. This level is normally considered to be toxic to chicken. However the reason why the effect of HCN was not exhibited in these experiments was due to its presence in the form of a cyanogenetic glucoside. Rubber seed is reported to contain very little glucoside splitting enzymes. Even this low level of enzyme may not be present in RSM which is subject to a temperature of about 160°C during the expeller extraction process. Thus it could be safely assumed that the HCN in the RSM is not harmful to the animal as long as the food is free of any exogenous enzymes.

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When the RSM level was increased the bone ash level was reduced, suggesting a possible calcium inhibitory effect. Pullets raised on a 10%, 20%, 30%, and 40% RSM diets from the third month of age matured late, but RSM had no effect on egg production. Also an increase in RSM in the diets lowered egg size, shell thickness, hatchability of incubated eggs and the weight of hatched chicken. Further it was observed tha t RSM increased the percentage of infertile eggs that were produced. The reasons for these effects of RSM have to be further investigated .

Gingelly meal:

The quality of gingelly meal varied inbetween batches. This was clearly shown by a marked variation in the protein content of different batches of gingelly analysed, which ranged between 24-35%. When gingelly meal was used at different levels in chick rations it caused a growth inhibitory effect above 10% level in the ration. Addition of methionine at 2 ozs per 100 lbs of ration did not improve growth.

(2) Energy supplements:

Manioc:

When manioc meal prepared by grinding dried whole manioc chips was fed to chicks at 10%, 20%, 30%, and 40% level in the ration progressive growth inhibitory effects were observed from 10% level upwards.

Addition of fat soluable vitamins, or an increase in the level of protein did not improve growth. However addition of Vitamin B complex improved growth. When the levels of vitamin B complex and protein were increased the growth inhibitory effect was over come completely. It was evident that the vitamin B binding factor of manioc was there in the peel more than in the peeled tuber. When HCN was removed from manioc chips made of whole manioc the growth inhibitory effects were not corrected.

However the HCN free chips of peeled tubers did not cause a growth inhibitory effect even at 40% level; suggesting that this effect is due to the vitamin binding effect present in the peel.

Elimination of hydrocyanic acid:

Manioc tubers harvested in 6 and 7 months contained more HCN than the matured tubers harvested in 8 to 9 months after planting. The total HCN content of the unpeeled manioc tubers was lowest at harvest. When the whole tubers were dry aged the HCN content increased by about 33% within 48 hours of harvesting. Further, dry ageing peeled tubers caused an increase of HCN by about 100% within 24 hours of harvesting. Wet ageing unpeeled tubers for 48 hours decreased the HCN content by 60%. However the length of time the unpeeled tubers were dry aged before peeling and wet ageing had a marked influence on the elimination of HCN. When unpeeled tubers that were dry aged for less than 6 hours were peeled and wet aged upto 40 hours, complete elimination of HCN was not possible. Whereas when the unpeeled tubers that were dry aged for 24 hours were peeled and wet aged, all the HCN was eliminated in 48 hours. Soaking dehydrated manioc chips for more than 6 hours in water and re-drying was found to be the most effective method of eliminating HCN, irrespective of the way the tubers were treated before drying the chips.

The undamaged tubers could be stored underground in a moist sandy place for more than two months. The tubers stored underground for different lengths of time, remained unspoilt for over 20 days once unearthed. The HCN levels of stored tubers remained unchanged. Only apparent change seems to be the increase of sweetness, decrease of the moisture content and change in the skin colour of the tubers.

Effect of boiling of manioc processed in different ways:

When manioc tubers were dry aged for different lengths of time and wet aged for 6 hours, 12 hours, and 18 hours and boiled it was observed that :

(a) Wet ageing tubers for 6 hours and boiling in open vessels caused very little reduction in HCN.

(b) But the HCN content reduced to about 33% of its original value when wet ageing time was increased to 12 hours and boiled.

(c) Increasing the wet ageing time to 18 hours and boiling reduced the HCN content to less than 5ngs/100gms which could be considered negligible.

However it should be noted that the peeled tubers should not be soaked for more than 24 hours due to the spoilage and marked exudation of starch.

Envisaged lines of future research:

Rubber seed meal:

(1) To study the level of breakdown of bound HCN present in the form of cyanogenetic glucoside in RSM consumed.

(2) To study the possible methods of correcting amino acid deficiencies in RSM.

(3) Evaluating the factor that causes the lowering of hatchability of eggs.

Gingelly meal :

(1) Study the cause of growth inhibitory effect of gingelly meal.

Manioc :

(1) Investigate further the possible vitamin B binding effect of manioc and evaluate possible ways of eliminating it.

(2) To estimate tolerance and toxic level of HCN for farm animals.

(3) Evaluate the origin of HCN synthesis in the newly uprooted tubers.

(4) Study the cause of the changes that occur in the injured manioc tubers when exposed to atmospheric air.

(5) To establish the techniques of the storage of manioc tubers and study the causes of spoilage of tubers.

(6) Study the ways of proper utilization of manioc leaf for animal feeding.

The constraints faced :

The main constraints faced in conducting research are the difficulty in obtaining chemicals, equipment and literature required for research.

The only possible way of changing the present set-up is to change the policies that govern the importation and distribution of inputs essential for research.

PLANT PROTEINS FOR HUMAN CONSUMPTION

Paper prepared by :

S. Sattheshanmuganathan*

INTRODUCTION :

The average diet in developing countries like Sri Lanka as in other under-developed countries, is deficient in quantity as well as in quality[19]. A recent survey carried out by the Medical Research Institute has shown that there is wide spread under-nourishment among the children of less favoured social groups in Sri Lanka[9].

Nutritional experts agree that shortage of protein in human diets is the most important part of the world food problem. Protein can be obtained from various sources (slide 1). The figure shown in slide 1, constructed to scale from data published by FAO[4,20] summarises the world food position in 1960 for the two groups, poorer and richer countries (Gp. I & II respectively). The population of Gp. I and Gp. II in 1960 were 2100 and 900 million respectively. An analysis of the diagram reveals that the average daily intake per head was about 58 and 90 g respectively of total protein in 1960. The most striking feature is that the daily animal protein intake per head in Gp. I countries was about 9 g compared to 45 g in Gp. II, or the amount of plant protein intake per head in Gp. I countries was 49 g compared to 45 g in Gp. II. Slide II gives detailed information regarding the various sources of protein consumed by the two groups and the population as a whole.

The FAO target for world food production in 1975 provides for an annual consumption in human diets of about 112 million tons of total protein (slides III and IV). This envisages an extra 12 M tons of animal and 31 M tons of plant protein. How can all this extra protein be obtained? Possible sources are meat, eggs, milk (produced from animals through plant proteins), cereals, pulses and leafy vegetables. The fundamental question is that, are we to get our protein directly from the plant kingdom or through animals and birds as milk, eggs, meat, cheese etc? All of us, whether in developed, developing or underdeveloped countries, obtain proteins from both sources. From slide II we can see that the average diet in the world in 1960 contained 2.4 times as much plant proteins as animal proteins.

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Without any exception, all the world's protein comes initially from plants and plant products. It has been estimated by FAO that in 1960, about 47 M tons of plant proteins were consumed directly by man and about 135 M tons were fed to livestock which yielded only 19 M tons of animal protein. FAO targets for 1975 envisage a considerable increase in global consumption of animal protein, and to obtain this extra amount, about seven times as much extra plant protein will have to be fed to livestock (slide V). A successful solution to the world protein problem will depend on making the most efficient use of land, water supplies and fertilisers by switching human diets as far as possible to plant proteins and diverting the enormous amount of plant protein at present being used for livestock, for direct human consumption.

A greater percent of the world's population needing extra protein lives in rural areas of the wet tropics, where communications are poor. The production of protein from a local source therefore becomes a prime need for these regions. Increasing the use of leafy vegetables is a quick and practical method of increasing the protein intake, but the presence of fibre in leaf protein limits its use for human consumption. The use of leaf protein in food has been projected as one of the important ways of supplementing the Indian diets.[12] Most of the people in the world use leafy vegetables, but the consumable quantity is limited by the human physiology.

Procedure:

A simple procedure has been devised for separating the fibre from the proteins mechanically, by Pirie.[13] Pleshkov and Fowden[11], Chibnall and Rees[3] and Gerloff, Lima and Stahmann[6] have shown that the amino acids composition of protein samples from leaves of different species, ages and cultural background are similar. Normally a leaf protein is a mixture of several proteins.

Many temperate plants have been found to be useful as a result of work over two decades at the Rothamstead Experimental Station, U.K. Some tropical plants have been screened in Ghana[1], Jamaica[10] and at the Central Food Technological Research Institute, Mysore, India. As a result of intensive work at the Rothamstead Experimental Station, suitable machinery for processing 1 - 2 tons of leaf per hour, in batches of about 200 lbs. has been designed.

In Sri Lanka, no attempts had been made till 1969 to isolate protein from leaves. This communication reports the results of work carried out on the isolation and analysis of leaf protein (in the laboratories of the Medical Research Institute). Three classes of leaves were chosen for study - those eaten as vegetables, those used as food for animals and non-edible but non-poisonous varieties.

Most of the leaves used in this survey were obtained from Colombo and adjoining areas where the annual rainfall is fairly high and the vegetation always fresh and green. The process followed was a modified procedure outlined[14] and used by other workers[2; 18] A weighed quantity of the washed leaves were homogenised in a waring blender and the green homogenate filtered through lint cloth to remove fibrous material. The process was repeated three times, the filtrates were pooled, pH adjusted to 8.0, filtered and the filtrate acidified to pH 4.5, heated to 65 - 70°, cooled and re-filtered. The protein precipitate was washed with acetone to remove lipoid material and the pale grey or brown powder dried in the desiccator.

Dry matter, total N and non-protein N (NPN) were determined in the fresh leaves and crude protein. From these N determinations, a balance sheet was prepared for each species examined, from which the percentage N extractability was calculated.

Results & Discussion:

All the results are expressed in g/100 g dry matter unless otherwise stated. The N contents of the isolated proteins were determined experimentally as well as calculated from the amino acid composition. The provisional patterns of essential and related amino acids are expressed in mg/g N. 'Protein Score' which measures the extent to which a food or food combination supplies the limiting amino acid as compared to the provisional pattern, was determined according to the FAO(1957)[5]. The results provided here are based on estimations made on duplicate collections of leaves on two different occasions. The results did not show more than 5 - 8% variation, hence the average values are provided in this paper.

Slide VI contains the names of the plants used in this survey and the total N, NPN and protein N in the original material together with the yields of the protein isolates.

In slide VII, the N contents of the protein isolates have been shown as well as the percentage extractability of N and the protein contents in both the original leaf as well as in the isolates. The proteins were analysed for N, ash, Ca and Fe. The results are given in slide VIII.

The amino acid composition, expressed in g/100 g dry isolates, is provided in slide IX. The sulphur-containing amino acids (cysteine, methionine sulphoxide and methionine) are given separately as well as total S-containing amino acids. The N content of the protein isolates observed experimentally and calculated from the amino nitrogen (amino acids) is given in the same slide VIII.

The contents of essential and related amino acids of the leaf proteins expressed in mg/g N are given in slide X, together with those of widely used protein-containing foods. Slide X also shows the provisional amino acid pattern as provided in the FAO (1957) report,[5] and the assigned protein scores calculated from the limiting amino acids as a percentage of that found in the provisional pattern.

Leaves eaten as Vegetables:

The method employed enabled high yields of the crude proteins to be obtained from the leaves of Sesbania grandiflora and Basella alba. The isolates were also found to contain a high percentage of protein (58.8% and 75%) and the percentage extractability of N was greater than 77% (slide VII).

By contrast, for Ipomoea aquatica and Alternanthera sessilis not only was the percentage extractability low but also the yield of protein. Both were thought to possess a high proportion of cellulose material, but modified extraction procedures should be tested before they are excluded as sources of leaf protein. The four species tested in this class contained a high proportion of Fe and Ca (slide VIII).

Leaves used as Food for Domestic Animals:

The N content in the original leaves of this class varied from 1.90 to 3.99% while the NPN varied from 0.27 - 0.48%. The percentage extractability of N was also low - ranging from 9.3 - 18.4% - but the isolates were rich in protein (slide VII).

Among the species studied in this category, Gliricidia sepium seemed to be the best source of protein. These leaves are readily available in all parts of Ceylon and throughout the year.

Non-edible but Non-poisonous Leaves:

Of these Ipomoea pescarprae grows luxuriantly along the sea coast of Ceylon. Carica papaya is found in plenty and is cultivated on a large scale. The tender leaves are at times used as chicken food. The leaves from Ipomoea batatas are normally discarded after harvesting of the yam, but occasionally they are used as cattle food.

The percentage extractability of N from Ipomoea spp. was more than 30%. Although Carcia papaya yielded only 8 g protein/100 g dry leaves, the isolate contained 65.6% protein. The percentage extractability of N was also the highest. The protein isolates from this plant contained a considerable amount of Ca. The iron content was found to be comparable to those found in other species.

A considerable proportion of the total N of the leaves investigated was NPN (slide VI). These findings tally with those of Swaminathan[17] and Kulkarni & Schonie.[7]

Classification by Protein Yields:

Recently Byers[2] classified tropical plants into six categories, based on the percentage extractability of protein N and N content of the isolates. According to her classification, of the twelve species studies, Sesbania grandiflora, Basella alba and Carica papaya are in category (a) because they contain 9% N in isolate and the percentage extractability of total N exceeds 40%; Gliricidia sepium is in category (b) because it contains 9% N in isolate although its percentage extractability of total N exceeds 40%; the Ipomoea species and Erythrina variegata are in category (d) because they contain 9% N in isolate and the percentage extractability of N is between 20 - 40%; and the rest are in category (f) because they contain 9% N in isolate and percentage extractability of N is less than 20% (slide VII).

Amino Acid Composition and Protein Score:

In six of the twelve samples analysed, the protein N calculated from the amino N was greater than 90% of that found experimentally; in four cases the values were 88% and in two cases the recoveries were 83% and 85% (slide IX). Since the crude proteins contained minerals and carbohydrates and hydrolysis was affected by acid, partial loss of the amino acids would have occurred by interaction

with non-protein components. In certain instances, hydrolysis was repeated but the results did not show any significant variation. When hydrolysis was carried out under alkaline conditions, the proteins which gave low recoveries produced highly coloured solutions.

Protein Score and Provisional Acid Pattern:

It can be seen from slide X that, except for the sulphur-containing amino acids, all the other essential and related amino acids were present in amounts comparable with those present in milk, soya flour, sesame seed and ground nut. These amino acids are also present in amounts higher than those found in the provisional amino acid pattern. It is however, noteworthy that none of the leaf proteins studied were deficient in lysine - in fact some species contained lysine in amounts greater than those found in the proteins of milk, egg and groundnut. The protein score (F.A.O 1957 value) was calculated from the limiting amino acid which in all thes. cases was the sulphur-containing amino acid. It ranged from 50 - 73. It is however, noteworthy that the high protein scores, of over 70, were obtained with the proteins isolated from three species which are not presently eaten as vegetables. The leaves which are normally used as vegetables however, have protein scores of about 50. One of the non-edible leaf protein isolates, however, had a value of 54 (protein score). The protein isolates obtained from edible leaves have protein score values almost equal to that of groundnut and seasame seeds.

It may be concluded that these leaf proteins may provide a means for improving the quality of protein-deficient vegetarian diets and other food materials which are deficient in the essential and related amino acids.

It has been reported that there are marked differences in the amino acid composition with variation in species[17] as well as in the degree of maturity of the leaves[8,15] but this aspect of the problem will need to be investigated further.

The above results were published in 1969[16].

Lines of Future Research:

Investigations on the amino acid composition of other species, with particular regard to degree of maturity, species variation and climatic conditions.

Animal feed trials on protein isolates (NPN analysis)

Pre-marketing human nutrition trials.

Further research on the product so as to make a more palatable isolate, will be carried out.

Constraints faced and Assistance needed:

a) Need of an amino acid analyser. The work was completed due to the generosity of Prof. Walter J. Nickerson, Institute of Microbiology, Rutgers, The State University, New Brunswick, New Jersey, U.S.A. who provided materials and equipment to carry out the analysis of amino acid composition of the protein isolation. At that time the author was on a Senior Fulbright Fellowship awarded by the U.S. Department of State.

b) Need for a pilot plant to produce leaf proteins to put on a field trial.

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ANTIBACTERIAL PROPERTIES OF SOME MARINE ALGAE OF SRI-LANKA.

Paper Prepared by :

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A. Sivapalan

** M. Mahendran

INTRODUCTION :

It has been shown in the past that some of the phytoplanktonic organisms exhibit antibacterial properties. Pratt (1948) reported the presence of an inhibitory substance chlorellin in cultures of Chlorella vulgaris and Chlorella pyrenoidosa. Similar inhibitory action among fresh water algae is found in the antibiosis observed between Chlamydomonas and Haematococcus. (Proctor 1957). Cupta (1962) showed the occurence of an antibiotic substance in Hydrodictyen reticulatum. Work carried out by Marcel (1963) indicated that liquid cultures of Phormidium uncinatum and Scenedesmus quadricauda produced extra cellular growth inhibiting substances. Ramamurthy (1967) made observations on the antibacterial activity exhibited by the marine blue green alga Trichodesmium erythraeum. Occurance of antibiotic substances in the marine macroscopic algae commonly known as sea weeds has been shown by many workers. Pratt (1951), Sieburth and Burkholders (1959), Chesters (1956) have studied the antibiotic properties of several species of sea weeds belonging to Chlorophyceae, Phaeophyceae and Rhodophyceae. Nadal (1965) isolated two antibiotic substances sarganin and chonalgin from sea weeds. Sarganin is a broad spectrum antibiotic substance isolated originally from Sargassum natans. Chonalgin is obtained from Chondria littoralis. Several other antibiotic substances have been isolated and their chemical nature have been dertermined.

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No previous attempts have been made to investigate the antibiotic properties of algae of Sri Lanka. This paper reports on the observation made on the antibacterial activity of some marine algae growing in waters around Sri Lanka.

Part I : Preliminary Studies on some species of marine algae

Materials and Methods

Eleven marine algae belonging to Chlorophyceae, Phaeophyceae and Rhodophyceae were collected from shores off Colombo and Galle and were tested for their antibiosis. The algal species tested were Ulva reticulata, Ulva fasciata, Chaetomorpha aerea, Halimeda macroloba Valoniopsis pachynema, Padina pavonia, Sargassum cervicone, Gracilaria Sp. Sarcodia Ceylanica, Laurencia sp. and Jania natalensis. The extracts of those algae were prepared in water, ethanol, benzene and petroleum ether. 100g of clean algae were extracted in 250 ml. of the solvent. The filtered extracts were concentrated by vacuum distillation. Sterile filter paper disks of 5 mm diameter were soaked over night in the extracts and were dried at room temperature. Six known type cultures (Table I) and six unknown isolates from the marine environment were tested against the algal extracts. Cultures were grown in medium (Lab.lemco 0.1%, yeast extract 0.2%, peptone 0.5% and agar 1.5%) prepared with distilled water for the six known types and with aged sea water for the six unknown isolates from the marine environment. The dried filter paper disks were placed in seeded plates and the inhibition zones, if any, were measured in mm distance from the edge of the filter paper disks to the inner margin of the microbial growth after 24 hour incubation at 37°C.

RESULTS

The extent of inhibition and the results for the different algal extracts are given in table II.

Table I - Culture types used as test organisms.

Known Types.

Pseudomonas pyocyanea
Escherichia coli
Staphylococcus aureus
Sarcina lutea
Bacillus subtilis
Candida albicans

Unknown types	Shape	Motality	Gram reaction
Culture No. 4	rod	-	-
Culture No. 6	Coccus	-	-
Culture No. 7	coccus	-	-
Culture No. 8	coccus	-	-
Culture No. 9	coccus	-	-
Culture No.10	rod	+	-

DISSCUSSION

Table II clearly indicates the existence of antibacterial activity in the algal extracts. Different extracts show varying degrees of of antimicrobial activity. Among the algal types Ulva fasciata shows considerable degree of antibacterial activity. The ether extract of this alga appears to be very effective against all the culture types. Among the other algal types Sargassum cervicone and Halimeda macroloba show marked activity. The culture type No. 8 seems to be very susceptible to all the algal extracts.

Part II : Detailed studies with Ulva faciata

EXPERIMENTAL

The fresh sample was extracted successively with petroleum ether (bp - 60-80°), ether, acetone and methanol. The solvents were evaporated under reduced pressure. The pet-ether extract gave palmitic acid and an unidentified oily substance. Concentrated ether extract, when allowed to stand overnight, gave colourless

Table II - Antibacterial activity of different extracts of algae tested against twelve culture types

Aqueous extract

Algae	C.albicans	E.coli	S.aureus	B.subtilis	S.lutea	P.pyocyanea	Culture No.10	Culture No. 9	Culture No. 8	Culture No. 7	Culture No. 6	Culture No.4
Ulva reticulata	T	1	T	1	2	2	T	T	N	N	N	N
Ulva fasciata	N	1	N	N	T	T	N	N	T	N	1	T
Chaotomorpha aorea	1	4	N	1	N	1	T	T	T	N	N	1
Halimeda macroloba	N	N	N	N	N	T	1	N	N	T	N	N
Valoniopsis pachynema	T	N	T	3	N	2	1	N	N	T	1	1
Padina pavonia	N	T	N	T	N	T	T	N	N	N	N	T
Sargassum cervicone	1	N	T	T	T	N	N	N	N	N	T	T
Gracilaria sp.	N	N	N	N	N	3	N	N	N	T	N	T
Sarcodia ceylanica	N	N	T	N	N	3	T	T	N	-	T	-
Lauroncia sp.	N	4	N	N	2	N	T	T	N	N	N	N
Jania natalensis	N	N	N	N	N	3	T	N	N	T	N	N

Ethanolic extract

Algae	C.albicans	E.coli	S.aureus	B.subtilis	S.lutea	P.pyocyanea	Culture No.10	Culture No. 9	Culture No. 8	Culture No. 7	Culture No. 6	Culture No. 4
Ulva reticulata	1	2	N	2	1	1	1	N	T	1	T	1
Ulva fasciata	[illegible]	2	T	1	N	3	1	T	2	T	1	N
Chaotomorpha aorea	-	-	-	-	-	-	-	-	-	-	-	-
Halimeda macroloba	T	T	1	N	T	T	N	3	T	T	T	N
Valoniopsis pachynema	N	N	1	2	N	1	T	N	2	-	T	T
Padina pavonia	T	T	1	T	T	T	T	1	2	T	T	N
Sargassum cervicone	N	N	T	N	2	T	N	T	3	N	T	1
Gracilaria sp.	N	N	1	T	N	T	T	T	T	1	1	N
Sarcodia ceylanica	N	N	N	N	N	N	N	T	N	N	T	N
Lauroncia sp.	1	4	T	N	N	1	2	3	1	2	3	N
Jania natalensis	N	N	N	T	N	N	N	N	T	N	T	N

Benzene extract

Algae	C.albicans	E.coli	S.aureus	B.subtilis	S.lutea	P.pyocyanea	Culture No.10	Culture No. 9	Culture No. 8	Culture No. 7	Culture No. 6	Culture No. 4
Ulva reticulata	T	1	2	T	T	2	1	N	N	T	2	T
Ulva fasciata	3	N	3	1	N	2	3	1	5	2	2	3
Chaotomorpha aorea	N	T	1	T	T	N	N	1	T	T	1	N
Halimeda macroloba	1	5	1	2	T	2	N	T	T	N	T	T
Valoniopsis pachynema	1	3	2	1	1	T	T	T	T	T	T	2
Padina pavonia	1	2	N	1	N	1	1	1	N	-	1	N
Sargassum cervicone	1	2	T	3	3	2	2	-	1	T	T	T
Gracilaria sp.	N	T	T	N	N	T	N	T	T	N	2	N
Sarcodia ceylanica	T	T	T	N	N	2	T	N	-	-	N	N
Lauroncia sp.	N	T	1	1	N	N	N	1	T	T	2	T
Jania natalensis	N	N	N	N	N	T	T	N	T	N	T	N

Pet-ether extract

Algae	C.albicans	E.coli	S.aureus	B.subtilis	S.lutea	P.pyocyanea	Culture No.10	Culture No. 9	Culture No. 8	Culture No. 7	Culture No. 6	Culture No. 4
Ulva reticulata	T	N	N	N	N	N	T	1	N	N	T	2
Ulva fasciata	2	3	2	1	1	1	2	N	3	1	2	2
Chaotomorpha aorea	N	N	1	1	N	N	N	1	T	T	1	T
Halimeda macroloba	2	4	3	T	2	N	N	T	T	-	T	T
Valoniopsis pachynema	1	2	T	T	T	N	T	T	T	T	T	2
Padina pavonia	T	2	T	T	T	T	1	1	N	-	1	2
Sargassum cervicone	2	2	2	3	2	1	2	T	N	T	T	N
Gracilaria sp.	N	N	N	1	T	N	T	T	N	2	N	-
Sarcodia ceylanica	N	T	T	N	2	N	N	T	N	N	T	N
Lauroncia sp.	N	3	T	T	N	N	N	1	T	N	T	-
Jania natalensis	N	N	N	T	N	N	N	N	T	N	N	-

The numbers indicate the zone of inhibition measured in mm. T = Trace, N = Nil, - = No test.

crystals (melting point 178°).

The ether extract, acetone extract, methanol extract and the crystals obtained from the ether extract were tested for antibiotic properties. The standard filter paper method was adopted.

RESULTS

The extent of inhibitions are given in Table III

Table III

	Ether extract	Crystals from the ether extract	Acetone extract	Methanol extract
S.aureus	8	2	5	Trace
P.pyocynae	1	Trace	2	Trace
S.lutea	10	4	7	Trace
B.subtilis	2	Trace	4	Trace
C.albicans	2	1	4	Trace
Culture No. 9	6	3	5	Trace
Culture No.10	8	4	6	Trace

An extensive quantitative study is necessary to determine the actual concentration of extract that causes inhibition.

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CURRENT STATUS OF RESEARCH ON ESSENTIAL OILS AND SPICES CARRIED OUT BY THE NATURAL PRODUCTS GROUP OF THE CISIR

Paper Prepared by :

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INTRODUCTION :

Spices and essential oil bearing plants grow abundantly in Sri Lanka and represent one of the island's oldest export products. More recently, Cinnamon, Pepper, Cloves, Cardamom and Nutmeg have contributed the major component to our spice exports, but these exports have been only in the form of whole spices. The present government's 5 Year Plan envisages a substantial stepping up of spice cultivation. Essential oils and notably spice oils have only recently appeared as export products in Sri Lanka. However the essential oils from Citronella grass, Cinnamon leaf, and Lemongrass were being distilled in the country, the latter only in the comparatively recent past. Today, oils of Cardamom, Clove, Nutmeg, Cinnamon bark, Pepper, Ginger, Turmeric, Lemongrass etc. are being distilled by several distillers in the country, and exported as opportunities arise. In addition other non-spice essential oils such as Citronella, Eucalyptus and Vetiver are

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also produced and exported. The fluctuations in prices of our major plantation crops has focussed attention on the need to develop the socalled "minor export crops" of which spices and other essential oil bearing plants are potential earners of foreign exchange. The chemical composition of the essential oils of many of the spices were well known by way of the work of classical organic chemists. Recent interest in this area is due to the advent of potent instrumental methods such as Gas Liquid Chromatography (GLC) and the various spectroscopic techniques such as IR, UV, NMR etc.

These have afforded a new dimension to our studies of the chemical composition of plant material. The programme of work at the CISIR was designed, firstly to include a systematic chemical examination of the essential oils produced in Sri Lanka. Its purpose was to study the constituents of these oils, their relationship to the corresponding oils produced in other countries, and the variations as a result of geographical and varietal factors even within the country. As a result it was hoped, new concepts of quality could be forged and new analytical techniques for assessment developed. These in turn would play a role in the development of an expertise that will help the industry, as well as establish a confidence in potential buyers of these products abroad.

Studies on Cardamom Oil [1] -

Three main varieties of Cardamom grow in the island viz :

1. Malabar type = Ellataria cardamomum Maton var minuscula Burkhill
2. Mysore type = Same nomenclature as above
3. Ceylon type = Ellataria ensal (Gaertn) Abeywick.

Of these, (1) and (2) are cultivated types and (3) is a wild variety indigenous to Sri Lanka. The three types are quite distinctive and morphologically distinguishable one from the other.

The studies on the comparative distribution of terpenoid constituents in the oils of the three types of Cardamom was begun collaboratively with University of California (Davis*). GLC and IR methods were primarily employed for identification. Several quantitative as well as qualitative differences between the oils from the three varieties were established as a result of this study. The Sri Lanka variety differed very much from the cultivated types. The characteristic components of Standard Cardamom oil namely 1 : 8 Cineole and - terpenyl acetate were present only in negligible quantities in the wild

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*During the tenure of a post-doctoral fellowship at the Davis Campus of the University of California.

variety. Instead it had comparatively large amounts of a different array of terpenoid compounds notably the pinenes-sabinene, trans sabinene hydrate, 4-terpinenol, 4-terpinenyl acetate and geranyl acetate. Several new compounds too were isolated and structural identification of these is yet in progress. The study also gave rise to ready techniques for quality assessment of the Cardamom oils produced in Sri Lanka.

Studies on Citronella Oil[2,3] -

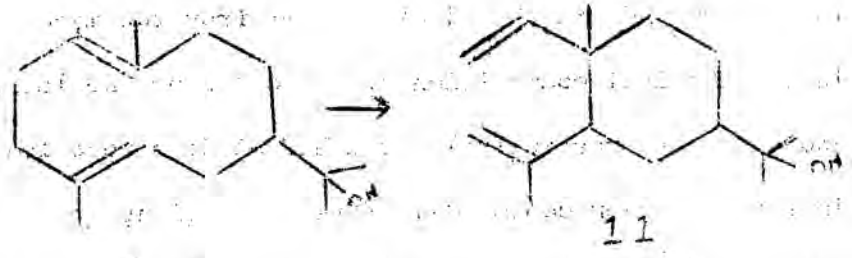
Citronella oil is the volatile oil from Citronella grass. Two cultivated types are identified generally :-

Lenabatu = Heen pengiri : Cymbopogon nardus (L) Rendel (Ceylon type)

Mahapengiri = Java type : Cymbopogon winterianus Jowitt.

The chemical composition of the two types of Citronella oils growing in Sri Lanka were examined using GLC and IR techniques. Several hitherto unrealised differences between the two types of oils were observed. The Ceylon oil had a very high content of monoterpene hydrocarbons almost 20% as against the 3-4% of the Java variety. Two solid terpenoid hydrocarbons Camphene and Tricyclene accounted for a substantial proportion of this.

The study also revealed the differences in the oxygenated terpenoids and also shed light on the likely biosynthetic routes to these compounds in Citronella. The unreliability of classical chemical methods for assessment of quality in Citronella oil became evident as in them allowances for geographical and varietal differences are not taken into consideration. New techniques were developed for quality assessment and a particular feature was a method for detection of kerosene oil as an adulterant. This was particularly important to Sri Lanka as the oil of Sri Lanka origin had been often labelled as "adulterated with kerosene". It became evident that the high proportion of terpenoid hydrocarbons was a reason for this impression which was based on the results of classical chemical tests. The presence of heretofore unidentified chemical compounds was also observed, viz : the occurrence of Hedycaryol (i) the thermolabile precursor of Elemol (ii) to which the former transforms on steam distillation was observed.



I II

The studies on Citronella also resulted in the discovery of several "chemotypes" of Citronella growing in Sri Lanka and this is discussed elsehwere.

Studies on Cinnamon Oils [4,5,6] -

The third major study was that of the volatile oils of Cinnamon. Cinnamon is a product for which Sri Lanka has been famous from very early times. The Cinnamon plant is unique, in that it produces three different kinds of oils, i.e. the leaf oil, the stem bark oil and the root bark oil respectively of the plant. The chemical composition of the Cinnamon oils had been studied before by classical methods. Our work employed for the first time the use of modern GLC techniques coupled with those of Infra-red spectroscopy, for the detailed analysis of these oils. Several hitherto unknown constituents in these oils were found, and the study has now developed into a study of the biosynthesis of these compounds in the plant. Apart from the major differences in the chemical composition of the oil from the leaf, stem bark and root bark respectively, the GLC studies revealed variations in several other compounds. These variations are of particular interest from a biogenetic view point. It has been recorded that the phenylpropanoids such as cinnamaldehyde and eugenol present in the plants arise by way of the shikimic acid pathway and the scheme followed is most likely similar to that

proposed for the biosynthesis of lignins. On the other hand, biosynthesis of terpenes occur by way of geranyl pyrophosphate and compounds like camphor arise from a carbonium ion of the bornane type. The occurrence both phenylpropanoids and terpenoids as the major constituents of three different parts of the same plant makes the biosynthetic mechanism of these compounds in cinnamon uniquely interesting. The question arises as to whether these compounds are synthesised at site or whether they are transported to the various sites of the plant in which they occur. This will have to await the results of the tracer studies now in progress. (U.M. Senanayake, University of New South Wales).

Some speculations have been made regarding the biosynthesis of phenylpropanoids in cinnamon. As mentioned, the phenylpropanoids eugenol and cinnamaldehyde predominate in the leaf and stem bark oils. Similar studies on varieties of cinnamon that occur in a different region of the island have revealed the presence of safrol and eugenol in leaf (60% safrol and 30% eugenol). In Cinnamon as in most other plants the route to the phenylpropanoids can be assumed to be via phenylalanine and cinnamic acid. The scheme I can explain the formation and interconvertions of the phenylpropanoids.

From these studies and from the comparison of the occurrence of similar compounds in other plants, the following generalisations can be made and appear to be in accord with mechanistic considerations.

The initial hydroxylation is ortho or para to the side chain. In Cinnamon, only the parahydroxylated compounds occur; any further hydroxylation of the ring should be ortho to the first hydroxyl group.

Para oxygenation appears essential for the elimination of the side chain oxygen during the formation of allyl benzene compounds and the following pathway is proposed for these elimination reactions. (vide scheme II)

This mechanism explains the co-occurrence of compounds having the propenyl and allyl side chain types. The mechanism also conveniently explains the formation of the dioxymethylene ring as in safrol. (vide scheme III).

A detailed study of geographical and varietal influences on the Cinnamon plant is now in progress and has drawn assistance from the International Foundation for Science in Sweden.

FIG 1

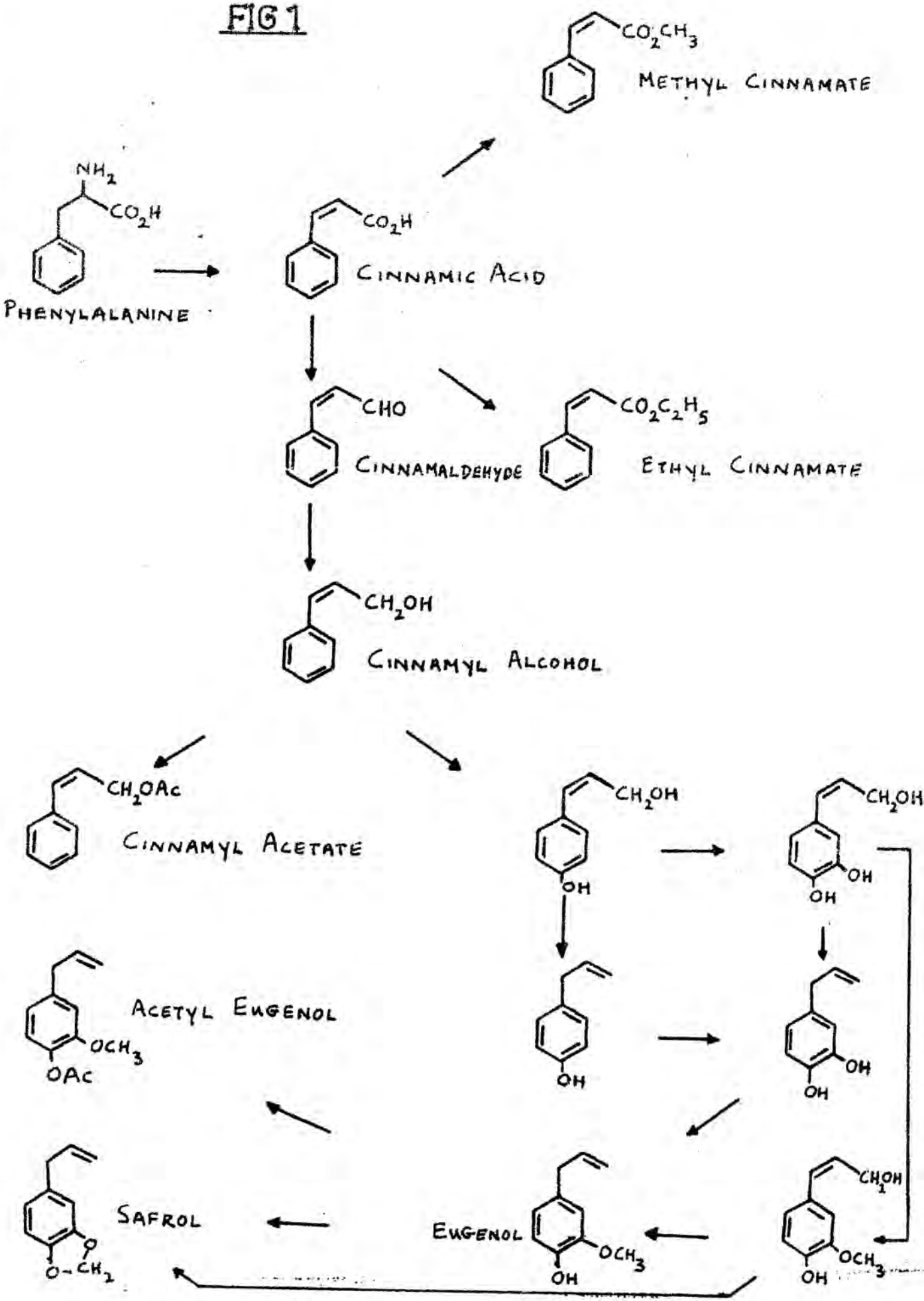

METHYL CINNAMATE
PHENYLALANINE
CINNAMIC ACID
CINNAMALDEHYDE
ETHYL CINNAMATE
CINNAMYL ALCOHOL
CINNAMYL ACETATE
ACETYL EUGENOL
SAFROL
EUGENOL

FIG 2

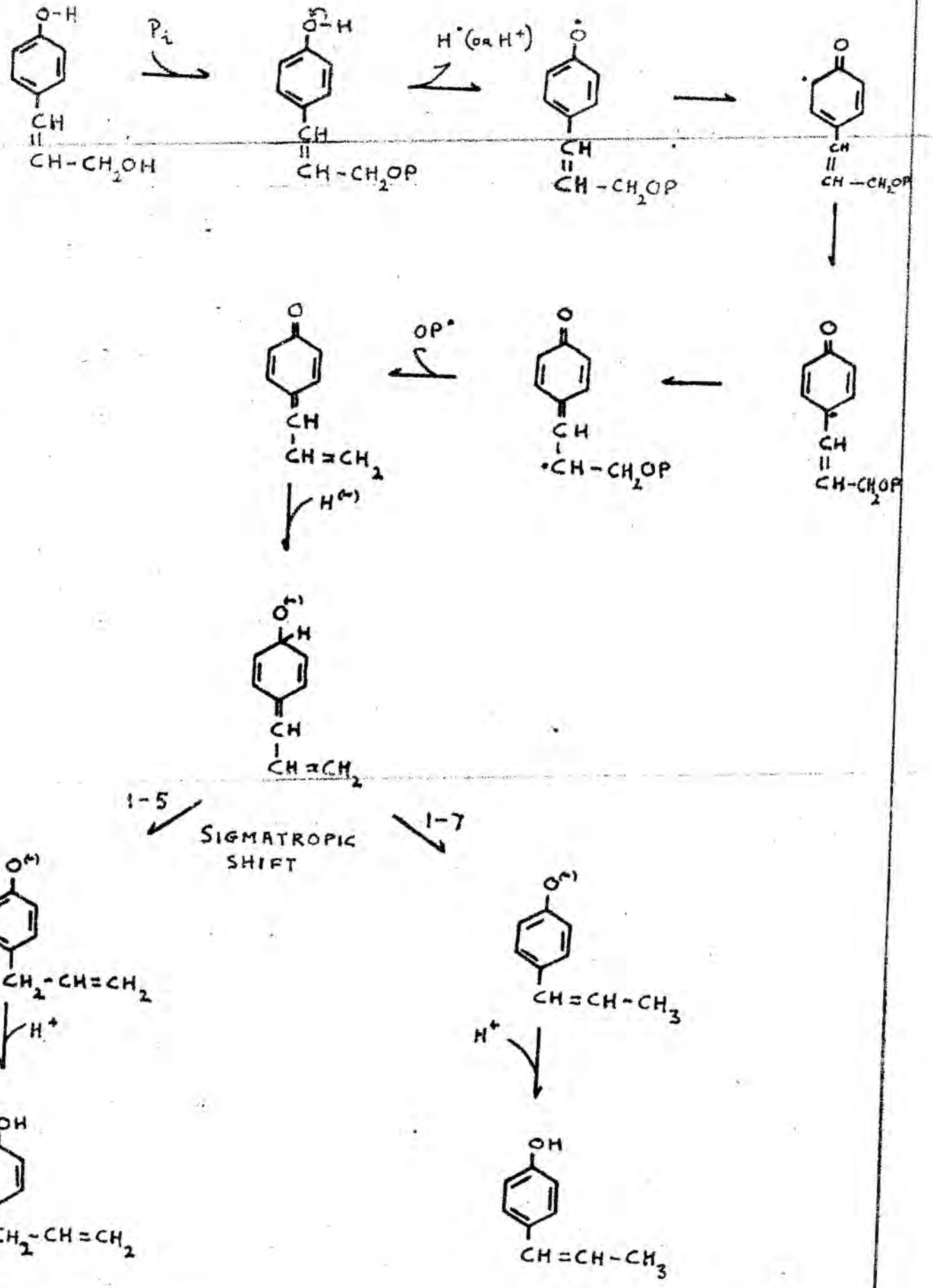
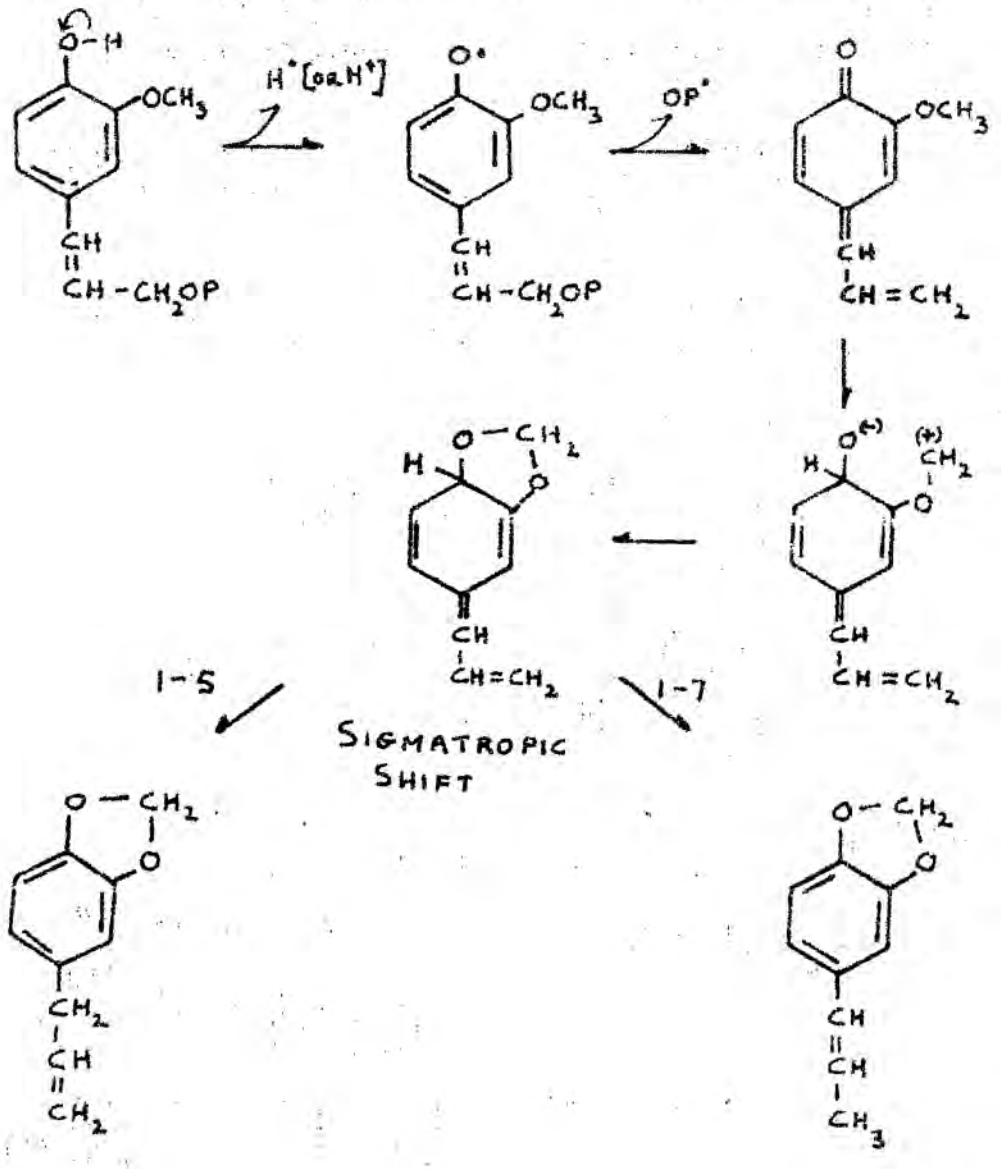


FIG 3



ASSISTANCE FOR RESEARCH :

The research on spices and essential oils would not have been accomplished but for the generous assistance of colleagues abroad. The assistance has taken several forms, viz :

1. Donation of rare authentic chemicals, for comparison purposes.

2. Assistance with determination of spectra, particularly NMR and MS.

3. Assistance in the training facilities for personnel.

4. Assistance to attend conferences and to visit advanced laboratories.

The following have helped in several ways[+] :

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Professor A.J. Birch : Australian National University, Canberra. (2), (4).

Professor Finn Sandberg: University of Uppsala, Sweden. (1), (2), (3), (4).

[+]Numbers in brackets refers to the types of assistance.

Professor Cyril Ponnamperuma : University of Maryland (1), (2).

Professor Richard A. Bernhard: University of California, Davis, (1), (2).

Messrs. Givaudan-Esrolko, Switzerland, (1), (4).

Messrs. Firmenich and Cie, Switzerland (1), (4).

I.F.F., U.S.A. (1).

Haarman and Reimer, Germany (1)

Museum of Applied Arts, Sydney. (1).

Dr. T. Moroe : Takasago Perfumery Co. (1), (2), (3).

Professor S. Shibata : University of Tokyo (1), (2), (3).

Special mention must be made of the assitance and training facilities given to three members of the group by the International Seminar of Chemistry (Uppsala), in the area of Phytochemistry. Financed by Swedish International Development Authority (SIDA), this included full passage, subsistance, cost of travel during the period and an allowance for books.

Grants for ressarch has been obtained for work on spices. The first grant was from the Ministry of Plantation Industries totalling over Rs. 100,000 for development of stills and for Synthesis of Aromatic Chemicals.

The National Science Council for Sri Lanka supports four research students for studies on :

(i) Transformation of Terpenoids

(ii) Biosynthetic Studies on Cinnamon

A grant from the International Foundation for Science (Sweden) totalling US $ 8,500 has been awarded for work on Cinnamon biosynthesis and varietal studies.

The UNDP FAO project on Research on Minor Export Crops through the Ministry of Plantation Industries is also arranging for a grant of equipment for work on spices and flavours.

FURTHER RESEARCH ON ESSENTIAL OILS :

The programme of future research on essential oils would include the following, besides the studies already in progress.

1. Varietal Studies on : Exotic types of Cinnamomum sp.
   Ocimum sp.
   Locally grown Eucalyptus sp.

2. Studies on the Flavour Development of Curry Powders and changes occuring during roasting.

3. Studies on Locally Grown Mint (Mentha javanica) - a Possible Substitute for Peppermint.

4. Studies on "Rampe" (Pandanus latifolius) and the development of a Characteristic Odour on cooking.

5. Composition of the Volatile Oil of Curry Leaf (Murraya Koenigii).

6. New Sources of Aromatic and Flavour Chemicals : eg. Studies on Mango leaf, Woodapple leaf, Beli leaf etc.

TECHNOLOGICAL DEVELOPMENTS :

The distillation of essential oils in Sri Lanka poses several problems, the lack of suitable equipment being one of the major ones.

The traditional distillation outfits employed generally in field distillations have a static water tank (capacity : 4000 gallons approximately), which serves as a cooling device for a condenser coil immersed in it. During periods of water scarcity, this outfit cannot be used. The CISIR developed a new Field Still, the CISIRILL MANAKOKA[7], which overcomes this problem by the use of a novel two-stage condensing system. In the first stage a Latent heat Exchanger is employed. This is a 400 gallon tank of water through which passes a coiled tube which carries the hot distillate vapours. The water in the tank is maintained at boiling by acquisition of its latent heat from the hot vapours. The vapours then enter a vane-type Air Condenser to complete the second stage of the cooling system. The still has been tried in the field in several centres and gives excellent results in terms of yield, quality of oil and continuity of operation.

A second type of still the CISIRILL SPICA[8], has been developed and is particularly suited for the distillation of fine spices such as Nutmeg, Pepper, Cardamom and Clove. The still operates by passage of steam through a shallow wide-diameter bed of raw

material and combats problems caused by caking of the raw material. There is evidence for the popularity of this still as it is economical to fabricate and maintain.

Other simple equipment for preparation of SPICE OLEORESINS and Fractional Distillation of oils have been designed and prototypes are being tested.

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Addendum

Facilities for Natural Products Research at C.I.S.I.R.

Instruments	Present Position	Requirements
1. Gas chromatographs	2	4
2. High pressure liquid Chromatograph	0	1
3. Infra-red Spectro-photometer	1	–
4. High resolution Infra-red Spectrophotometer	0	1
5. Automatic Recording Ultra-violet spectro-photometer	0	1
6. TLC densitometer	0	1
7. Automatic Recording spectropolarimeter	0	1
8. General laboratory eg. Balances, Evapo-rators, Chromatographic equipments	+	+++
9. NMR spectrophotometer 100 MHz	0	1 Availability at some institute would suffice
10. Mass Spectrometer (G.C, combined)	0	1 Availability some where in the country would suffice
11. Recorders for above instruments	3	8

STUDIES ON THE CHEMOTYPES OF CITRONELLA GRASS CULTIVATED IN SRI LANKA

Paper prepared by :

S. Ponnuchamy *

Citronella oil is the essential oil obtained from the Citronella grass. There are two types of citronella grass known in cultivation, namely, Cymbopogon nardus or the Ceylon type exclusively cultivated in Sri Lanka only, and Cymbopogon winterianus or the Java type cultivated in all the other citronella oil producing countries such as Java (Indonesia), People's Republic of China, Taiwan, Gautamala and Honduras. It is believed that both these types originated in Sri Lanka. Both C. nardus and C. winterianus are closely related types distinguished morphologically by the shape and length of their leaves and chemically by the composition of the essential oil obtained from them.

There was much controversy among the botanists in the early part of the 1900's, over the identification of the two types of citronella grass, based on morphological features alone. Most of the botanists believed that both belonged to the same species. Jowitt (1908) brought an end to this controversy by citing the chemical composition of the two oils. Due to lack of analytical techniques at that time, no qualitative differences in the composition of oils were detected.

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Presently - Industrial Development Board of Sri Lanka, Katubedde Moratuwa.

but distinct quantitative differences of the major constituents in both types of oils such as citronellal, citronellol and geraniol, were taken as the criteria to differentiate the two types of grasses. The Ceylon type oil was said to contain 7 - 10 percent of citronellal, 10 - 15 percent of citronellol and 20 - 25 percent of geraniol, and the Java type oil was said to contain 30 - 35 percent of citronellal, 30 percent of citronellol and and 25 - 30 percent of geraniol.

In Sri Lanka even though C.nardus is exclusively cultivated, isolated patches of C. winterianus still exist in some plantations. Studies were carried out on the chemical composition of the oil distilled from the C. winterianus found in Sri Lanka in order to propagate this more commercially valuable variety. But the studies revealed that the chemical composition of the oil of C. winterianus found in Sri Lanka differed both, qualitatively and quantitatively from the oil of C. winterianus grown in other countries.

Chemical Composition of the oil of Cymbopogon winterianus

Major Constituents	Sri Lanka	Other Countries
Terpene hydrocarbons	33.5 %	1.3 %
Citronellal	18.8 %	32.7 %
Borneol	5.8 %	Traces
Citronellol	10.4 %	15.9 %
Geraniol	21.7 %	23.9 %
Phenolic constituents	2.4 %	2.3 %

The chemical composition of the C. winterianus found in Sri Lanka indicates that hybridisation with Cymbopogon nardus, which is found in abundance in Sri Lanka, had occured. This has not been established yet and more work has to be done to confirm this.

Studies on the C.nardus variety revealed that, based on simple morphological features it could be further sub-classified into at least five different types. These morphological variations are not sufficient to classify them as sub-species or varieties, and the chemical composition of the oil of the five types identified, showed no qualitative differences. However, significant quantitative differences exist among the major constituents of the oils. The morphological and chemical differences are tabulated below:

Morphological Features

	Type 1 (Red)	Type 2 (Powder)	Type 3 (Dull red)	Type 4 (Dwarf)	Type 5 (White)
Stem	Short 80-100 cm Fine red base	Short 80-100 cm Base covered with a fine white powder	Short 80-100 cm Dull red base	Dwarf 60-80 cm Different coloured base	Short 8 - 10 cm Pale white base
Leaf	Narrow 8 - 10 mm Neither dark nor light green	Narrow 8 - 10 mm Light and dark green shaded	Narrow 8 - 10 mm Dark green	Very narrow 6 - 8 mm Light green	Narrow 8 - 10 mm Light green
Type of drooping	$\frac{1}{3}$ length	$\frac{1}{3}$ length	$\frac{1}{3}$ length	No drooping	$\frac{1}{3}$ length

Chemical Composition (Mean of 3 collections)

Terpene hydrocarbons	18.9	18.6	22.3	16.0	15.4
Citronellal	9.1	7.3	13.7	3.4	2.2
Borneol	7.2	4.2	3.4	5.9	15.8
Citronellol	9.9	7.5	9.7	3.5	2.7
Geraniol	25.1	36.4	20.6	45.1	12.0
Phenolic constituents	12.0	16.8	9.6	12.0	20.1

Proposed Studies:

Samples of C. winterianus found in Sri Lanka and the different types of C. nardus variety were collected from the growing areas and planted at the University farm in Peradeniya, near Kandy. Studies of the chemical composition of the oils of different types, under different climatic conditions, are envisaged. It is hoped to ascertain whether the chemical characteristics are carried over from generation to generation.

N.B. This work was initially done on a grant from the National Science Council of Sri Lanka.

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SOME STUDIES ON LEMONGRASS AND CITRONELLA CARRIED OUT AT THE FACULTY OF AGRICULTURE, PERADENIYA

Paper Prepared by :

H.M.W. Herath *

PART I -

Growth Performance of Some Strains of Lemongrass - Cymbopogon citratus Stapf. and Cymbopogon flexuosus Stapf -

Two main types of lemongrass oil are recognised commercially, namely Indian or Cochin Lemongrass oil obtained from Cymbopogon flexuosus which is extensively cultivated in Travancore, near Cochin on the Malabar coast and the "West Indian" Lemongrass oil obtained from Cymbopogon citratus which is cultivated in Thailand, Indonesia, China, Madagascar and the Comoro Islands. It is also grown in tropical America and Africa.

Lemongrass (C. citratus) has been grown in home gardens for use as a condiment in cooking, but its cultivation on a commercial basis for extraction of essential oil commenced only about 10 years back. With the recent emphasis on crop diversification and the increasing demand for lemongrass oil both locally and abroad, the area under this crop has increased from a few ...

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hundred acres in 1970 to over three thousand acres at the present time. These plantations were established mainly with the East Indian strain of Lemongrass (OD 19) and the local strain (C. citratus). These two types are being grown in many parts of the country, representing various ecological conditions. The performance of this crop has been better in some areas than in others, both with regard to yield of grass and oil.

Therefore it was important to find suitable strains for different areas and with this objective in view four strains were introduced from Izu Experiment Station of Medicinal Plants, National Institute of Hygienic Sciences, Shizuoka-ken, Japan in 1970. The following table give some information of these strains :-

Strain No.	Place of Origin	Grass Yield	Oil Content	Citral Content
1	Java	Medium	Medium	Medium
7	Not clear	Low	High	Low
8	Singapore	High	Medium	High
9	Not clear	High	Low	High

Utilising these four introduced strains, the local strain and the East Indian strain, a series of trials were conducted in the Mid-country Wet Zone, Mid-country Dry Zone and the Dry Zone

which included a comparative study of their adaptability to different location and their response to different agronomic and cultural practices.

The East Indian Lemongrass affords a comparatively low yield of grass which however contains a high percentage of oil. The oil is also comparatively rich in citral. When this strain was grown in the Dry Zone (Maha Illuppallama) the total quantity of oil produced per unit area of land was less than that obtained for the "West Indian" type (C. citratus). It is presently being tested along with other types in the Mid-country Wet Zone and the Up-country Dry Zone.

Among the C.citratus strains, the percentage of oil from the local strain was lower than that from the introduced strains. Growth of all strains (both local and introduced) were affected by location. The frequency of cutting had a greater effect on the yield of grass and oil, than the height of cutting or levels of fertilizer. Plots harvested at two month intervals yielded more grass than those harvested at three or four month intervals. The length of the interval of cutting was negatively correlated with the yield of grass and oil.

The concentration of oil in the leaf blade is approximately 50% more than in the leaf sheath . However, in the local strain oil concentration was found to be more or less equal in both the leaf and the leaf sheath.

Future Research :

(1) Studies on the effect of temperature and light on the growth of Lemongrass

(a) Temperature - The impact of temperature, due to seasonal variations, on plant and growth, oil and citral will be investigated.

(b) Light Intensity - There appears to be an effect on the growth of Lemongrass due to low light intensity. As it is one of the crops considered for inter-cropping with coconut, selection of varieties adopted to low light intensity would be an advantage. The objective of this investigation therefore would be to study the response of various strains to different light intensities.

(c) Effect of duration of light on induction of flowering in non-flowering types.

2. Collection, identification and improvement of locally available strains.

3. Physiological Studies - In plants with low compensation values (lacking-photo-respiration) the initial products of photosynthesis are formed by the C_4 - dicarboxytic acid pathway, whereas the high compensation plants (with photorespiration) produce compounds typical of the carbon cycle.

The leaf veins of the low compensation species are

surrounded by a specialized parenchyma bundle sheath containing a high concentration of chloroplasts with large quantities of starch.

It is proposed to carry out studies on Lemongrass and Citronella grass, where the main objective would be to find low CO_2 compensation plants which are efficient in photosynthesis and produce more grass and oil.

A major constraint in carrying out any programme of research in both Lemongrass and Citronella is the lack of equipment such as growth chambers for controlled environmental studies, CO_2 infrared gas analysers for compensation studies etc.

PART II

Identification and Characterization of Citronella (Cymbopogon sp.) Grown in Sri Lanka -

Citronella exists in a variety of forms, wild, semi wild, and cultivated. The oil from the cultivated types contains a much greater proportion of the commercially valuable compound than the oil of the wild types.

Several types are known to occur in Sri Lanka, namely Maha pengiri or Java type, and Lenabatu. Botanically the two types Lenabatu and Maha pengiri are classified as Cymbopogon nardus (L. Rendle) and Cymbopogon winterianus (Jowitt) respectively. Although several strains of these species are grown in Citronella plantations, no efforts has so far been made to identify and characterize them on the basis of their morphological, anatomical and cytological characters. Some of these strains, it is felt, are the results of different edaphic, micro-climatic or biotic influences on natural selection. It is also possible that the genetic composition of these strains or ecotypes could be different.

After a preliminary survey conducted in Citronella growing areas, several different strains of both groups were collected and grown at the University farm, Meewatura. Ten strains which showed morphological differences were selected and a detailed study of each strain in respect of their morphological, anatomical and cytological characters was initiated. Further investigation on the chemical composition of the oil and their potential for commercial exploitation, has been undertaken by the Natural Products Section of the C.I.S.I.R.

Differences in colour and the intensity of colour of leaf sheath and lamina from the ten strains were recorded. The length of leaf sheath and lamina and size of auricle were also found to be different in the various strains. Some of the strains had drooping, semi-erect or erect leaves. The oil yield and composition showed differences in all the strains.

Envisaged Lines of Future Research -

(1) In addition to the study of morphological characters in the leaf the following investigations will be carried out

(a) Stem morphology

(i) Number of tillers and rate of tillering.

(ii) Number of leave/tiller

(b) Root morphology

(i) Adventitious, seminal and epicotyl root

(ii) Length of root s

(iii) Weight of roots

(c) Floral and inflorescence morphology

(i) Nature of panicle

(ii) Floral characters

(iii) Pollen morphology

(d) Seed morphology

(2) Anatomical and Cytological Characters.

(a) Stomatal distribution and density on leaf lamina and sheath

(b) Distribution and density of oil gland on leaf lamina and sheath

(c) Structure of leaf tissue

(d) Chromosome number and chromosome morphology

(3) Yield Characters

(a) Yield of grass

(b) Yield of oil

(c) Response to fertilizer

Physiological Studies -

Studies on the effect of light and temperature on CO_2 exchange rates and CO_2 compensation will be undertaken as for Lemongrass.

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CHEMICAL INVESTIGATION OF MEDICINAL PLANTS

Paper Prepared by :

L.B. de Silva*

Indigenous plant material is the basis of ayurvedic therapeutics. There is a host of indigenous plants which are reported to possess therapeutic action and their use in indigenous medicine dates back to the early beginning of Sri Lanka history. The early settlers in Sri Lanka would have brought with them the customs and the practices prevalent in the neighbouring sub-continent. Perhaps Charaka's treatise on medicine and materia -medica was the foundation on which our materia-medica was developed. In Charaka nearly 2,000 vegetable remedies have been described together with a few mineral and animal remedies. It is interesting to note that Charaka stresses not only on the correct botanical identification of the plant material but also of the soil, season and the time of gathering of medicinal plants.

There had never been a proper scientific evaluation of the indigenous plants and it was not unreasonable to expect at least some of the plants to possess valuable pharmacological properties. After all "we have seen in recent years the medicinal value and indus-

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~~trial stimulus provided by such a natural alkaloid as reserpine,~~ isolated from plant material for long used in oriental fold-medicine" (1). Lord Todd goes on further to state "that still other substances with significant and valuable pharmacological properties remain to be isolated from plant materials, and that incidentally, clues to some of them may still be found in folk medicine of primitive people" (I).

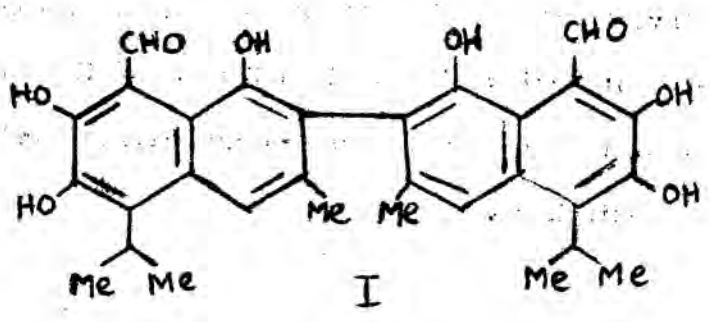
It was with this in view that we undertook our investigations in the field of indigenous plants nearly 2 decades ago; and the earlierwork was reviewed at International Symposium on Medicinal Plants held in Kandy, Sri Lanka, 13th - 18th December 1964 (2). Our aim was to isolate the active principles of these indigenous medicinal plants which had first been clinically and pharmacologically screened and found to be therapeutically active. Due to the lack of such background information, the choice of plants material for investigation was decided upon on the literature available. The present review will deal with some of the chemical constituents isolated from indigenous plant material and also some that are not endemic here.

Thespesia populnea is a common tree in Asia, Africa and the Pacific island. In Sri Lanka extracts of the bark have been used for the treatment of certain allergic conditions such as Asthma and Eczema. Previous chemical investigations of the plant have been

reported by T.R. Seshadri et al (3) who isolated Kaempferol and herbacetin and their glucosides from the flowers.

We have reinvestigated this species and by light petroleum extraction of both the bark and the flowers and have obtained a yellow phenol in 1.25% yield from the bark and 0.4% from the flowers.

Phenol was a mixture of inactive gossypol and optically active gossypol (I) (4) and the separation was affected by fraction crystallisation from chloroform in which the inactive gossypol was the less soluble fraction. The active gossypol which was freely soluble in chloroform was purified by repeated crystallisations from aqueous acetone when the pure active form crystallises with acetone of crystallisation. The unsolvated form could be readily isolated from boiling light petroleum (100 - 120°) m.p. 181 - 183 (Kofler $(\alpha)_D^{19}$ + 445 ± 10° (C 0.15 in chloroform).



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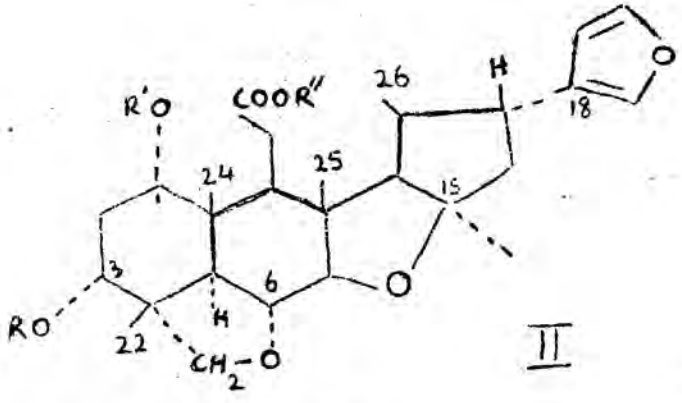
As far as we are aware this is the first report of gossypol occuring elsewhere than in gossypium species and the active form would seem to be the first β-β^1 dinaphthyl derivative showing optical activity due to restricted rotation.

Bitter Principle of Melia Cubia Cav.

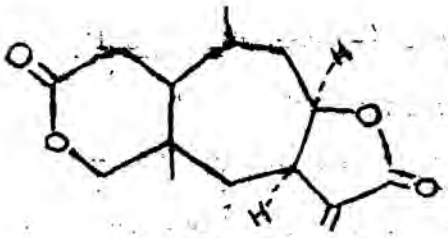
The family meliacea has received intensive study in recent years and has yielded a large number of compounds of general class described by the term "limanoid". Melia azadiracta L (Nim) has received particular attention; all parts of the tree-seeds, bark, root bark, blossoms and leaves have been investigated (5). We have now examined the fruits of Melia dubia Cav. (Sinh. Lunumidella) a common tree of the West forests of Sri Lanka and found it to contain Salanin II (6) as the principal limonoid constituent. Lunumidella is a soft wood and is extensively used in Sri Lanka for ceiling boards as the timber considered to be resistant to insect attack.



II

Psilotropin from Psilotrophi Cooperi -

A sesquiterpenoid dilactone, psilotropin III (7) isomeric with vermeerin IV (8) a constituent of geigeria aspera Harv. was isolated from Psilotrope cooperi and its structure is given in



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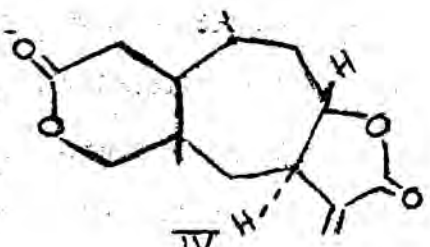
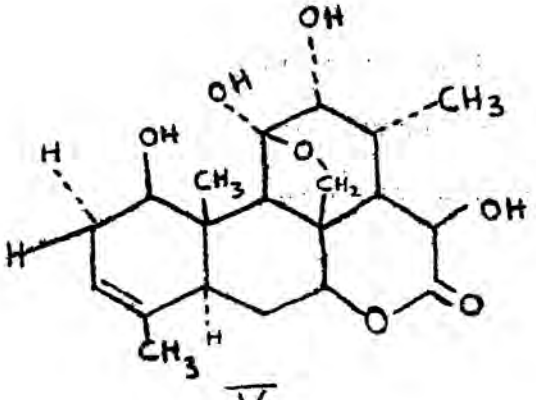


IV

In psilotropin the C_7/C_8 lactone is ClS and the lactone of vermeerin is transOfused.

Glaucarubol and (-) - Syringaresinol from Holacantha emoryi Gray.

Holacantha emoryi Gray is a shrub common in Southern California and Arizona and there was some doubt about its classificatiom. The isolated of Glaucarubo (V) (9) convincingly proved that Holacantha emoryi Gray in fact belongs to the simaroubaceae family. Along with glaucarabol ellagic acid, belitin and (-) - syringaresinol (VI) were isolated.



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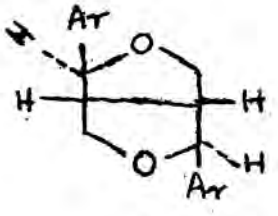
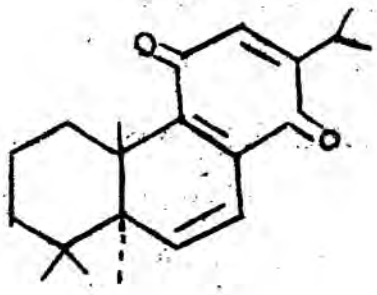


VI

Plectranthus zeylanicus (Sinh. Iruveriya) belongs to the family Labiatae and has been used in ayurvedic medicine for the treatment of dysentery. R.N. Elizarova, A.D. Zuzavkov, P.N. Kipalchich and A.I. Streter (9) have reported the isolation of a diterpene Plectrin, $C_{20}H_{28}O_4$ mp. 213-15 from Plectranthus glaucocalyx. S.A. Vichkanova and M.A. Runinchik (10) have reported that Plectrin was effective against Trichomonas vaginalis, E. histolytica, Staph. aureas and Mycobacterium tuberculosis in vitro.

On steam distillation the fresh plant gave dihysroroyleanone I identical with dehydropxoyleanone isolated by J.H. Gough and M.D. Sutherland (II) from the Plectranthus species (I) and from the roots of Inula royleana by Edwards, Feneak and Los (II).

The dry powdered plant on petroleum ether extraction followed by concentration deposited yellow prisms mp. 226-7 (dec.). The compound analysed for $C_{22}H_{30}O_6$ and this is supported by the mass spectrum which however gives no other information which is useful other than showing a very easy loss of 60 mas units (CH_3COOH probably). The olifinic H doublet at 4.2 τ is coupled with a peak at 5.6 τ which is presumably due to the $CH - OOOCH_3$. There is another peak whose position is dependant on concentration at about 8τ(visible in the 10 mHz spectra) which also exchanges with D_2O. There is one isopropyl group, three singlet methyls and one acetyl methyl. The X ray analysis of the crystal revealed the structure to be VIII.



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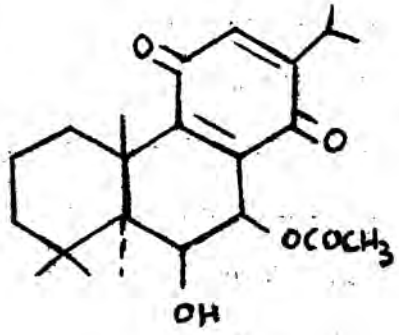

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Addendum

Current Research :

Research on Indigenous drugs already underway will be completed. Just now triterpenes of Symplocus racemosa (Sin. Loth sumbulu) are under investigation.

Constraints -

Factors that seriously affect the progress of Natural Products Research in Sri Lankaare the lack of apparatus, chemicals and Journals. Further there are no opportunities to take part in International Conferences and Symposia on related topics; in other words we find ourselves completely isolated from the main streams of activity in our fields. There is plenty of laboratory space available and enough ordinary glassware; but repair facilities for the more complex glass apparatus and electrical appliances are limited. There is no institution in Sri Lanka where NMR, Mass Spectral and O.R.D. determinations could be done. When such determinations are necessary, the speimens have to be sent abroad and this involves red tape, delay and to say the least it is discouraging. Quite often letters and speciments get lost in the post.

It is therefore very necessary that foreign aid be sought to equip at least one central laboratory where such facilities are available. This central laboratory could service the need of all workers who need such facilities. Along with the installation of such expensive instruments trained personnel should be made available for the operation and maintenance of these instruments along with the necessary spares. We would welcome any collaborative work with any foreign University or Institution.

NATURAL PRODUCT CHEMISTRY AT THE DEPARTMENT OF CHEMISTRY UNIVERSITY OF SRI LANKA (PERADENIYA CAMPUS)

Paper prepared by :

* G.P. Wannigama

The Flora of Sri Lanka offers excellent scope for research in natural product chemistry. There are over 3300 flowering plant species belonging to 1294 genera and 192 families. Of these about 830 plant species belonging to 342 genera and 94 families are to our knowledge endemic to Sri Lanka. In addition there are many plant species confined to South India and Sri Lanka but more abundant in Sri Lanka than in South India.

Research in natural product chemistry at Peradeniya has been confined mainly to an investigation of the endemic plants, as it was expected and subsequent results have borne out that such plants, confined as they have been for long periods in a limited region of the globe, have developed certain chemical characteristics of their own. In spite of the abundance of some of the endemic plant species, medicinal uses have been recorded for only about 33 species. This is due to native physicians relying heavily on the system of medicine in India and prescribing herbal preparations from India. Within a genus, the medicinal value of the endemics may be equal to or even superior to the non-endemics but quite often the non-endemic species is imported into the country even though the endemic species may have served equally well. No systematic study of the endemics had been undertaken before and hence a study of the medicinal value of these plants appeared to offer prospects of import substitution.

As a necessary complement to the chemical study, a list of the endemic plants of Sri Lanka was prepared by Bandaranayake and Sultanbawa.

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This list was based on Trimen's classification of the flora of Sri Lanka. It was prepared from Willis's catalogue of the flowering plants and ferns of Sri Lanka, which had been revised by Abeywickrema with incorporation of nomenclatural changes. Next came a compilation describing the location by districts of the endemics. Finally, as a guide to the collection of the species, a glossary of the Sinhala and Tamil names of the total indigenous flora was prepared by Bandaranayake, Sultanbawa, Weerasekera and Balasubramaniam.

One of the first endemic species to be investigated was Holarrhena mitis in the sub-family Plumerioideae in the Apocynaceae family. The Plumerioideae sub-family contains several alkaloid bearing species of proven pharmacological value. However all these alkaloids, with the exception of the alkaloids of Holarrhena, are indolic in nature. Alkaloids of Holarrhena, which is in fact in the same tribe (Plumericae) as Catharanthus and Vinca, are usually steroidal in nature and in this respect are similar to the alkaloids of Funtumia, a genus found in Africa, belonging to tribe Nericae in the Echitoideae sub-family. The chemical similarity of Holarrhena with Funtumia has led to the theory that Holarrhena is the probable starting point for a mutation from the Plumerioideae to the Echitoideae. Studies on Holarrhena mitis showed strong resemblance to other Asiatic Holarrhena in the existence of the aminoglycocardenolides, mitiphylline and nor-mitiphylline. However there were striking resembalances to African Holarrhena. The purine base triacanthine found in African Holarrhena and never in Asiatic Holarrhena was found in Holarrhena mitis in high yields. So it was with holafebrine, though in lower yields than in African Holarrhena. Compared with the Indian Holarrhena antidysenterica, the yield of alkaloids of the conessine ring type were poorer while the yield of alkaloids of the holarrhimine ring type were much higher.

There are seven other endemic plants of the Apocynaceae. Petchia ceylanica in the Rauvolfieae tribe of the Plumerioideae contained a mixture of oxindole alkaloids, sensitive to light and air. The total alkaloidal extract has been tested and shown to have no antihypertensive activity.

Two other endemic Apocynaceae in the Nericae tribe, namely Wrightia angustifolia and Waliddha zeylanica have been checked and found to be free of alkaloids. This observation is of importance owing to the earlier grouping of some species of Wrightia and the monitypic Waliddha Zeylanica as Holarrhena species.

All nine endemic Guttiferae * as well as a few non-endemics have been studied and a variety of chemical compounds isolated. Xanthones are the most abundant. A number of biflavonoids, coumarins, acids containing a 2,3-dimethylchromanone system and triterpenes of the friedelane, oleanane, taraxerane, lupane and adiantane groups have also been isolated.

The family Flacourtiaceae contains several species of medicinal value especially in the treatment of leprosy. It has anatomical similarities with the Celastraceae and has at one time been classified under the family Guttiferae. Chemical investigations were in support of the botanical similarities. Thus, friedelane carboxylic acids and friedelane aldehydes have been isolated from two endemic Flacourtiaceae. Friedalane aldehydes are reported in the literature both from the Celastraceae and Guttiferae. Although only one xanthone, mangiferin had been reported in the literature from the Flacourtiaceae, the isolation of the xanthone, mangostin from two endemic Flacourtiaceae evidently brings the Flacourtiaceae chemically as well as botanically closer to the Guttiferae. Mangostin had never been found so far outside the Guttiferae.

Many tree species which are valuable for timber purposes such as teak and ebony have been shown to contain betulinic acid in high yields. Five plants of the Dilleniaceae contained betulinic acid in sufficiently high yields to suggest that it may be a chemotaxonomic marker for the family. In the endemic Diospyros of the Ebenaceae the related compounds lupeol, betulin and betulinic acid occur in high yields and the group of compounds may be used for chemotaxonomic identification of Diospyros.

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*(Vide also the review article by Sultanbawa : The Chemistry of the Guttiferae.)

The presence of cycloartenol, cycloartenyl acetate and cycloartenone in several species of Artocarpus in the Moraceae is significant and may have taxonomic value for the genus. Five new chromeno flavonoids have been isolated from the endemic Artocarpus nobilis. Furano-chromenoflavonoids have been isolated for the first time from this plant.

This report is principally a summary of the published work from the Department of Chemistry at Peradeniya. It is regretted that unpublished work and work in progress had to be excluded.

Grateful acknowledgement is made of financial support from the University of Sri Lanka, from the National Science Council and from the United States Department of Agriculture.

Thanks are also due to our many friends abroad, notably Professors W.D. Ollis and R.H. Thomson, who have provided us with NMR and MS data at no cost. During the last two years 41 NMR spectra and 58 mass spectra were received at Peradeniya. However it takes about three months for receipt of the data, with consequent slowing down of our research programme. The provision of at least an NMR instrument in the country in the near future would be a big leap forward.

The grave shortage of foreign exchange in the country has added a further impediment to our research activity. No journals have been received for the past two years and little foreign exchange is available for the purchase of chemicals and glassware. This is not a situation to be passed off lightly and meaningful steps must be taken without delay to provide research programmes with the necessary foreign exchange.

There is almost unlimited scope for further work on the endemic plants. In fact the alkaloid screening programme and the pharmacological testing have only recently been commenced. There is no doubt that with the devoted enthusiasm of Professor M.U.S. Sultanbawa and other colleagues, natural product chemistry would continue to flourish at the Department of Chemistry, Peradeniya.

Apparatus available in the Department: (a) Infra red spectrometer (Perkin Elmer 257), (b) Ultraviolet spectrophotometer (Unicam SP 8000 B) with recorder, (c) Gas Liquid Chromatograph (Perkin Elmer F11) with recorder, (d) Drying Chamber and grinding equipment, (e) Large scale continuous extractors, (f) Counter current liquid-liquid extractors, (g) Facilities for chromatography, (h) Fraction collector, (i) Polarimeter (manual), (j) High and atmospheric pressure hydrogenerators, (k) Ozoniser, (l) Facilities for glass blowing and (m) a jeep for collection of plant material.

Botanical identification of plant material: Dr. S. Balasubramanian Department of Botany, Peradeniya Campus, University of Sri Lanka; Professor A.J. Kostermans, Father L.H . Cramer and Mr. M. Jayasuriya of the Flora of Ceylon Project.

Supply of plant material: Mr. F.H. Popham, Smithsonian Representative in Sri Lanka in the Flora of Ceylon Project; Conservator of Forests, Forest Department, Colombo; Superintendent, Botanical Gardens, Peradeniya.

Collaboration in the Chemical Investigations: Dr. S. Balasubramanian Department of Botany, Peradeniya Campus, University of Sri Lanka: Dr. I. Kitagawa, University of Osaka, Professor W.D. Ollis, University of Sheffield, Professor L. Crombie, University of Nottingham Professor R.H. Thomson, University of Aberdeen, Professor M. Shamma, Pennsylvania State University, Dr.D.E. Games, University College, Cardiff, Dr.A.Cave, University de Paris-Sud, Chatenay-Malabry.

Collaboration in the screening programmes: Dr.R.L. Wickramasinghe, Tea Research Institute, Hantane (saponin screening); Professor S.N. Arsecularatne, Department of Bacteriology, Peradeniya Campus (antibacterial and anti-fungal activity); Dr. Yoder of the Liaison Office, National Cancer Institute, Brussels (anti-tumour screening); Dr.J. Wilson, Smith, Kline and French Laboratories, Philadelphia (anti-arthritic screening and galactosyl enzyme transferase screening).

Physical data: 41 NMR spectra, 58 mass spectra and 3 ORD curves were received in 1973 and 1974 free of cost through the generosity of the following: Professor W.D. Ollis, University of Sheffield; Professor R.H. Thomson, University of Aberdeen; Professor C Ponnamperuma, University of Maryland, Professor L. Crombie, University of Nottingham; Professor M.Shamma, Pennsylvania State University; Professor Sir Derek Barton, Imperial College, London; Dr. I. Kitagawa, University of Osaka, Dr. Peter Bladon, University of Strathclyde; Dr.R. Goutarel, CNRS, Gif-sur-Yvette, France; Dr.B.S. Joshi. CIBA Research Centre, Bombay, Drs. J.B. Davies and M.J. Nagler of the Tropical Products Institute, London.

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EXTRACTION OF CANNABINOIDS WITH MILK

Paper prepared by :

C. Satkunananthan *

The term Cannabis in this paper is used to mean "the flowering or fruiting tops of the Cannabis plant (excluding the seeds and leaves when not accompanied by the tops) from which the resin has not been extracted, by whatever name they may be designated". (Definition in Single Convention on Narcotics 1961 ; Article I, para 1.).

The primary mode of consuming Cannabis is by smoking, but it may be ingested as a food or beverage. In India and Sri Lanka a significant amount is taken orally as a beverage and as numerous confections and food preparations. However, in most parts of the world these modes of consumption are minor compared to smoking. It has been stated that smoking of cannabis produces stronger effects than ingestion. Two reasons have been advanced for this; firstly some of the inactive cannabinoids are converted to the active tetrahydrocannabinol during the smoking process and secondly the active tetrahydrocannabinol is destroyed in the gastro-intestinal tract.

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The fact that oils and fats dissolve cannabinoids easily has been known for some time; the "Bengal Dispensatory" of 1842 describes how oils are used to extract cannabis to make a preparation called "Majoun". Recently, concentrated extracts of cannabis in oil have appeared; two laboratories making it - one in Kabul, Afganistan and one in Beirut, Lebanon - were raided and the Norwegian Customs seized a sample, the tetrahydrocannabinol content of which was found to be as high as 65 percent. In Sri Lanka itself a large consignment of cooking fat containing cannabis extract was detected; the tetrahydrocannabinol content of this fat was, however only 0.7 percent.

The fats solubility of tetrahydrocannabinol has another significance; it tends to be cumulative and takes some time to be eliminated from the body. It has been reported that it takes six days for 80 percent of labelled THC to be eliminated from the body. A phenomenon that has been noticed with people who take cannabis is that even long after they have discontinued cannabis they get a return of the acute anxiety state, the so-called "flash back phenomenon". It has been said that this could be due to the release into the blood of the THC from the fat deposits.

The drink "subji", made by boiling cannabis in milk, would appear to be used only in Sri Lanka; it is a potent drink and the hallucinogenic effects are said to last two to three days. Experiments were carried out to determine how much of the cannabinoids were extracted by the milk.

One portion of a sample of cannabis was extracted with petroleum ether. Another portion of the same sample was boiled in milk and filtered. The milk extract was subjected to the classical stas-obto process to separate the fats and proteins from the cannabinoids.

The cannabis residue from the milk extract was air-dried and extracted with petroleum ether. Three further portions of the cannabiz sample were each extracted with 12% ethanol, 95% ethanol and water.

The extracts were examined for the three cannabinoids - tetrahydrocannabinol cannabinol and cannabidiol - using thin layer and gas liquid chromatography.

For TLC the solvent system was Benzene: n-Hexane: Diethylamine (15 : 10 : 1) and the Detecting Agent was Fast blue salt B (15 mg/20 ml 0.1 NaOH) on silica gel plates.

GLC was performed on a Perkin-Elmer 900 Gas liquid chromatograph using 6 ft. glass columns (internal diameter 4 mm) packed with 3% OV-17 (phenyl-methyl-silicone) on 100 mesh chromosorb.

The column temperature was 240°C Isothermal and the Internal Standard was Methadone hydrochloride.

RESULTS:

Extract	Cannabidiol		Tetrahydro-cannabinol		Cannabinol	
	TLC	GLC(%)	THC	GLC(%)	THC	GLC(%)
a) Milk	++	0.58	++	0.64	++	0.88
b) Milk residue in petroleum ether	+	0.07	+	0.06	+	0.13
c) Petroleum ether	+++	1.08	+++	1.16	+++	1.52
d) 12% ethanol	Neg	-	Neg	-	Neg	-
e) Water	Neg	-	Neg	-	Neg	-
f) 95% ethanol	+++	-	+++	-	+++	-

The results indicated that:

1. 54% of the cannabidiol,
   55% of the tetrahydrocannabinol, and
   38% of the cannabinol.
   present in the cannabis have been extracted by the milk.

2. Since the petroleum ether extract of the residue did not contain significant amounts of the three cannabinoids, the loss or destruction of the remainder of the cannabinoids had occurred either during the boiling process or drying process, or both.

3. Since water did not extract the cannabinoids, the extraction of the cannabinoids by milk was probably due to the fact that milk is an emulsion containing about 3 - 4% fat. However, more experiments with hot and cold milk and hot and cold water should be conducted before a definite conclusion can be drawn.

4. Ethanol and petroleum ether are effective solvents for cannabinoids, while water and 12% aqueous ethanol are not.

FURTHER OBSERVATIONS ON THE CHRONIC TOXIC EFFECTS OF PALMYRAH (BORASSUS FLABELLIFER) FLOUR ON RATS.

Paper prepared by :

R.G. Panabokke *

S.N. Arseculeratne *

The young shoot of the palmyrah palm (Kottakilangu) is consumed by people of this country, certain regions of Africa and possibly Malaysia and South India. The composition of the flour was reported as follows[1]:

Composition of Palmyrah Flour

(gm/100 gm.)

Water	12.88
Protein	4.59
Ether extr. fat	0.52
Minerals	1.40
Carbohydrates	79.06
Calcium	.013
Phosphorus	0.119
Total calories	347

This material was found to be toxic to rats[2], which when fed with this material only, died within 7 days, with ataxia, convulsions and immobility of the hind limbs. The most marked lesions seen in acute intoxication, were in the liver and consisted of severe sinusoidal congestion and haemorrhages in the centrilobular zone, hydropic and

* Departments of Pathology and Microbiology, Faculty of Medicine, University of Sri Lanka, Peradeniya.

fatty degeneration, while the kidneys showed venous congestion and the brain in some rats, had congestion and oedema. The liver mitochondria of poisoned animals showed decreased succinic oxidase and succinic dehydrogenase activity; this effect was reproduced in vitro with normal mitochondria treated with aqueous extracts of the flour. The existence of at least two toxic factors was postulated, one a lethal factor and another acting on mitochondria.

Further experiments have now been done on rats on the effects of chronic feeding of this flour. Animals were allowed to recover from the acute toxic effects resulting from one or two days feeding of the flour alone and were then returned to their diet of pellets before being given further doses of the flour. Other rats were given a continuous diet of a mixture of pellets and the flour in a proportion of 3 : 1.

Clinical Observations:

A noteworthy feature was bleeding from the eyes and nostrils which occurred approximately a week after commencement of feeding. This feature has also been observed in rats given toxic doses of dimethylnitrosamine which is also a hepatotoxin. Prolonged feeding resulted in reduction of weight gain and falling of hair on the body. Withdrawal of the flour after the appearance of the acute toxic effects did not always prevent death, which occasionally occurred 2 - 3 days after the withdrawal suggesting that the flour may have a cumulative toxic effect.

Histology:

Liver: a) Vascular lesions: Rats surviving for over one week after feeding showed the following lesions in the centrilobular and portal veins and in the sinusoids of the centrilobular region :- Mononuclear cell infiltration in the walls of the sinusoids and the centrilobular zone near the central vein; oedema of the subendothelial connective tissue which also showed mononuclear cell infiltration; narrowing of the lumen of the vessel; endothelial cell proliferation and almost total occlusion of the vessel's lumen with hyaline collagen.

b) Parenchymatous lesions: Focal hydropic degeneration of the hepatic cells around the central vein; (This was also observed in mice fed with this flour), increased amounts of reticulin in the portal region; biliary hyper-plasia and well marked fibrosis was seen in the liver of one rat after one year of feeding.

Lungs: In acute intoxication, several rats showed severe vascular congestion, haemorrhages and oedema of the alveoli. Similar lesions have been described in rats after toxic doses of pyrollizidine alkaloids. It has also been suggested that the centrilobular venous congestion which is prominent in rats poisoned with these alkaloids, is a result of the pulmonary congestion. However, some of our rats did not show the pulmonary changes although hepatic venous congestion was prominent.

Brain: In the acute phase of the poisoning, the brain showed congestion and oedema while with prolonged feeding these regions showed mononuclear cell infiltration of the meninges, gliosis with appearances suggestive of nerve cell degeneration and 'satellitosis'.

Chemical Analysis:

Cyanide: Clinical disorders such as convulsions, spasms and unconsciousness and organic lesions in the nervous system such as demyelination and oligodendrogliosis have been reported to have been produced in experimental rats which were given toxic doses of cyanide. Kodagoda* has identified cyanide levels of 0.2 - 0.5 mg per 100 gm of the flour. The highest content was in the lower regions of the shoot which are also the bitterest. Further experiments will be necessary to determine the relation of these levels to the toxic effects on the nervous system.

Alkaloids: In view of the similarity of some of the clinical effects seen in our intoxicated rats (haemorrhages from the mucosal surfaces and veno-occlusive reactions to those of Senecios) the flour was examined for alkaloids, especially of the pyrollizidine type** Five alkaloid spots were detected on TLC, with one compound present in high concentrations; tests for pyrollizidine alkaloids were negative with this compound. Further studies with the other four compounds

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* Dr. N. Kodagoda - Department of Forensic Medicine, University of Sri Lanka, Colombo.

** Dr. Leslie Gunatilaka - De-artment of Chemistry, Faculty of Science, University of Sri Lanka, Peradeniya.

are in progress. Pyrollizidine alkaloids are reported to be absent in monocotyledons.

Organic N-nitroso Compounds:

Earlier tests for these compounds in the flour by the method of Preussmann[3] were negative. However, in view of the close similarity of some of the lesions observed in our rats to those resulting from these compounds, a re-examination of the flour for such compounds is being done since we are now informed that some of these compounds are not detected by the TLC method which we used in our earlier report.

J.B.Greig* informs us that "using the extract and giving an amount equivalent to that an animal would have consumed in the 7 - 10 day period as 2 oral doses in the morning and afternoon, we see symptoms and frequently death within 36 - 72 hours. These symptoms are 'fitting' with salivation and convulsions similar but more violent than those seen in the feeding experiments. Frequently these terminate in death with the rapid onset of rigor. Only in one case have we seen tonic convulsions following on the clonic phase.

As yet I have no ideas as to the cause of these signs nor the nature of the toxic agent; however, the nature of the extraction process eliminates certain categories of material from consideration, namely proteins, glycosides, lipids and many organic amines."

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* Dr. J.B. Greig - MRC Toxicology Unit, Carshalton, Surrey, England.

In view of the hepatic lesions (increase of reticulin, cirrhosis and venoocclusive reactions which could lead to parenchymatous damage) observed in our experimental rats on prolonged feeding, further investigations of the hepatotoxic factors involved and their relation to human disease in this country (where consumption of this flour especially in the Northern province is common) are being pursued. This is particularly relevant to the clinical impression that cirrhosis of the liver is significantly commoner in this province than in the rest of the Island.

* * * * * * * * *

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ADDENDUM:

Further research in our department is directed towards:

a) the isolation and identification of the hepatotoxins

b) the study of the effects of prolonged feeding of "Kottakilangu" to rats with protein deficiency, malnutrition and fatty change in the liver.

c) the incidence of Cirrhosis of the liver in the Northern Province in relation to consumption of "Kottakilangu"

While local facilities in regard to both, academic and technical expertise are available, shortcomings in resources for the pursuance of these projects are mainly in library reference material especially journals and funds for the purchase of chemicals from abroad.

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BIOGENETIC PRECURSORS OF TERPENOID INDOLE ALKALOIDS

Paper Prepared by :

K.T.D. de Silva*

Much progress has been made over the last decade in understanding the biogenetic pathway of terpenoid indole alkaloids[1-3]. The following three approaches have been used in recent years to discover the biogenetic intermediates.

(a) Decide on chemical, structural and biosynthetic grounds, the compounds that can be the probable intermediates, synthesise them and test them as precursors of the alkaloids;

(b) Determine the changes in oxidation level which occur at various carbon atoms as the compounds are transformed through the many stages leading to the alkaloids. This involves extensive use of tritium labelling[4];

(c) Isolate the probable intermediates and test them as precursors.

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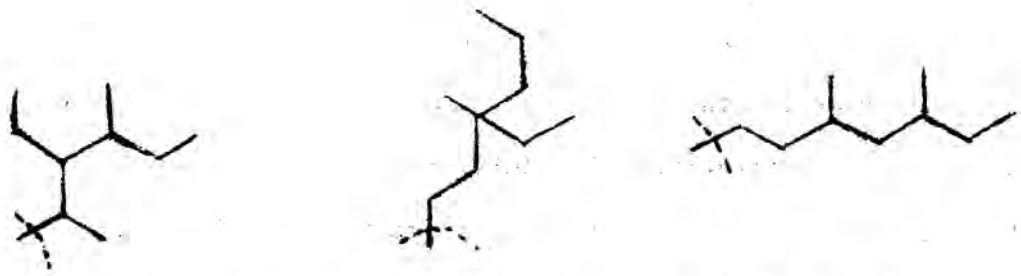
The use of these methods, aided by the ready availability of radio tracer compounds and the new tracer counting techniques, has led to a direct examination of the pathways of biosynthesis, with the result a satisfactory biogenetic theory has now emerged[3,5,6]. Although a number of important questions still remain to be answered, the theoretical outline is clear and is unlikely to undergo rigorous modification.

Our research is directed towards finding answers to some of these questions. In this regard we have approached the problems using the methods (a) and (c). A short account of the current biogenetic theory and the earlier work of the author which helped him to identify the particular areas of research that needed clarification are given below.

The vast majority of indole alkaloids of diverse structure can be considered to be formally derived from a combination of a tryptamine unit and a fragrament containing nine or ten carbon atoms. However, a close examintion of this "C_9 - C_{10}" unit of apparently variable structure reveals three basic skeletal types[7]. In alkaloids containing a C_9 unit, the dotted line indicates the carbon atom that is invariably lost.



Type A (Corynanthe) Type B (Aspidosperma) Type C (Iboga)

Representative examples of the three types with C_9 and C_{10} units are given in Fig. 1 .

All three types of "C_9 -C_{10}" units have been shown to be of monoterpenoid origin[5,6]. The monoterpenoid moeity has been proved to arise from mevalonate[3,5] (1). The pathway from mevalonate (1) to the secoiridoid precursor, secologanin (7), is summarised in Scheme I.[3,5]. Although most of the intermediates in this scheme have been experimentally tested, an important intermediate between loganin (5) and secologanin (7) is yet to be discovered.

The first nitrogenous intermediate in the biogenesis of indole alkaloids can be considered to be produced by the condensation of secologanin (7) with tryptamine (9)[3,8,9]. Of the two C_3 epimers of this proposed biointermediate, vincoside (10) has been shown to be the precursor of alkaloids in Vinca[10] and Cinchona[11] alkaloids. The proposed biogenetic pathway of the indole alkaloids including certain mechanistic speculations is depicted in Scheme II.[3,6,12].

Experiments relating to the precursor role of loganin (5) secologanin (7), tryptophan (26) tryptamine (12) and vincoside (10) have been conducted mainly using Vinca rosea and Cinchona ledgeriana plant. Consideration of this biogenetic theory in the light of the cumulative knowledge of the glycosides of Rhazya species,[13,14,15] raises the important question of its general applicability. Vincoside (10), the key intermediate in the proposed biogenetic sequence has not been found in Rhazya, a species rich in indole alkaloids[16]. On the contrary, large amounts of Strictosidine (11)[8,13,15] and Secologanin (7) have been found in Rhazya species[13,17]. Controlled micro-isolation work involving different methods, led only to the isolation of strictosidine (11) in both Rhazya and Vinca plants[18]. Dilution analysis has also shown the absence of vincoside (10) in Rhazya species[17]. Hence the validity of vincoside (10) being an isolable biointermediate has thus become doubtful.

The other intriguing question is why Vinca rosea utilises Vincoside (10) for the biosynthesis of Conynanthe alkaloids[3], (through geissoschizine) which involves an inversion at the C_3 centre with retention of H, when Strictosidine (11) with the correct steriochemistry is available. This discrepancy is difficult to rationalise in terms of a universal specific precursor.

The precursor role of tryptophan (26) in the genesis of the tryptamine unit of indole alkaoids has been established by incorporation experiments[9,10,19,20]. However the direct incorporation

of tryptamine (9) into indole alkaloids has led to the current hypothesis[10] that tryptophan (28) is decarboxylated to tryptamine (9) prior to incorporation. But the isolation of the tryptophan (28) derived intermediate 5 α - carboxystrictosidine (29) from Rhazya species[16,21] raises the question of it's possible biogenetic significance. The very high incorporation of the primary metabolite L. tryptophan (28) into 5 α- Carboxystrictosidine (29) point to a direct biosynthetic route[17]. Thus a plausible alternative route can be the direct incorporation of tryptophan (28) and decarboxylation after condensation.

It can be that the carboxycompound serves as an alternative precursor. Evidence in this favour is available from separate tryptophan (28) and tryptomine (9) feeding experiments. Administration of labelled tryptophan (28) and tryptamine (9) to Vinca rosea under identical conditions has resulted in higher incorporations of tryptophan (28)[20]. It is also possible, that with some alkaloids the carboxy group is required for initial transformations and is lost at a later stage, as in ergot alkaloids[22] where tryptamine (9) is not a precursor.

van Temelen[23] has proposed that a dihydro- β- carboline (33) can be an in-vivo precursor of the Sarpagine-Ajmaline type (31) alkaloids. This (Scheme III) intermediate (33) could be formed by specific enzymatic dehydrogenation of a tetrahydro- β- carboline unit (34) where the chemically preferred oxidation to (35) must be

avoided. Van Tamelen proposed, the oxidative decarboxylation of the corresponding amino acid (32) as a less exceptional and a reasonable means of achieving this biochemical sequence. The key intermediate (33) in this hypothesis can easily be derived from 5 α- carboxy-strictosidine (29). It is possible that the low incorporations of tryptamine (9) and vincoside (10) into perivine (36) which is a sarpagine (31) type alkaloid[10], compared to that of the incorporation into alkaloids of other classes points to an efficient alternative biosynthetic route.

The hypothesis (Scheme IV) advanced by Leete[19] for the biosynthesis of quinine (37) envisages a tetra-hydro β- Carboline amine acid (32) which could easily be formed from 5 α- Carboxystrictosidine (29). In modifying this hypothesis van Tamelen[23] has proposed a biogenetically modelled oxidative decarboxylation mechanism (Scheme III) by which the amino acid intermediate (39) could give rise to the presume quinuiclidine aldehyde (40) which was previously considered to arise by the oxidation of cinchonamine (38). It is thus likely that 5 α - Carboxystrictosidine (29) could be first nitrogenous monoterpenoid intermediate in the biosynthesis of some indole alkaloids.

The C_3 epimer, 5 α- Carboxyvincoside (30) has not been isolated from Rhazya species[3]. The failure to isolate both vincoside (10) and 5 α- Carboxyvincoside (30) from Rhazya species show that the in-vevo synthesis of the precursor s is under enzymatic control As one of the essential requirements for a true precursor is it's

presence in the living system, vincoside (10) or 5 α- Carboxyvincoside (30) cannot be considered to be an authentic precursor of indole alkaloids in Rhazya species. On the other hand, the natural occurrence of Strictosidine (11) and 5 α- Carboxystrictosidine (29) in both Rhazya and Vinca plants is a strong indication that they can be the precursors. This point has to be investigated by carrying out carefully controlled feeding experiments, as the tracer work on the current biogenetic scheme has so far been conducted only by one group of workers and only in Vinca plants.

The author's group is engaged in trying to sort out some of the discrepancies stated earlier. In the first instance a number of indole alkaoids producing plants were screened for the occurrence of the first nitrogenous monoterpenoid precursor[24]. Rauwolfia serpentina, Cinchona ledgeriana strychnos nux-vomica. Mytragyna sp. and Vinca species were tested for the presence of vincoside (10) and 5 α- carboxyvincoside (30), Methanolic extracts were run with authentic samples and tested by specific colour tests. Both vincoside (10) and 5 α- Carboxyvincoside (30) can be easily tested as the lactams (43) and (44) respectively having characteristic colour reactions. Strictosidine (11) was tested as vallesiachotamine (45). Macro-isolation techniques showed the presence of strictosidine (11) in Rauwolfia, Vinca, and Strychnos plants and 5α- Carboxystrictosidine (29) in all plants. There were no detectable amounts of vincoside (10) or 5 α- Carboxyvincoside (30)

in these plants. 5α-Carboxystrictosidine (29) and strictosidine (11) wereiisolated from Rauwolfia and Strychnos plants; and were characterised as the methoxycarbonylpenta-acetates (46) and (47). The isolation of these compounds from the other plants is in progress.

Confirmation of the absence of $C_3\beta$ antipodal series of compounds in these plants has to await dilution analysis experiments. The role of strictosidine (29) in the biosynthesis of indole alkaloids in these plants has to be tested by tracer experiments. This progfamme of research cannot be presently undertaken due to the non-availability of scintillation counter in Sri Lanka. There is news that the Radio Isotope Centre of the Colombo Campus is to get a Scintillation counter early next year.

Some work is in progress to isolate the missing intermediates in the proposed biogenetic scheme. In order to search for the intermediate (6) (Scheme I) between loganin (5) and secologanin (7), a number of plants were screened to find a plant which contained significant amounts of loganin (5) and secologanin (7). Hydrangia plant was selected for the large scale isolation of secologanin (7). Concentrates of secologanin (7) were obtained by counter-current extraction using a solvent system having a volatile phase in which secologanin (7) had a partition coefficient of one. Final purification was by preparative tlc and the compound was shown to be identical with an authentic sample. The plant extract is

now being screened for the hydroxyloganin (6) type of compound. A search is also being made to find a plant which has secologanic acid (48), as it can be the precursor of the alkaloids having the C_9 unit.

Partial synthesis of strictosidine (11) and 5 α- Carboxystrictosidine (29) has been undertaken with a view to convert them to geissochizine (14) and carboxygeissochizine (49) respectively.

An important contribution relevant to our work has come from the biogenetically modelled synthesis of Ajmaline (50)[25]. In this synthesis (Scheme V) the tetrahydro - β - Carboline carboxylic acid (51) was converted to deoxyajmalal (52) by a biomimetic cyclisation involving the established oxidative decarboxylation reaction. This laboratory analogy demonstrates the potential importance of 5 α- carboxystrictosidine (29) derivatives in the biosynthesis of ajmaline (50) type alkaloids.

It is hoped to carry out this type of transformation using carboxy alkaloids which can be synthesised from 5 α - carboxystrictosidine (29).

Another missing link is the biogenetic sequence (Scheme II) is at the stage of the conversion of vincoside (10) to geissochizine (14). The compound (13) has been postulated to be possible intermediate. A search can be made for this compound by hydrolising strictosidine to it's aglycone (16). In-corporation

experiments using such a compound lead to a definite answer. In this connection hydrolysis of the glucose moeity in both strictosidine (11) and 5 α - Carboxystrictosidine (29) is contemplated. We are presently awaiting the arrival of β glucosidase to affect this hydrolysis.

The final stage is one of feeding radio-active precursors. This will assist in establishing the proper role of strictosidine (11) and 5 α - Carboxystrictosidine (29) is the biogenesis of indole alkaloids.

Limitations :

(1) As most of the precursors occur in such minute amounts, micronalytical techniques are used in their isolation and purification. There is a very slow process, as tlc is the only monitoring device available. We do not have UV and IR spectrophotometers which can also be used for monitoring purposes. The work is further slowed by the time factor involved in getting Mass Spectral and NMR data from overseas.

(2) Macro isolation work of compound which are unstable has to be done using counter current procedure. Presently the transfers are done manually. Hence a counter current instrument will be an asset.

(3) Radio active compounds are needed for tracer work. Due to foreign exchange difficulties there can be difficulty in getting these compounds.

(4) The biggest draw back is the non-availability of journals, to keep abreast with current research work. It will be helpful if at least one institution in Sri Lanka can get the requisite journals.

ACKNOWLEDGEMENTS :

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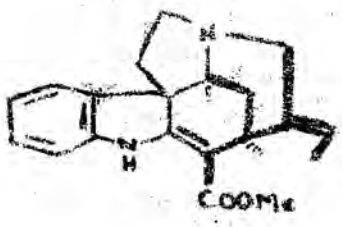
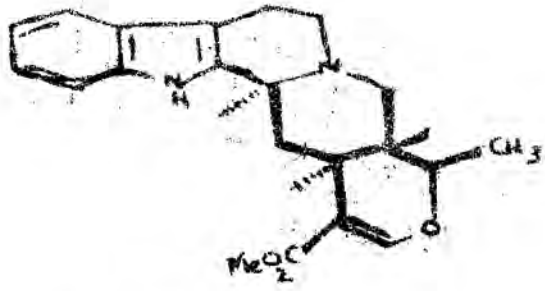
TYPE A



Akuammicine



Ajmalicine

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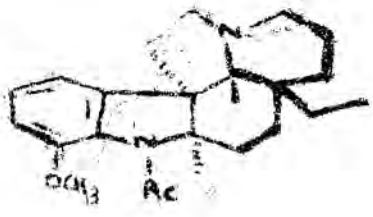
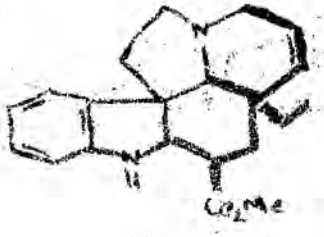
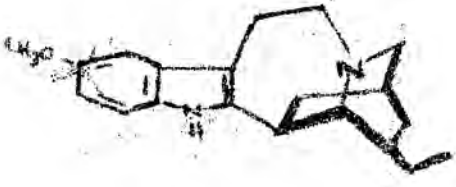


Aspidospermine

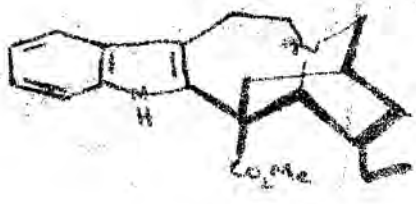


Tabersonine

TYPE C

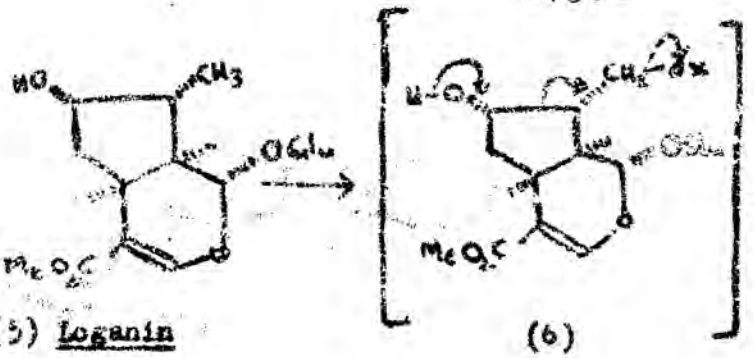


Ibogaine

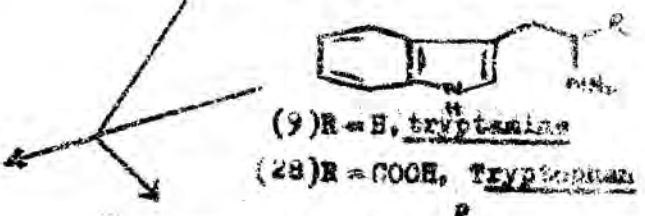


Catharanthine

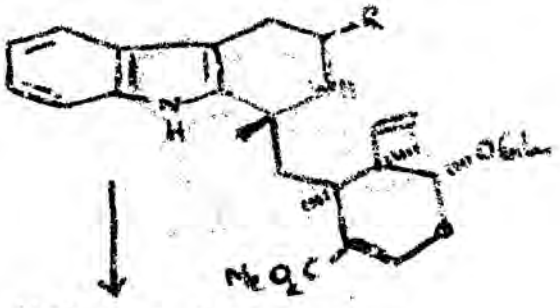
Fig 1



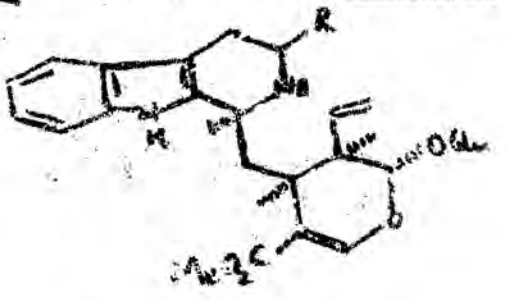
(5) Loganin (6) (7) Secologanin



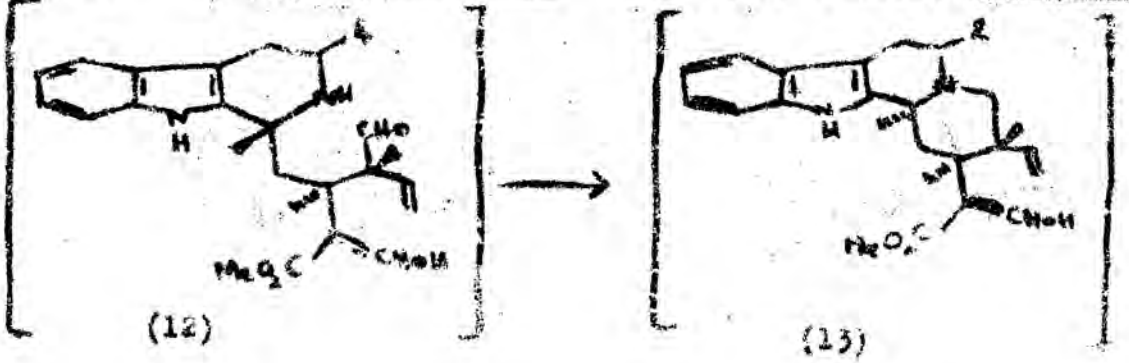
(9) R = H, tryptamine
(28) R = COOH, Tryptophan



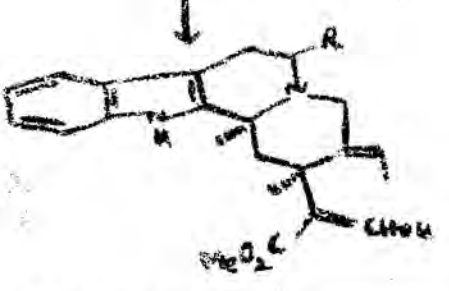
(10) R = H, Vincoside
(30) R = COOH, Carboxyvincoside



(11) R = H, Strictosidine
(29) R = COOH, Carboxystrictosidine



(12) (13)



(14) R = H, Geissoschizine
(49) R = COOH, Carboxygeissoschizine

INDOLE ALKALOIDS

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THE CHEMICAL CONSTITUENTS OF SOME MEDICINALLY IMPORTANT PLANT SPECIES OF THE FAMILY FLACOURTIACEAE

Paper Prepared by :

S.P. Gunasekera*

The family flacourtiaceae consists of about 84 genera and about 850 species. In Ceylon there are about 10 genera and 16 species of which 8 genera and 9 species are endemic. Though very little systematic work has been done on the family, as a whole it is known from early days for its characteristic oils obtained from the seeds.

Hegnauer has briefly discussed the seven fatty acids isolated from the family. The striking feature of these optically active acids is that all contain a terminal cyclopentene ring system and a linear side chain containing the acid group. They differ from each other in the length of the side chain and its oxidation state but structurally some what resembles pharmacologically active prostaglandins.

In addition to these low melting crystalline fatty acids oils have been isolated from the seeds.

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Chalmoogra oil has been isolated from Hydnocarpus venenata Gaertn, H. wightianus and H. anthelmintica. The oil obtained from Taraknogenus kurzii had been used to cure skin diseases, head aches and specifically for leprosy and tuberculosis patients as an ointment.

Hallier and other classified these plants species under the family Guttiferae and rfurther they anatomically resembles those of family Celastraceae. To investigate the pharmacological active compounds and chemotaxonomical relations with the above two families, three plant species Trichadenia zeylanica Thw., Hydnocarpus octandra Thw., and H. venenata Gaertn have been studied.

The bark and timber were separated dried, powdered in a mill and extracted with hot light petroleum, hot benzene and hot methanol. The extracts were separated into pure crystalline compounds by repeated column chromatography over silica gel. In some cases the crude fractions collected from the columns were further purified using thin layer chromatography.

The chart below gives the compounds isolated from the three plant species :-

Compounds Isolated	T. zey.	H. oct.	H. vene.
1. Friedelan-3-one	—	B,T,P	-
2. Friedelan-3α-ol	-	B	-
3. Friedelan-3β-ol	-	B	-
4. Friedelan-3α-olacetate	B	B	-
5. Friedelan-3α-ol-29-al	-	B	-
6. Friedelan-3 -on-29-al	-	B	-
7. Friedelan-3α-ol-29-oic acid	-	B	-
8. Friedelan-3-on-29-oic acid	-	B	-
9. Friedelan-3α,29-diol	-	B	-
10. Friedelan-3-on-29-ol	-	B	-
11. Friedelan-3β-ol-26-oic acid	-	B	-
12. Friedelan-3α-ol-26-oic acid	B	B	-
13. Friedelan-3β-acetoxy-26-oic acid	B.T	-	-
14. Friedelan-3α-acetoxy-26-oic acid	B	-	-
15. Friedelan-3-on-26-oic acid	B	-	-
16. Friedelan-3β-acetoxy-26-al	B	-1	-
17. Friedelan-3β-ol-26-al	B	-	-
18. Acetyl ursolic acid	-	-	B
19. Ursolic acid	-	B	B
20. Acetylbetulinic acid	-	-	B
21. Betulinic acid	-	-	B
22. Betulonic acid	-	-	B
23. β - sitosterol	B,T	B,T,P	B,T
24. Chalmoogric acid and oil	-	-	S
25. Mangostin	-	B	B

B = Bark, T = Timber, P = Pericarp and S = Seeds

It is interesting to note that 13 out of 17 compounds isolated are new friedelane derivatives. These compounds can be grouped as C-26 and C-29 oxygenated friedelin derivatives. The structure of all these compounds were characterised using chemical and physical data and the structures were confirmed by partial synthesis and by chemical interconversions. All known compounds were confirmed by comparison with authentic samples.

Isolation of prenylated xanthone mangostin which is found only in the family Guttiferae and isolation of several friedelan aldehydes shows some chemotaxonomical relations to the families Guttiferae and Celastraceae where similar compounds have been isolated. The pharmacological activity of these isolated compounds are under investigation.

The lack of recent books and journals and also the great delay in getting NMR and Mass Spectral data from abroad limits further rapid study of more species of this interesting family.

A CASE FOR AN ASIAN INTERNATIONAL CENTRE OF NATURAL PRODUCT RESEARCH

Paper Prepared by :

R.O.B. Wijesekera*

In stating the reasons for the establishment of an International Centre for Theoretical Physics at Trieste, Professor Abdus Salam[1], related this story :-

> "Five hundred years ago - around 1470 A.D. - Saif-ud-din-Salman, a young astronomer from Kandhar, working then at the celebrated observatory of Ulugh Beg at Samarkand, wrote an anquished letter to his father. In eloquent words Salman recounted the dilemma, the heartbreaks, of an advanced research career in a poor, developing country :
>
> 'Admonish me not, my beloved father, for forsaking you thus in your old age and sojourning here at Samarkand. It's not that I covet the musk-melons and the grapes and the pomengranates of Samarkand; it's not the shade of the orchards on the banks of Zar-Afshan that keeps me here. I love my native

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Kandhar and its tree-lined avenues even more and I pine to return.

'Bur forgive me, my exalted father, for my passion for knowledge. In Kandhar, there are no scholars, no libraries, no quadrants, no astrolobes. My star-gazing excites nothing but ridicule and scorn. My countrymen care more for the glitter of the sword than for the quill of the scholar.

'In my own town I am a sad, pathetic misfit'.

Professor Salam one of the world's leading theoretical physicists who became the first Director of this centre, a joint venture of UNESCO and IAEA further observed :-

"For Samarkand of 1470 read Berkeley of Cambridge; for quadrants read high-energy accelerators; for Kandhar read Delhi or Lahore and we have the situation of advanced scientific research and its dilemmas in the developing world of today as seen by those who feel in themselves that they could, given the opportunity, make a fundamental contribution to knowledge".

The main theme of this story is that in the ethos that surrounds scientific endeavour in Asia, and there particularly the smaller Asian Nations - the development of indigenous centres of high quality research by indigenous means is not possible. Twenty years ago this was an obvious surmise. Today it is an established experimental fact. The flight of qualified scientific talent from the smaller nations of the third world is the most evident and grave symptom. The Brain Drain as far as its "external" aspect is concerned is now a veritable flood. The "internal" aspect seems to tend to the procreation of a breed of pseudo-scientific pundits who fit their deeds to the demands of expediency in order to facilitate their climb to positions of power, authority and privilege. In the light of these phenomena the comparatively huge sums of money invested by a small nation like Sri Lanka on Education seem like the meaningless discarding of the wealth of an age. It is so far from being the investment it ought to be.

Kenneth Mellanby[2] has stated :

> "In considering research I am therefore uncompromising in my belief in the dependence of scientific progress on an elite of scientists. I believe that success and originality depend almost entirely on the efforts of a few gifted

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[2] K. Mellanby : (1974), The disorganisation of Scientific Research in Minerva, 12, 67-82.

> individuals. On the other hand, development, once the fundamental principles are understood, can often be done best by teams of run-of-the-mill though technically competent individuals under skilled direction".

Evidently the "few" are the most important in a nation's future development. The use that is made of these 'few' is the vital factor. The need to keep the new within the bounds of the country of origin, is more important to the Nation's survival than more ostensible measures towards social development. Tragically this fact is scarcely even comprehended.

Science Development in India :

In considering Asia as a region one should deviate somewhat from previous practice. In scientific matters India must now be considered as a region unto itself; and the smaller nations must form the second component of what is essentially a two-unit system. Indian science can now be considered to have reached the self-generating stage. There are several reasons for this. Firstly, India had at the time of independence, and for a long time prior to this, a scientific tradition, even in the modern sense. She had produced her own

"Eponyms"[3] of Science, like C.V. Raman, Ramanujan, Krishnan and Bhaba. Equally significant was the fact that many great European scientists actively worked during the peak periods of their scientific lives, in India and made their contribution to science on Indian soil. In doing so they built up traditions of scientific endeavour which their Indian "proteges" carried on after them. Sir John Simonsen working in Madras was one such and the present high standard of Indian organic chemistry may be partly attributable to men like him. By the time that India achieved her independence she had several developed and recognised schools of research in the Organic Chemistry of Natural Products. She had her own leaders in this area of research like Seshadri in Delhi, Chatterjee and Chakravarti in Calcutta, Govindachari in Madras, K. Venkataraman in Poona and D.K. Bannajee in Bangalore. These

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[3]The term is explained by Edward G. Boring thus : in SCIENCE, 145, (1964), 681.

"The conventional view of the history of science is that science advances gradually by the hard work of many investigators, but that its course involves sudden spurts where someone who is eventually to become known as a "Great Man" has a revolutionary insight and makes a crucial discovery which changes the speed or direction of progress in scientific endeavour. If the change is radical enough, the "Great Man" after he has been recognised as great on account of his contribution, has his name put down upon the discovery or the theory or the resultant school of thinking and thus becomes an Eponym".

leaders gave rise to another generation of leaders like Sukh Dev in Poona who were then of doubtless international calibre. In the field of physics too this phenomenon was evident in the performances of for example Sarabhai and Bhaba. The necessary paraphernalia of modern science, equipment, opportunities of intercourse with international science, freedom for creative scientific endeavour, came in the wake of international recognition and particularly in the case of India from Internatinnal agencies partly on account of the ponderous overtones a giant political entity could command. Another important factor is the development of Indian science was that governmental patronage at the highest possible level was available. The Science Policy Resolution tabled in the Indian Parliament by Nehru in 1947 was a classical document which spells out almost all that is necessary for the development of science from a national standpoint. The leadership of men like S.S. Bhatnagar Hussain Zaheer and Homi Bhabha helped in the translation of ideals into practice. Thus the overall picture of Indian Science in the 1950's was one of correct prospectives, positive trends and an uncompromisingly stated commitment on the part of government.

The Smaller Nations :

The smaller nations had nothing like these advantages. Their own resources and pre-independence scientific build-up were inadequate. They boasted no "Eponyms". Their political commitment to science was less than zero. Indeed the climate was in its entirety, inimical to the germination of science. Their only asset was an "elite" of foreign trained scientists who had often the right ideas but not the ear or favour of the political leadership. Also public faith in science was non est.

In their endeavour, if indeed there was such - to afford some assistance to the development of science in these countries, UN and other international agencies like UNESCO were guilty of the fundamental error of regarding the Asian region as a single entity. Accordingly whatever help and assistance was forthcoming was swallowed up in the canyon-esque requirements of the Indian subcontinent. This was inevitably so and is not stated in any disparaging way towards India. Even a country like Pakistan suffered in comparison. It was like feeding rabbits together with a rhinocerous. The UNESCO Regional Office for Science was stationed in Delhi and of the many seminars and conferences organised a paltry few appeared outside the Indian continent. The support given to working groups, was even more illuminating. In 1964 one noted that substantial gifts of equipment for research in chemistry had been made available from Colombo-Plan, and UN agencies to the several research centre in the State of Madras alone. Yet there was at the time not even one single

infra-red spectrophotometer - a comparatively cheap yet vital instrument - available in Sri Lanka in either the University or in any of the several Research Institutes, despite arduous efforts to obtain one through these same agencies. It is true the mechanism of obtaining these was more positively directed in India, but the fault lay also in the primary concept of grouping together small countries with one large one in the dispensing of aid towards obtaining these. In the present context therefore it would be most opportune to bring in a new concept of regarding the Ssmaller Asian nations as a single unit and making a concerted effort to develop science in some relevant form, within each of them. There is then a strong case for the formation in all or some of these nations International Centres for Research specialised fields relevant to them, funded and maintained with help from outside agencies. A somewhat distant parallel would be the Ford Foundation's Rice Research Institute in the Phillipines . But this is not quite the analogous situation. One is stressing here the development of a discipline of science in each country that is of some relevance to it rather than an institute directed towards the solving of a common major problem or the accumulation of a fund of expertise that could be dispensed within the region. What is proposed is the organisation of a Centre of Research, more like the International Centre for Theoretical Physics at Trieste, in each of the countries of the region where scientists of the smaller Asian nations could work together and develop a "scientific elite".

This "scientific elite" would be then a "regional elite" rather than a "national elite" but each small nation unable by circumstances to generate its own such elite would in compensation have a share of the common elite. In this manner the present "Brain Drain" would be channelled into a reservoir for common utilisation. The educational investments of each constituent nation would be made in this manner to bring in some returns and the products of these small countries need not be forced to seek positions in developed countries in order to get a measure of scientific fulfilment. The process of keeping in constant touch with one's own country can be worked out in some manner as at the Trieste Centre.

A Centre for Natural Products Research in Sri Lanka :

Sri Lanka being an island possesses a unique and varied flora. This would form an attractive and compelling basis for all types of research scientists interested in natural products. Yet the development of research into the Chemistry of Natural Products in Sri Lanka has been rendered etiolate by the intractable nature of the obstacles facing the development of science in general in a small developing nation. There has been no deep history of Natural Products Research in Sri Lanka. The beginnings were in the form of certain studies on plants used in ayurvedic medicine made by Chandrasena who was Professor of Chemistry in the University College in Colombo prior

to World War II. Chandrasena's pioneering efforts were cut short by his untimely death in 1940. Research work in chemistry did not form more than a part-time occupation in the University of Ceylon which came into existence in 1941 mainly due to the overemphasis on teaching and the shortage of qualified personnel. However the University of Ceylon's Department of Chemistry under Professor A. Kandiah was able to develop a flourishing honours school in Chemistry, and the products from this school formed the nucleus of chemists serving the country in all branches of the science. From them there also developed several organic chemists who received post-graduate training in the reputed schools of Natural Products Research mainly in Britain. The first attempt at a systematic study of the Chemistry of Medicinal Plants was made at Medical Research Institute from 1954 onwards but due to the constraints inflicted by government regulations and the inability to comprehend the requirements of such a programme in a primarily service oriented institution the progress of research was slow.

In 1964 UNESCO realising the significance of research in medicinal plants and in part as a gesture towards the smaller countries of the South Asian region, staged its 2nd International Symposium on Medicinal Plants" at Kandy. (The first symposium was held in Peshawar four years earlier). At this symposium the work on the Medical Research Institute's group was reviewed. This work which was in its early stages was the only work in chemistry from Sri

Lanka, and was even rendered possible by the help and generosity of distinguished scientists from outside like Lederer and Polonsky in France and Sandberg in Sweden.

At this UNESCO Symposium in 1954 the idea of an International Centre was mooted when the Minister of Health Dr. Badi-ud-in-Mahmud stated :-

> "The financial resources and the scientific personnel needed for this work will not be within the capacity of any single developing country. I would therefore urge for your consideration the setting up of an International Institute to undertake research on medicinal plants with the support of all the countries that have met here today. We would welcome such an Institute to be located here ...".

Sometime after this, the government created the Bandaranaike Memorial Ayurvedic Research Institute (BMARI) but this Institute has confined its interest so far to clinical trials on Ayurvedic drug preparations. Over the last 5-8 years two other research groups have substantially developed. They are the Natural Products group at the Ceylon Institute of Scientific

and Industrial Research (CISIR), andthe Chemistry Department of the University of Sri Lanka at Peradeniya. The CISIR group has directed its efforts mainly in the direction of the chemistry of spices and essential oils, and studies leading to biosynthesis of volatiles and chemotaxonomic considerations due to varietal and geographical variations. Some work on alkaloids have also been conducted on medicinal plants. The Peradeniya group have conducted structural studies on the extractives of heartwoods and barks, and have isolated and assigned structures to several new compounds. Both groups have drawn heavily from the generosity of foreign scientists who have assisted by conducting spectral analyses and even by training of personnel. They have produced some useful work without even some of the basic instrumentation available to Natural Products Chemists in other laboratories in the world. In the Colombo and Vidyodaya Campuses of the University of Sri Lanka too some research on medicinal plants and alkaloids has commenced recently.

Altogether in the island there are now at least four to five groups interested in a wide variety of studies on Natural Products. A most significant thing too is that the island has also a unique flora where almost a third of it is endemic. Studies on Natural Products and the development of a strong line of research into the chemical constituents of the many interesting plants available cannot but bring considerable benefits to the

country and the region. Novel drugs, industrially important chemicals such as perfumery chemicals, natural insect repellants, novel steroids are some of the likely practical benefits of such an effort. The development of the discipline and of a scientific elite will be the long-term achievement that will have lasting value. Several distinguished Natural Products Chemists who have visited the island have stressed the importance of a programme of Natural Products Research in the island. These include such men as R.D. Haworth F.R.S., Finn Sandberg, Edgar Lederer, A.J. Birch F.R.S., Sir Ewart Jones F.R.S., A.W. Johnson F.R.S., T.R. Seshadri F.R.S., Sukh Dev, S. Shibata, Anders Kjaer, Cyril Ponnamperuma and many others. The development of such a programme in the context of the requirements of modern organic chemistry involves a big outlay in terms of equipment and instrumentation. There is not one Mass Spectrometer or N.M.R. Spectrophotometer, routine instruments in today's chemistry, in a single centre in Sri Lanka. Heroic efforts to obtain these have been made but these have only ended in frustration. There is also the need for the creation of opportunities to link up with scientific progress elsewhere. For example in the developed countries there are such things as "Summer Courses", Refresher Courses" "Seminars on Specialised Topics", available to and designed specially for the active research workers. These opportunities hasten the progress of research work to a remarkable degree. Modern library and documentation facilities, programmed study courses on tapes are also available. These are some of the things that are completely out of reach of

the scientists in a country like Sri Lanka. There is also the lack of opportunity to interact with science and scientists in the outside world. Attendance at conferences for scientists is an exercise which appears to present intractable difficulties. Even where funds are available, bureaucratic stringencies and lack of sympathy often militate against scientists moving out of the country for Seminars, Symposia and such International Scientific Excercises. Policy makers in Sri Lanka have been slow to acknowledge the presence in the country of a number of trained scientists and the promise of more if only those produced by the Universities could be persuaded to stay. This would only be possible if these scientists could perform fruitfully within the country and if they can be assured the ingredients of intellectual stimulation and creative opportunity. Surely there is the case here for an International Centre for Natural Products Research located in Sri Lanka, complete with all equipment, literature and documentation services and the opportunity to liase and actively associate in the work endeavour with the international scientific community. The concept of such an International Centre has been developed by Professor Carl Djerassi, Chairman of the National Academy of Sciences of the United States in the address given to the Seventeenth Pugwash Conference on Science and World Affairs, held in Ronneby, Sweden, in 1967*. Professor Djerassi discusses the creation of a centre of excellence in a country where no such

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*A High Priority? Research Centres in Developing Nations (1968). Bulletin of Atomic Scientists pp. 24-27 N.B. I am indebted to Professor Djerasi for a copy of his article.

centres exist and where the requisite scientific manpower is not yet available. Professor Djerassi proposes a model based on his own experiences in the Latin American countries which embodies the following features.

1. An international cadre of post-doctoral research Fellows.

2. Overall scientific direction by a group of part time Directors from major Universities in different developed countries.

3. Selection of research areas with a possible ultimate economic pay-off, and a maximum multiplication factor.

This concept has been successfully made a practical reality in the establishment of the International Centre for Insect Physiology and Ecology (ICIPE) at Nairobi. It is apparent that the development of such centres is the only mechanism for the development of good research within a developing region that cannot afford its own funds and where the social acceptance of scientific research as a means of development is explicity acknowledged and implicity rejected by policy makers. This is a characteristic of most countries of the Asian region (except perhaps India) and certainly of Sri Lanka. There are many striking

points in which the case for such a centre in Sri Lanka differs from the Latin-American examples quoted by Professor Djerassi. Some of these differences are on the positive side. For example we have the advantage of the presence in Sri Lanka of a core of Ph.D. level trained organic chemists who have experience of Natural Product Research abroad and who have contrived to do such work in this country too, even under appalling circumstances. The presence of these chemists is a distinct asset. In addition there is already available a body of graduate chemists of high calibre coming out of our University each year. At the present time this young group of people invariably find positions abroad with alarming ease. They would undoubtedly stay in this country if they could find employment that is intellectually satisfying and recognised by the international scientific community. In any event a small country like ours could ill afford to lose them, who represent the most valuable products of our expensive free-education system. So it must be noted that the question of basically trained manpower is nothing like as discouraging as it was in Mexico at the period described by Professor Djerassi. On the other hand our problem is to keep the ones being produced here at home. The important requirement here is that of Research Leaders at all levels and in particular those that can be described as "EPONYMS". They would at first have to be imported and it is here that the creation of a Centre such as envisaged, would serve a great purpose. The availability of part-time Directors of [illegible] -

Research - well known scientists from developed countries, such as described by Professor Djerassi would be in the nature of a great boon to Sri Lanka, as it will help to enable us to put our own material - the graduate scientists - to maximum use. It will be a sort of maximisation of our return on our own investment in free-education.

A Centre established in Sri Lanka would necessarily have to be immunised from the bureaucratic stringencies that cripple other local scientific institutions in the country. Accordingly some preferential "diplomatic style" treatment should be afforded such a centre. There is a precedent for such treatment even within the country. For example most organisations connected with Tourism are given preferential treatment in many respects such as foreign travel, imports of essential items etc. All arrangements therefore connected with the scientific research requirements of such a Centre will have to be treated at a special level.

In Professor Djerassi's article he deals with the basic operational problems of such a Centre as well as funding. The same considerations that apply to the Mexican model are relevant to our situation. Perhaps even more so. For example a 'ten year commitment' in funds is an alien concept of funding authorities here. However if-as will be-required- the funds are drawn from

foreign sources, viz - several international aid groups, - such a commitment may not be too difficult to envisage. There is no question but that the same financial stringencies that are now inflicted on our research institutes if permitted to apply would grind any organisation to a standstill. Vastly liberal ideas on finance will have to be employed.

CONCLUSION :

This paper proposes the concept that the only way to develop sustained research of international standard in a small developing country like Sri Lanka with limited resources in funds is via the concept of an International Centre for Research. The case of India is first distinguished from that of a small developing country as the former's drawing power from foreign sources to establishg its own science has worked to fruition. The availability of a nucleus of research workers to commence such a Centre is recognised and the key factor is the requirement of Research Leaders with high performance and reputation. Natural Products as a Research Field for such a Research Centre in Sri Lanka has many undoubted advantages and the idea a Centre of Natural Product Research located in Sri Lanka merits wholehearted support.

Grants Awarded since the inception of the National Science Council

for Projects relevant to topics under discussion at the Workshop

(This list does not include, projects connected with Tea, Rubber and Coconut)

Year of Award 1969/1970

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/NSCA/1/17/2 Prof. M.U.S. Sultanbawa Dept. of Chemistry, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Chemical investigation of endemic plants of Ceylon".	5	Rs. 95,000.00
2/NSCA/1/17/7 Prof. S.N. Arsekularatne, Dept. of Bacteriology, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Mycotoxins in food stuffs with special reference to local products".	2	Rs. 19,200.00
2/NSCA/1/17/11 Dr. Y.D.A. Senanayake, Dept. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Inducton of flowering of some species of biennial exotic vegetables in the mid-country of Ceylon".	2	Rs. 13,700.00

Year of Award 1969/70 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/NSCA/1/17/23 B Dr. K. Mahadeva, Ayuvedic Research Institute, Nawinna, Maharagama.	"Botanical identification and chonical analysis of medical herbs and indigenous medicine".	3	Rs. 10,000.00

Year of Award 1970/71

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/NSCA/1/17/25 Dr. H.P.M. Gunasena, Dept. of Agriculture, Univ. of Sri Lanka, Peradeniya Campus, Peradeniya.	"Factors affecting grain sterility of inproved varieties of rice oryza sativa L".	3	Rs. 1,750.00

Year of Award 1970/71 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/NSCA/1/17/26 Mr. P. Pawanasasivan, Dept. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Micronutrient studies in great soil groups of Ceylon".	3	Rs. 14,190.75
2/NSCA/1/17/27 Dr. H.P.M. Gunasena, Dept. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Agronomic studies on the cultivation of manioc manihot utilisinna".	2	Rs. 6,800.00
2/NSCA/1/17/29 Dr. H.P.M. Gunasena & Dr.H.M.W.Herath, Dept. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Use of Soyabean (Glycine max L) in multiple cropping programmes"	2	Rs. 4,100.00

Year of Award 1970/71 (Contd.)

Name & Institution	Title	Duration year	Total allocation (Rupees)
2/NSCA/1/17/30 Dr. H.M.W. Herath, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Strain selection and cultural requirements of lemon grass for the mid country wet zone Ceylon".	2	Rs. 3,900.00
2/NSCA/1/17/31 Dr. H.M.W. Herath, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"A study of the factors that affect growth and reproduction of Salvinia (auriculata) with a view to find a method of biological control".	2	Rs. 4,150.00
2/NSCA/1/17/44 Prof. A.C.J. Weerakoon, Dept. of Bio. Science, Vidyodaya Campus, Univ. of Sri Lanka, Nugegoda.	"Irradiation effects on yeast with special reference to fermentation morphology and enzyme distribution"	2	Rs. 2,390.00

Year of Award 1970/71 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/NSCA/1/17/45 Dr. M.W.C. Dharmawardena, Dept. of Chemistry, Vidyodaya Campus, Univ. of Sri Lanka, Nugegoda.	"Comparative account of yeasts isolated from fermented saps of palms in Ceylon".	2	Rs. 7,200.00
2/NSCA/1/17/51 Dr. R.O.B. Wijesekera, C.I.S.I.R., Colombo 7.	"Synthesis of fine chemicals from Ceylon essential oils"	3	Rs. 36,550.00
2/NSCA/1/17/52 Dr. R.O.B. Wijesekera, Miss C.L.M. Nethsingho, C.I.S.I.R., Colombo 7.	"Preparation of a compendium of spices and essential oils of Ceylon"	3	Rs. 23,100.00

Year of Award 1972

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/72/3 Drs. V. Arkely & M. Mahendran, Dept. of Chemistry, Colombo Campus, Univ. of Sri Lanka, Colombo.	"Investigations of natural products of Ceylon of possible medicinal use".	2	Rs. 14,600.00
2/RG/72/7 Dr. M.P. Wesenthi-pulle, Dept. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"The study of the feasibility of sugar production from sugar beet as a cottage industry".	3	Rs. 30,100.00
2/RG/72/16 Dr. H.G. Nandadasa, Dept. of Biology, Vidyodaya Campus, Univ. of Sri Lanka, Nugegoda.	"Genotical investigations of bronzing disease in paddy".	3	Rs. 25,000.00
2/RG/72/21 Dr. K.T.D. de Silva, Dept, of Chemistry, Vidyodaya Campus, Univ. of Sri Lanka, Nugegoda.	"Lichens of Ceylon - A study of the chemical constituents & their antibiotic activity".	3	Rs. 9,272.60

Year of Award 1972 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/72/26 Mr. L.A.C. Alles, Dept. for Development of Marketing, Colombo 5.	"Investigation of freeze concentration of fruit juices".	2	Rs. 14,400.00
2/RG/72/27 Mr. L.A.C. Alles, Dept. for Development of Marketing, Colombo 5.	"Investigation on fermentation products (Wines, Vinegar, Alcohol) from waste fruit juices".	2	Rs. 14,400.00
2/RG/72/28 Mr. L.A.C. Alles, Dept. for Development of Marketing, Colombo 5.	"Utilization of limes (citrus aurantifolia)".	2	Rs. 14,400.00
2/RG/72/30 Dr. K. Vivekanandan, Forest Department, Colombo 2.	"Vegetative propogation of species of pinus grown in Ceylon".	2	Rs. 749.60
2/RG/72/36 Dr.(Mrs.) A.S. Seneviratne, Dept. of Botany, Colombo Campus, Univ. of Sri Lanka, Colombo.	"Determination of the Development of a yeast culture to give higher production of rectified spirits".	2	Rs. 10,800.00 from N.S.C. Rs. 10,800.00 from Sugar Corp.

Year of Award 1972 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/72/39 Dr.(Miss) U. Kandiah, Dept. of Botany, Colombo Campus, Univ. of Sri Lanka, Colombo.	"Virus disease of papaw. (Carica papaya in Ceylon)".	3	N.S.C. Studentship for 3 years.
Year of Award 1973			
N ame & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/73/5 Dr. P.A.J. Perera, Dept. of Biochemistry, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Lipase activity in rice bran and its deactivation"	2	Rs. 3,100.00
2/RG/73/6 Mrs. T.M.S. Athukorala, Dept. of Biochemistry, Fac. of Medicine, Colombo Campus, Univ. of Sri Lanka, Colombo	"Lipase activity in rice bran and its deactivation".	1	Rs. 900.00

Year of Award 1973 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/73/10 Dr. S.N. de S. Seneviratne, Division of Plant Pathology, Central Agricultural Research Station, Gannoruwa, Peradeniya.	"Investigation on virus diseases of passion fruit"	3	Rs. 50,760.00

Year of Award 1974

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/74/1 Dr. C.S. Weeraratne, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Residual effects of Agro-chemicals in soils of Sri Lanka",	2	Rs. 10,200.00
2/RG/74/6 Dr. N.N. de Silva, C.W.E. Research & Development Division, 21, Vauxhall Street, Colombo 2.	"Handling and utilization of Cashew 'Apples' (Kaju puhulang) and Nuts".	1	Rs. 20,800.00

Year of Award 1974 (Contd.)

Name & Institution	Title	Duration Year.	Total allocation (Rupees)
2/RG/74/7 Dr.(Mrs.) N.S. Kumar, Dept. of Chemistry, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"To investigate the utilization of factory waste from the passion fruit industry".	2	Rs. 24,400.00
2/RG/74/26 Dr. S.A. Kulasooriya, Dept. of Botany, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Survey of blue green algae in rice soils of Kandy District and the extination of nitrogen fixing types".	3	Rs. 37,600.00
2/RG/74/29 Dr. K.T.D. de Silva, Dept. of Chemistry, Vidyodaya Campus, Univ. of Sri Lanka, Nugegoda.	"The Chemistry of some native medicinal plants and their pharmacological actions".	2	Rs. 14,400.00

Year of Award 1975

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/75/1 Dr. C.S. Weeraratne, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Effect of pesticides on some soil biological processes".	2	Rs. 28,535.00
2/RG/75/2 Dr. R.H.G. Clements, Dept. of Crop Sciences, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Agronomic studies on Soya bean".	2	Rs. 22,000.00
2/RG/75/3 Dr. H.M.W. Herath, Dept. of Agricultural Biology, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Characterization and identification of Citronella strains".	2	Rs. 31,110.00
2/RG/75/4 Mr. A.S.B. Rajaguru, Dept. of Animal Husbandry, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Study of less known agricultural and natural products for animal feeding".	2	Rs. 78,058.00

Year of Award 1975 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/75/5 Mr. M.S. Wijayasinghe, Dept. of Animal Husbandry, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Possibilities of utilising leaf meals in pig and poultry feeding".	1	Rs. 10,600.00
2/RG/75/6 Dr. E.R. Jansz, Mr. E.E. Joyaraj, C.I.S.I.R., Colombo 7.	"Toddy fermentation-improvement of efficiency and flavour with reference to commercial exploitation".	1	Rs. 19,400.00
2/RG/75/12 Dr. H.P.M. Gunasena, Dept. of Crop Sciences, Fac. of Agriculture, Peradeniya Campus, Univ. of Sri Lanka, Peradeniya.	"Cultivation of sugar beet in Sri Lanka and its potential for sugar production".	1	Rs. 13,900.00
2/RG/75/17 Dr. R.O.B. Wijesekera & Mr. A.L. Jayawardena, C.I.S.I.R., Colombo 7.	"Studies on Cinnamon to improve quality and production".	3	Rs. 47,700.00

Year of Award 1975 (Contd.)

Name & Institution	Title	Duration Year	Total allocation (Rupees)
2/RG/75/36 Dr. V. Kunar & Dr. S. Mageswaran, Dept. of Chemistry, Univ. of Sri Lanka, Peradeniya Campus, Peradeniya.	"Study of compounds suitable for use a substitutes in the perfumery industry"	3	Rs. 33,600.00

RESEARCH IN NATURAL PRODUCTS CARRIED OUT IN SRI LANKA IN THE PERIOD 1970-73*

AGRONOMY

Title of Project	Name of Author	Institute
AGRONOMY of condiments (Fennel, Cummin, Fenugreek, Mustard, Coriander)	K. Suntheralingam	Agricultural Research Station, Boralanda - Dept. of Agriculture
SOYA bean trials	A. O. C. De Zoysa	Agricultural Research Station, Maha-Iluppallama - Dept. of Agriculture
FERTILIZER response trial with manihot esculata FERTILIZER and varietal trials with ipomea batatas	S. P. R. Weerasinghe	Regional Agricultural Research Office, Bandarawela - Dept. of Agriculture
CULTURAL studies with different methods of planting of sugar cane in low lying areas INTERCROPPING sugar cane with soya bean	E. H. N. Jegasekera R. Kunarajah	Sri Lanka Sugar Corporation, Kantalai-Agronomy Division
VARIETAL evaluation of sugar cane MATURITY trend of sugar cane and its relation to age PRELIMINARY studies on chemical ripening of cane STUDIES on the rooting behaviour of some main varieties of sugar cane in relation to type of soil and cultivation MATURITY test, its impact on harvest schedules and its relationship to juice quality status of cane at the factory	R. Kunarajah	Sri Lanka Sugar Corporation, Kantalai-Agronomy Division
N - P - K FERTILIZER response studies in sugar cane under irrigated conditions	R. Kunarajah S. Kathiragamathiya	Sri Lanka Sugar Corporation, Kantalai-Agronomy Division

* Extracted from the Directory of Scientific Research Projects in Sri Lanka - National Science Council 1970-73

AGRONOMY

Title of Project	Name of Author	Institute
FURTHER studies on crop nutrition N - P - K response with new varieties of sugar cane	R. Kunarajah R. Sathiendrakumar	Sri Lanka Sugar Corporation, Kantalai Agronomy Division
AGRONOMIC studies in Manioc - Manihot esculenta.L. AGRONOMIC studies on the cultivation of castor - ricinus communis.L.	H. P. M. Gunasena	Univ. of Sri Lanka, Peradeniya Campus Dept. of Agriculture
GROWTH and yield of five strains of lemon grass at three levels of nitrogen SELECTION and cultural practices on cardamon (Elatheria cardamomum. L.) EFFECT of spacing and nutrient levels on the growth and yield of pepper EFFECT of frequency and height of cutting and levels of fertilizer on regrowth and yield of lemon grass (Cymbopogan)	H. M. W. Herath	Univ. of Sri Lanka, Peradeniya Campus Dept. of Agriculture
BIOCHEMISTRY - AGRICULTURE		
PURIFICATION of papain	K. G. Gunatilake O. Perera	Ceylon Institute of Scientific and Industrial Research - Food Technology Division

BIOCHEMISTRY-AGRICULTURE

Title of Project	Name of Author	Institute
EFFECT of vegetable juices on Cyanogenic glucosides of manioc	E. E. JeyaRaj E. R. Janz S. A. Amarakone	Ceylon Institute of Scientific and Industrial Research - Food Technology Division
IRRADIATION effects on yeasts isolated from the saps of palms grown in Ceylon	P. Jayatileke (Miss) S. Sentheshanmuganathan	Medical Research Institute - Biochemistry Division
COMPARATIVE studies of yeasts isolated from fermented saps of palms grown in Ceylon	A. W. Liyanage S. Sentheshanmuganathan	Medical Research Institute - Biochemistry Division
STUDIES on the fermentation of kithul Sap	T. Theivendirarajah S. Jayaseelam	Univ. of Sri Lanka, Peradeniya Campus Dept. of Botany

BOTANY - AGRICULTURE

CHARACTERIZATION and selection of Citronella strains	H. M. W. Herath Y. D. A. Senanayake R. O. B. Wijesekera J. T. A. Dayananda	Univ. of Sri Lanka, Peradeniya Campus Dept. of Agriculture

FISHERIES AND WILD LIFE

STUDY of the growth rate and abundance of sargassum crassifolium	M. Durairatnam	Fisheries Research Station - Research Division

BOTANY – AGRICULTURE

Title of Project	Name of Author	Institute
CHEMICAL analysis of fresh and cured fish in Sri Lanka	L. St. C. Gunasekera T. S. G. Peiris	Fisheries Research Station – Research Division

FOOD PROCESSING AND STORAGE

PROCESSING manioc PROCESSING soya beans NOVEL process for oil and protein separation in coconut PREPARATION of canned or bottled coconut cream PROCESSING fruit juices	K. G. Gunatileka	Ceylon Institute of Scientific and Industrial Research – Food Technology Division
REGENERATION of dry fish waste	R.C. B. Wijesekera A. Bamunuarachchi	Ceylon Institute of Scientific and Industrial Research – Natural Products Division
UTILISATION of dried fish in new product development	A. M. A. A. De Silva	Co-operative Wholesale Establishment Research & Development Division
UTILISATION of cashew	U. M. de Silva K. L. R. F. Wijewardhane	Co-operative Wholesale Establishment Research & Development Division
USES of manioc	G. Ganage (Mrs.)	Co-operative Wholesale Establishment Research & Development Division
COMMERCIAL utilisation of limes	L.A.C.Alles S. M. Gnanasuriyam W.B. Wijeratne A. M. L. B. Somaratne	Dept. for Development of Marketing, Fruit and Vegetable Utilization Laboratory

FOOD PROCESSING AND STORAGE

Title of Project	Name of Author	Institute
FERMENTATION of waste fruit juice in the production of alcohol, wine and vinegar	L. A. C. Alles A. V. Liyanage Malini De Almeida	Dept.for Development of Marketing - Fruit and Vegetable Utilization Lab.
FREEZE concentration of passion fruit juice	L. A.C. Alles Malini Ratnatunga M.B. Wijeratne	Dept. for Development of Marketing- Fruit and Vegetable Utilisation Lab.
CORROSION of tin plate by passion fruit juice	L.A. C. Alles A. M. L. B. Somaratne	Dept. for Development of Marketing - Fruit and Vegetable Utilization Lab.
UTILIZATION of passion fruit peel for animal feed	L. A. C. Alles M.B. Wijeratne A. M. L.B. Somaratne	Dept. for Development of Marketing - Fruit and Vegetable Utilisation Lab.
INVESTIGATIONS into the processing and preservation of avacado PREPARATION and processing of cheese from non-dairy products	M. V. Pulle	Univ. of Sri Lanka, Peradeniya Campus Dept. of Agriculture

CHEMISTRY - INDUSTRIAL

PREPARATION of a thin boiling starch from manioc starch for the textile industry	Savithri Kumar D.S. Jayasuriya S. Silva	Univ. of Sri Lanka, Peradeniya Campus Dept. of Chemistry

CHEMISTRY - INORGANIC

Title of Project	Name of Author	Institute
RADIATION effects on selected food materials - initial study on manioc	P. P. G. L. Siriwardena K. G. Dharmawardena	Univ. of Sri Lanka, Colombo Campus Dept. of Chemistry

CHEMISTRY - NATURAL PRODUCTS

TRANSFORMATION of terpenoids	R.O.B.Wijesekera S. Lakshimi Rajapakse	Ceylon Institute of Scientific and Industrial Research - Natural Products Division
THE isolation of chemical compounds of pharmaceutical interest from endemic plants -(2) Studies on Ceylon lichens .	R.O.B.Wijesekera K.T.D. de Silva A.L. Andrody E. Lederer J. Polonsky R. Gontaral B.C. Das	Ceylon Institute of Scientific and Industrial Research - Natural Products Division
DEVELOPMENT of new analytical techniques for assessment of quality in essential oils	R.O.B.Wijesekera A.L.Jayawardena U.M. Senanayake S. Lakshimi Rajapakse K. Kanthi Fonseka	Ceylon Institute of Scientific and Industrial Research - Natural Products Division
CULTIVATION of cympopogan	R.O.B.Wijesekera S. Ponnuchamy M. M. W. Herath	Ceylon Institute of Scientific and Industrial Research - Natural Products Division

CHEMISTRY - NATURAL PRODUCTS

Title of Project	Name of Author	Institute
SYNTHESIS of organic compounds with likely antioxidant activity SYNTHESIS of aromatic chemicals from constituents of essential oils	R.O.B.Wijesekera V.U. Ratnayake	Ceylon Institute of Scientific and Industrial Research - Natural Products Division
CHEMICAL studies on the constituents of essential oils in spices of Sri Lanka	R.O.B.Wijesekera U.M. Senanayake A.L. Jayawardena S. Lakshimi Rajapakse H. Kanthi Fonseka	Ceylon Institute of Scientific and Industrial Research - Natural Products Division
IMPROVEMENT in the technology of the distillation of essential oils	R.O.B.Wijesekera B.Wijerathna K. Ratnasingham M.A.V.Devanathan M.U.C.Wijetunga S. Ponnuchamy S.F.Laurentius	Ceylon Institute of Scientific and Industrial Research - Natural Products Division

MICROBIOLOGY

USEFUL products from manioc using microbial methods	E.E.JeyaRaj E.R.Janz S.A. Amarakone	Ceylon Institute of Scientific and Industrial Research - Industrial Microbiology Section
BIOLOGY and biochemistry of yeasts isolated from local raw materials	E.E.JeyaRaj Anandi Vanniasinkam P.M. Jayatissa S.A. Amarakone	Ceylon Institute of Scientific and Industrial Research - Industrial Microbiological Section

PHARMACOLOGY

Title of Project	Name of Auther	Institute
EVALUATION of the Effect of Haridra (Saffron) of Asthma and the Absolute Eosinophil Count	K. Mahadeva S. Arunachalam	Bandaranaike Memorial Ayurvedic Research Institute - Division of Research
ASSESSMENT of the Efficacy of 'PUNARNAVA MANDOORA' on Pandu (Anaemia)	K. Mahadeva S. Arunachalam S. Dissanayake (Mrs.) J. Thillainathan (Mrs.) K.G. Dharmawardana V. Arkely	Bandaranaike Memorial Ayurvedic Research Institute - Division of Research
THE Effect of Ayurvedic Drugs on Leucoderma (SUDU KABARA)	K. Mahadeva H.I. Chandrasekera K.D. Dharmasena Senaratne	Bandaranaike Memorial Ayurvedic Research Institute - Division of Research
EVAULATION of the Effect of Ayurvedic Drugs in the Treatment of Bronchial Asthma	K. Mahadeva H.I. Chandrasekera D.H. Rajapakse K.D. Dharmasena E. Karunanayake S. Weerakoon (Mrs.) J. Thillainathan (Mrs.) S. Arunachalam S. Goonatilaka	Bandaranaike Memorial Ayurvedic Research Institute - Division of Research
EVALUATION of the Effects of Ayurvedic Drugs on Renal Calculi	K. Mahadeva G.N. Perera W. Alwis	Bandaranaike Memorial Ayurvedic Research Institute - Division of Research

PHARMACOLOGY

Title of Project	Name of Author	Institute
EVALUATION of the Effect of Ayurvedic Drugs on Arthrophathy	D.H. Rajapakse R.B. Heenkenda D.P.R. Waidyawansa	Bandaranaike Memorial Ayurvedic Research Institute- Division of Research
ANTHISTAMINIC Activity of Extracts of Indigenous Plants Used in Ayurvedic	B.A.V. Perera D.S.S. Lecamwasam H.N. De Silva	Medical Research Institute - Pharmacology Department
ANTHISTAMINE Effects of Extracts of 'WALBIN KHOMBA' and 'DUMBELA'	B.A.V. Perera D.S.S. Lecamwasam H.N. De Silva	Medical Research Institute- Pharmacology Department
HYPOGLYCAEMIC Activity of Extracts of the Roots of Ficus Religiosa (BO TREE)	B.A.V. Perera D.S.S. Lecamwasam H.N. De Silva	Medical Research Institute - Pharmacology Department

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