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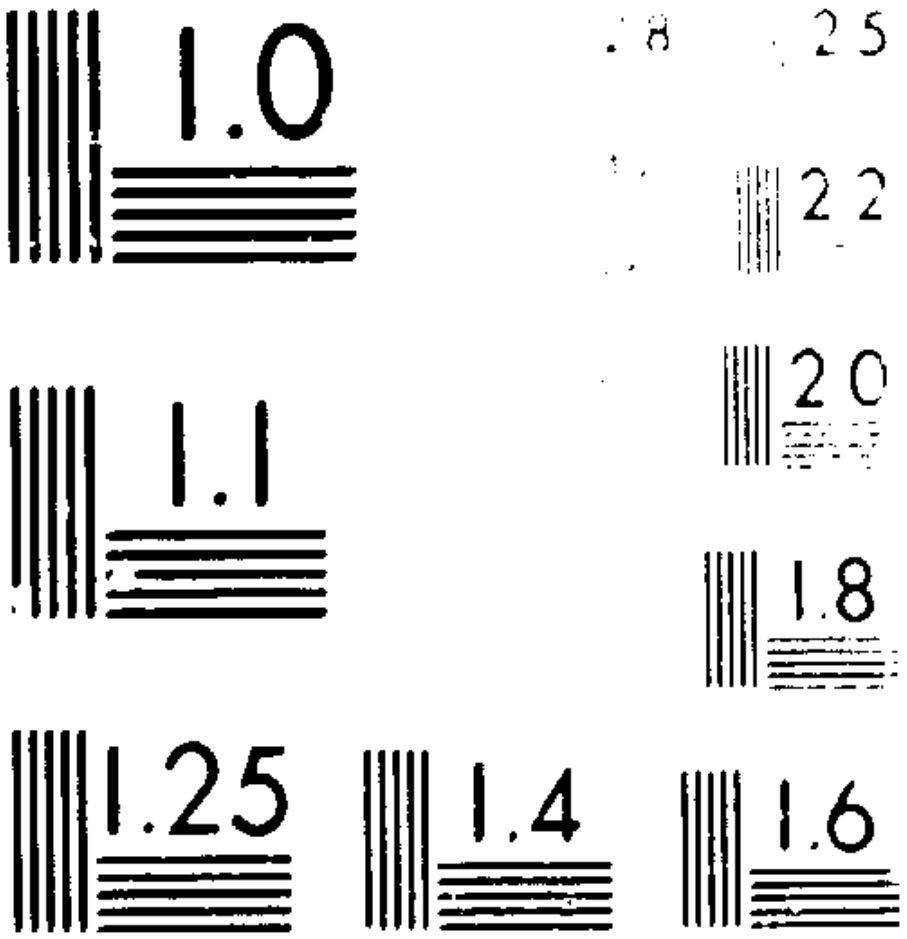
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UNIDO/IO.505
3 June 1982

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

MEDICINAL AND AROMATIC PLANTS FOR INDUSTRIAL DEVELOPMENT*

A review of UNIDO activities on the utilization of medicinal and aromatic plants for the production of pharmaceuticals in developing countries

by

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CONTENTS

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1. INTRODUCTION

1.1 Man's symbiotic relationship with the plant kingdom, which stretches well beyond the limits of recorded time, has given the world of today many invaluable benefits. Apart from the raw materials that go to form our variety of foods, the most important plant products are medicines, cosmetic and flavour products, and other pharmaceuticals. Perhaps it is correct to infer [1] that ancient man in his quest for food stumbled upon the properties of plants that could be used for: healing ailments; preserving foodstuffs and adding piquancy to them; generating perfumes and deodorants to counteract unpleasant odours; and poisons for hunting and combat. Over the millenia, spanning many great civilizations these early empirical observations of man have served as the basis for the preparation of cosmetics, drugs and pharmaceuticals and finally the emergence of the great modern pharmaceutical, cosmetic and flavour industries. The development of prototype disciplines related to modern chemistry, pharmacy and botany, enabled the production of medicinal preparations from plant products on which the traditional medical systems of the various geographic regions are still based. Similarly, beginning with the impressive Arabian civilizations, of the pre-Christian era, mankind knew of the use of spices in foods. Although the origin of perfumery itself is submerged in obscurity the derivation of the word perfume (per = through, fumum = smoke) seems to suggest as Rosengarten [2] contends, an origin in the "burning of aromatic gums and hardened oozings from resinous woods". Ironically, there is evidence of the earliest use of perfumery substances in ancient Egypt for purposes of embalming the dead - a scented passage to another world! There is also recent evidence of the production of scents and perfumes during the Mohendro-dars civilization of Ancient India. [3]

1.2 The growth of modern organic chemistry based itself at the early stages to a large extent on the study of natural products obtained from plants.

The classical studies such as those on the structures of the alkaloids quinine, atropine, morphine, strychnine etc. played their part in the hands of the great chemists like Fischer, Perkin, Robinson, and later Woodward, in the development of organic chemistry itself. And yet these substances and a host of others like them, were of early interest, on account of their biological activity (therapeutic, narcotic or toxic). In a like vein the studies of aromatic constituents of plants gave rise to a knowledge of the chemistry of the important group of organic compounds - the Terpenoids - the predominant constituents of the "essential oils" - the aroma

giving "essence" of plants. Based on early attempts to synthesize these newly identified chemical structures, synthetic organic chemistry as a science (or perhaps an art as well) erupted into recognition so that in the mid-twentieth century decades in particular, the synthesis of natural products was a preferred method of drug manufacture, in the industrial world.

1.3 Utilization of plant material - be it for drugs or cosmetics or other pharmaceutical use - was kept minimal even as a matter of policy by those who controlled the manufacturing industries. 4/ Synthetic materials had come to stay, and the plants were only recognized as a source of new chemical structures, which may have new physiological actions and effects, which sooner or later may be synthesized for production if warranted.

1.4 In the 1970s and now, it would appear that there is a gradual revival of interest in medicinal and aromatic plants. It has been estimated that the value of raw materials of plant origin destined for the pharmaceutical and cosmetic industries rapidly increased from US$52.9 million in 1967 to US$71.2 million in 1971 with an annual progression of 5-7 per cent since then.

And as Jean Marie Pelt 5/ records: "Anxiety concerning the excess of industrial civilizations and threats which they pose to physical and mental health, is leading more and more men and women to seek herbal remedies for their suffering and illness, in a movement of reconciliation with nature." A similar but less emphatic situation can be seen in regard to the utilization of aromatic plants in the cosmetic and flavour industries. At the beginning of the century perfumery products utilized about 99 per cent of materials from natural sources and only about 1 per cent were synthetic. 6/ Later on due to the dramatic rise of the chemical industry the beginnings of the 1970s saw only about 15 per cent of natural products being used in perfumery, and the prediction seemed to be reasonable, that the use of natural products will fall off to nothing. However, due to some resurgence of activity, particularly in developing countries, there is forecast that <u>at least</u> 20-25 per cent natural products will continue to be used up to the 1990s. However this ratio may, due to reasons similar to the increased use of medicinal plants, be even more favourable towards natural products than the prediction leads us to believe.

2. INTEREST OF INTERNATIONAL BODIES

2.1 Medicinal and aromatic plants have been the subject of major interest in the activities of several international and intergovernmental agencies during the past couple of decades. UNESCO has had a long-standing interest which reaches back to the first Symposium held in Peshawar (Pakistan) in 1960 to serve the Asian region. This was followed by a Symposium on medicinal plants held in Kandy, Sri Lanka in 1966. [7,8]

The Third Asian Symposium on Medicinal Plants and Spices (3-ASOMPS) held in Colombo, Sri Lanka in 1977, [8] which followed, had also a practical workshop on phytochemical and pharmacological Screening attached to it, and this was also held in Sri Lanka. The series continued with the Fourth Asian Symposium on Medicinal Plants and Spices (4-ASOMPS) held in Bangkok in 1980 and UNESCO plan to stage their next Symposium, 5-ASOMPS, in Manila. In 1980, UNESCO had also staged in the Latin American region, a Symposium on Pharmacologically Active Natural Products, in Havana (Cuba). Besides these UNESCO is sponsor of two Regional Networks on Natural Product Chemistry in South Asia and South-East Asia where the participating scientists within the Network have a major interest in medicinal and aromatic plants. [9]

2.2 The World Health Organization has had similar interests and a meeting organized jointly with the Instituto Italo-Africano on Research and Training in the Traditional Systems of Medicine in Developing Countries, was held in Rome in April 1979. This meeting drew participants with very wide and varied interests ranging from practitioners of traditional medicine, administrators and many scientific disciplines. [10] The WHO Division on Traditional Medicine has also staged consultations on plants used in cancer therapy etc., and it is in general committed to the development of traditional medicine in the countries in which these systems are practised. The World Health Organization's other programme involving medicinal plants is that run by its Task Force on Indigenous Plants for Fertility Regulation. In this programme plants selected by computer are being researched within a multicentre programme where three of the centres are located in developing countries. [11]

WHO has also compiled and published [12] an inventory of medicinal plants with a list of the world's most widely used plants. This shortlist is a good beginning for all research work aimed towards different objectives.

2.3 The Commonwealth Science Council (CSC) (United Kingdom) has also activity and interest in the broad area of the utilization of natural products and has organized meetings in the Anglophone countries of Asia, Africa and the Caribbean.

2.4 The International Foundation of Science (IFS) (Sweden) operates several projects on medicinal and aromatic plants. They are small projects and funds are committed to individual grantees for research work. The grantees are geographically widespread and meetings of grantees have been arranged to facilitate liberal exchanges of ideas and information.

2.5 The Organization of African Unity (OAU) has been one of the most consistently active regional bodies displaying great interest in the activities connected with medicinal and aromatic plants. [13/] The first OAU Symposium on Traditional Pharmacopoeias and African Medicinal Plants was held in Dakar, Senegal, in 1968. Since that time the OAU has been actively engaged in promoting and encouraging the development of the plant-based traditional pharmacopoeias.

2.6 Besides these interests - which are specifically geared to the needs of developing nations - the regular Symposia on the Chemistry of Natural Products organized by IUPAC also display the world-wide attention that is enjoyed by bioactive agents derived from plants.

3. UNIDO PROGRAMMES: GENERAL

3.1 UNIDO programmes in the area concerning medicinal and aromatic plants have reflected the emphasis which derives from its mandate [14/] "to promote and accelerate the industrialization of the developing countries". In this respect the projects differ from those of other organizations. UNIDO's main thrust, has been, and understandably will continue to be, in the direction of industrial utilization, of medicinal and aromatic plants. Hence the UNIDO programmes have fallen into one or more of the following categories:

(a) Survey of the potential of the flora for its utilization as a source of plant-derived pharmaceuticals and/or economic natural products;

(b) Transfer of technologies for the systematic cultivation of selected medicinal and economic plant species for industrial processing;

(c) Transfer of expertise in instrumental analytical techniques for the quality assessment of plant-derived pharmaceuticals and economic natural products, with a view to the establishment of production units;

(d) Transfer of technologies, for the pilot scale processing (distillation, extraction etc.) of plant-derived pharmaceutical preparations and preparations from traditonal pharmacopoeias, and methods of formulation of products;

(e) Training, exchange of expertise and institution strengthening.

3.2 These programmes also reflect a necessary methodology that must be substantially adhered to if pharmaceuticals based on plants are to be produced to consistent and acceptable standards. This methodology includes, [15] inter alia, the following:

- Botanical authentication of plant material, and assessment of resource potential (economic mapping of plants). Study of all available published literature;
- Systematic cultivation of plant species selected for processing, and continuing phytochemical evaluation;
- Establishment of criteria of quality, methods of quality assessment, and techniques of standardization of products;
- Ensurement of accessibility to adequate technologies for processing and laboratory expertise for physio-chemical and biological standardization.

The UNIDO ongoing programmes which are described in the sections that follow are directed towards goals and ideals based on the above considerations.

4. THE EXPLORATORY MISSIONS BY THE UNIDO MOBILE UNIT FOR THE PHARMACEUTICAL AND ESSENTIAL OILS INDUSTRY IN THE LDCs OF ASIA AND AFRICA

4.1 In many ways this project of UNIDO's was an important pioneering project, and could claim many unique features both in concept and execution. The project arose through a proposal made by the Joint UNIDO/Romania Centre [16-19] which was established in 1971 as an agency for international co-operation in the fields of chemical and petrochemical industries for the benefit of developing countries. The Centre is under the direction of a Joint Committee consisting of four members appointed by the Executive Director of UNIDO and four others appointed by the Government of Romania. The two working units of the Centre which carry out the programmes are in Bucharest and at UNIDO Vienna. Regarded by UNIDO as a specialized technical assistance organ, the Centre has the following stated objectives:

- Facilitating the transfer of technology and information to developing countries;
- Contributing to the training of technical personnel from developing countries;
- Broadening direct contacts between the industrial circles of the developing countries.

4.2 In accordance with these objectives, UNIDO in 1977, with the collaboration of the Centre, initiated a three-phase programme for the utilization of medicinal plants confining itself in the first instance to the least developed countries (LDCs) of Africa and Asia. Exploratory missions were sent to visit Afghanistan and Nepal in February 1977 and to Botswana, Burundi, Rwanda, Tanzania and Uganda in December 1977. These exploratory missions , which constituted the initial phase of the exercise, gathered preliminary information from available published sources, and from in situ observations and inquiries regarding the occurrence, location, and relative abundance of medicinal and aromatic plants in each country, and their reputed usage.

4.3 Following these exploratory missions the next phase was the organization of a visiting "mobile unit" to several of these countries. This unit which was manned by five specialists consisted of two vehicles (Aro cross-country vehicles) which bore laboratory and semi-pilot scale equipment and supplies for demonstrating, phytochemical extraction, steam distillation, phytochemical screening and field botanical methods. This was the Romanian contribution to the exercise while UNIDO bore the costs of fielding the experts.

The total cost of the project was around US$80,000 which included the Romanian Government's contribution in terms of equipment and UNIDO's costs of fielding the experts.

The work of this mobile unit warrants further description particularly in respect of the methodologies used and the results obtained, in each of the LDCs visited.

5. WORK OF THE MOBILE UNIT IN THE LEAST DEVELOPED COUNTRIES OF ASIA

A. Afghanistan

B. Nepal

5.1 A. Mobile unit's work in Afghanistan

The mobile unit's mission to Afghanistan and Nepal [19-21] lasted five months from the time of its departure from and return to Bucharest. The mission recorded that the flora of Afghanistan in comparison with that of the Asian region in general was characterized by a relatively reduced number of species many of which however, were available in comparative abundance. There were also many endemic species spread out in the arid mountainous zones. Afghanistan currently exported the following species as raw materials, the main buyers being India and Pakistan.

Wild growing species: Glycyrrhiza glabra
Ziziphus vulgaris
Eremurus stenophyllus
Ferula asafoetida
Astragalus gummifera
Centaurea behen

Cultivated species: Coriandrum sativum
Cannabis sativa
Sesamum indicum
Papaver somniferum

The route taken by the mobile unit in Afghanistan between 25 July and 16 August passed the following districts: Kabul, Bamyan, Gor, Herat, Badgis, Foryab, Jevzjan, Balh, Samolgan and Badahsan.

Along the route, plants were collected for herbarium voucher specimens. Plant samples were collected from 51 species which are listed in table 1.

Table 1

Plant species collected in Afghanistan by the mobile unit

	Name of plant species	Reputed usage (see code below)
1.	Achillea santolina	EO
2.	Anemone spp.*	
3.	Apocynum spp.*	
4.	Artemesia spp.	EO
5.	Artemesia absinthum	EO, ga
6.	Artemesia dracuncalus	EO, ah
7.	Artemesia cina	ah, XP
8.	Arthrophytum griffithii	
9.	Astea spp.*	
10.	Astragalus gomifera	XP
11.	Berberis vulgaris	
12.	Berberis spp.*	ad, dm, fb, du
13.	Carum copticum	EO, ga
14.	Capparis spinosa	
15.	Calystegia sepium	lx
16.	Centaurea spp.*	
17.	Chrysanthemum spp.*	
18.	Chenopodium spp.*	ah
19.	Clematis spp.*	
20.	Corydalis moocroftiana	

Table 1 (cont'd)

	Name of plant species	Reputed usage (see code below)
21.	Convulvulus spp.*	
22.	Crambe orientale	
23.	Daphne spp.*	
24.	Delphinium spp.*	
25.	Ephedra procera	ap
26.	Ephedra major	rp, XP
27.	Ficus spp.*	
28.	Fraxinus oxycylla	
29.	Gentiana spp.*	tn
30.	Geranium collinum	
31.	Glycirrhiza glabra	au, rp, lx, XP
32.	Glaucium spp.*	
33.	Heliotropicum lasiocarpum	
34.	Hypericum perforatum	ga, dm
35.	Iris spp.*	du, dm
36.	Inula rhyzocephala	du
37.	Ipomea spp.*	
38.	Juniperus excelsa	
39.	Melitus albus	
40.	Peganum harmala	
41.	Phlomis cashmeriana	
42.	Physalis minima	du
43.	Plantago spp.*	
44.	Polygonum spp.*	du, vm
45.	Polygonum paranychioids	du, vm
46.	Ranunculus spp.*	
47.	Rheum palmatum	lx
48.	Rosa spp.*	vm
49.	Solanum sigrum	
50.	Thymus afghanicus	rp
51.	Trichodesma incanum	

Code indicating usage (also applies to Table II)

ad. = anti-diarrhoea
ah. = anti-helmintic
au. = anti-ulcerous
ar. = anti-rheumatic
dm. = dermatological
du. = diuretic
EO = Essential oil-bearing
fb. = febrifuge
ga. = gastrointestinal, antispasmodic
lx. = laxative
rp. = respiratory tract activity
sd. = sedative
tn. = tonic
vm. = vitamin
XP = Plants exported
ap = drugs with action on the respiratory tract

The mobile unit also made an evaluation of the extent of some of the plants growing in abundance along the route; among them: Glycyrrhiza glabra, Ferula asafoetida, Artemesia herba-alba, Salvia ritidea, Carthamus finctorius, Cuminum cyminum, Plantago major, Hyoscyamus reticulatus, Ziziphora afghanica, Eremurus robusta, E. stenophyllus, and Berberis vulgaris.

For example, in the central region the unit found the average density of plant species of Artemesia herba-alba, as approximately 2.5 plants/m^2 and given that each plant could supply 32.5 g raw material it works out to 800 kg of raw material per hectare. This exemplifies the nature of the basic information on plants which had to be collated during the preparatory stages of the mission. Similar quantitative evaluations were carried out for the essential oil-bearing species Salvia ritidea, in the Carsambe area; the average density was 7 plants/m^2, on an area of 7 ha. Each plant could supply 50 g raw material, and assuming an essential oil content of approximately 1 per cent on a fresh weight basis, about 35 l/ha of essential oil could be expected.

Datura metel gathered in Afghanistan had an alkaloid content of 0.15 per cent compared with 0.01 per cent on the same basis in Datura stramonium species collected in Afghanistan, and this species had tremendous prospects.

5.2 The technique of "Economic Mapping", as developed by Ovidou Bojor [20/] was demonstrated to the Afghan counterpart personnel by the UNIDO experts, and an economic map of the area surveyed is reproduced as Map 1. It would be useful to apply this methodology to survey the more important plants in the area at a later date, and indeed would seem a most desirable prerequisite to a project in Afghanistan for the development of a pharmaceutical industry based on medicinal and aromatic plants. The methodology for survey of economic plants which was followed by the counterpart Afghan personnel preceded demonstrations of the cultural practices and methodology for the systematic cultivation of medicinal and aromatic plants as relevant to the climatic and soil conditions prevailing in Afghanistan.

5.3 The mobile unit's personnel also discussed and demonstrated a sequential methodology for phytochemical screening. The main laboratory work was carried out at the laboratories of the Institute of Public Health and at the Faculty of Pharmacy of the Kabul University.

By chemical analyses conducted with equipment from the mobile unit the principal constituents of 21 species of medicinal plants were identified and 11 quantitative estimations were completed for the purpose of preparing for demonstration purposes some standardized pharmaceutical formulations.

5.4 On the basis of the results obtained, it was concluded that the following were suitable for further pilot-plant scale preparations:

Radix liquiritiae (extract)
Asafoetida
Gummi tragacanthaceae
Herba Ephedrae (extract, tincture)
Cortex granti fructus
Radix Rhei (extract, tincture)
Folium stramonii (total alkaloid extract)

5.5 B. Work of the mobile unit in Nepal

In Nepal, a country with a comparatively rich indigenous flora and an established tradition of the use of plant-based therapeutic substances, the mobile unit had a ready rapport with the Royal Drugs Research Laboratory (RDRL) in Kathmandu. The Laboratory which functions under the Department of Medicinal Plants of the Ministry of Forests, has facilities for botanical and phytochemical investigations and is responsible for seven experimental farms of medicinal plants, some of them with production capabilities.

At the Brindhawan Herbal Farm there is an essential oil distillation unit for processing of Cymbopogon flexuosus (Lemon grass) and Cymbopogon winterianus (Citronella).

The experts of the mobile unit in collaboration with local specialists of the RDRL were able to organize a trek between Trisuli Bezaar (500 m altitude) and Lantan Himal (3,600 m altitude) for a distance of 2,700 km.

The plant species collected during the trekking for herbarium voucher specimens are listed in table II.

Particularly abundant in this area were: Swertia cuneata, and other members of the genus, viz. S. angustifolia, S. chirata (and these are exported to India for use in Ayurvedic preparations) and others such as Rheum emodii, Paris polyphylla and Delphinium denudatum. The essential oil-bearing plants Cymbopogon citratus (lemon grass oil) and Gaultheria fragrantissima (oil of winter green) and , roxberghii (Pine oil) were found to grow well at altitudes of over 1,500 m.

In the upper regions between 2,900 - 4,000 m (Trisuli river, and Langtang Valley) the mobile unit's experts came across substantial growths of Rosa macrophylla. It was estimated that 4-5 tonnes/year of rose hips would be yielded by this area alone,

which could be a rich source of Vitamin C and B carotene enriched preparations; further, the seeds of this species were rich in Vitamin E. The hecogenin containing Agave sisalana was another valuable species which the mobile unit found between Kathmandu and Trisuli Bazaar, and in other areas such as Pokhara, Daman etc. Several other indigenous species important from the point of view of the preparation of plant-derived pharmaceuticals were the following:

Acorus calamus, Dioscorea deltoidea, Rauwolfia serpentina, Zingiber orientalis, Vinca rosea, Centella asiatica and Valeriana walichii.

5.6 Practical demonstrations of the methodology of economic mapping were carried out in the area under the Kiangin top of the upper basin of the Lentang Valley and the results are represented in Map 2. The method of economic mapping of medicinal plants is a useful and interesting one developed by O. Bojor [21] and used particularly effectively in Nepal. It involves the following sequential steps:

(i) A geographical survey of the territory to be mapped and a delimitation of its boundaries;

(ii) A literature survey and study of publications on the flora of the selected territory;

(iii) Research programming and preparations for field surveys - including selection of personnel, and equipment for collection of plant samples and preparation of herbarium voucher specimens. Equipment will include: inter alia suitable vehicles capable of traversing difficult terrains, maps of the terrain, an inflatable boat, documentation equipment, pressing machine for herbarium samples, reagent kits for spot identification of common natural products such as alkaloids, glycosides, polyphenols, etc. and tools;

(iv) Compilation of a selected short list of the most economically useful medicinal herbs expected. (The "economic mapping" does not imply that all species and their abundance in a given region will be documented only the amount of raw material of medicinal herbs evaluated as having potential for profitable utilization is taken into account.);

(v) Quantitative estimation of the abundance of species. There are several systems for quantitative assessments and qualitative evaluation.

(Species abundance is evaluated on the basis of several degree scales, for example the Braun-Blanquot scale which arbitrarily ranges its classification

from very scarce, scarce, few, numerous and very numerous individual species; the Emberger scale of abundance where 10 categories based on the presence of selected numbers of individuals in the area are considered etc.);

(vi) Collection of samples for laboratory analyses. About 50 g amounts of each plant part is collected and authenticated for this purpose. A typical map represents therefore a wealth of information and Bojor and his team have used this technique subsequently in an assessment of the flora of Nepal [24/] under another specific UNIDO sponsored project, as a follow-up of the mobile unit's activity.

5.7 The information gathered by the team will form the basis of two further projects now reaching finalization between the Government of Nepal, UNDP and UNIDO.

The projects are designed to enhance and enlarge the present capabilities of the Royal Drugs Research Laboratory, to undertake all aspects of the utilization of medicinal and aromatic plants within the country, and play an important role in the development of a Nepalese Pharmaceutical Industry based on plants.

Table II

List of plants collected from Nepal in the Lantang area

	Name of plant species	Reputed usage (vide code)
1.	Acer sterculiaceum	
2.	Adriantum venustum	
3.	Allium wallichi	
4.	Anaphalis contorta	
5.	A. margaritaceae	
6.	A. triplinervis	
7.	Artemisia dubia	EO., ga.
8.	Arthromeris wallichiana	
9.	Begonia rubella	
10.	Berberis chitria	ad., dm., fb., du.
11.	Bidens biternata	
12.	Boenninghausenia albiflora	
13.	Botrychium virgenienum	
14.	Bulbophyllum hookeri	
15.	Campanula bolorata	
16.	Cantleya spicata	
17.	Caragana nepalensis	
18.	Castanopsis lystrix	
19.	Codonopsis viridis	
20.	Coelogyne cristata	
21.	Coleus forskolii	
22.	Colquhounia coccinia	
23.	Cotoneaster acuminatus	
24.	C. frigida	ad.
25.	Cryprimus ebenipes	
26.	Cuscuta reflexa var vrachystigma	ah, lx., fb.
27.	Cyananthus lobatus	
28.	Cymbopogon citratus	EO, XP
29.	Cynostossum zeylanicum	
30.	Datura strammonium	ga., XP
31.	Delphinium altissimum	
32.	Delphinium denudatum	
33.	Didymocarpus pulcher	
34.	Elastoema liocolatium	
35.	Elscholtzia blanda	
36.	E. flava	
37.	Epilobium cylindricum	
38.	Eupatorium wallichii	
39.	Galium hisdiflorum	
40.	Galium spp	
41.	Gaultheria nammularioides	EO
42.	G. fragrantissima	EO, rp.
43.	Geranium wallichianium	
44.	Giradinia heterophylla	

Table II (cont'd)

	Name of plant species	Reputed usage (vide code)
45.	Goodyera hemsleyana	
46.	Helictrotrichon virescens	
47.	Heracleum nepalensis	
48.	Herpetospermum pedunculosum	
49.	Hydrocotyle nepalensis	du., tn.
50.	Impatins biocornuta	
51.	I. racemose	
52.	I. scabrida	
53.	Inula cappa	
54.	Iris nepalensis	du., dm.
55.	Larix potanini	
56.	Lepisorus bicolor	
57.	Lespedeza eriocarpa	
58.	Leucas molissima	rp.
59.	Lobelia pyramidalis	ga., rp.
60.	Michelia kisopa	
61.	Moboelia latifolia	
62.	Morina longifolia	
63.	Myricatis nepalensis	
64.	Nicandra physaloides	
65.	Onychium japonicum	
66.	Osbeckia stallata	
67.	Paris polyphylla	XP
68.	Pedicularis annopumensis	
69.	Peperomia tetraphylla	
70.	Phytolocea acinosa	ar, rp, vm
71.	Picris formosa	tn.
72.	Pityrogramma colomelanos	
73.	Polygonala arillata	
74.	Polygonum chinensis	dm., tn., vm.
75.	P. molle	ad.
76.	P. poseemba	
77.	P. hydropiper	du., vm.
78.	Polypodium lachnopus	
79.	Pteris cretica	
80.	Quercus lineata	ad.
81.	Rhaphidophora decursiva	
82.	Rhododendron lepidotum	
83.	Rosa macrophylla	vm.
84.	R. sericea	vm.
85.	Rubia manjith	ad., tn.
86.	Salix fruticosa	ad., tn., fb.
87.	Sarcococca hookariana	
88.	Saxifraga diversifolia	
89.	Selenum tanuifolium	
90.	Sedum spp.	
91.	Swertia paniculata	
92.	Valeriana hardwikii	sd.
93.	Vittaria trimalayensis	

6. WORK OF THE MOBILE UNIT IN THE LDCs OF AFRICA

A. Botswana - (4-17 February 1980)
B. Burundi (22 December 1979 to 5 January 1980)
C. Rwanda (7-22 December 1979)
D. Sudan (3 November to 3 December 1979)
E. Tanzania (6-31 January 1980)

6.1 The visit by the mobile unit to the five African LDCs represented the second phase of the mobile unit's programme and was a follow-up of their previous exploratory missions. 22-25/

The team consisted of a Chemical Engineer who was the team leader, two Pharmacists and a Botanist. The main objectives of this phase were to gather relevant data concerning medicinal and aromatic plants in each country, to carry out phytochemical analyses on plant material in collaboration with local personnel and institutions, and to examine the prospects of processing them locally with the final aim of developing a pharmaceutical industry.

A. Botswana

6.2 Botswana, despite the Kalahari desert, is not entirely deprived of vegetation. The team found that large areas of savannah grasslands, forests, hills and table-lands and even a delta in the north, characterized the relief of the country. The flora appeared rich in the neighbouring zones of the desert, where the rainy conditions favoured forest vegetation. An important number of species from these zones were medicinal and aromatic plants used in the country's traditional medicine.

Due to travel difficulties the vehicles were left elsewhere and the UNIDO experts went by air with a minimum of transportable equipment.

6.3 Chemical analyses were carried out by the UNIDO team in the laboratories of the Department of Agriculture.

In order to collect information, the botanist in the team made visits towards Lobatse, and Francis town regions and in the surroundings of Tschabong towards the southern part of the country.

Table III gives a list of seven species of medicinal and aromatic plants identified by the Botanist and which on the bases of phytochemical analyses were considered by the team to be suitable as a basis for the preparation of pharmaceuticals. These plants are recognized as such by the international pharmacopoeia. It was obvious that the list was not a comprehensive one as travel difficulties severely hampered the survey.

Table III

Seven plant species of Botswana suitable for production of pharmaceuticals

Botanical name of plant	Plant used	Content of pharmaceutical (from published literature)	Therapeutic activity
Achillea millefolium	Flowers	0.1 to 0.5% essential oil containing 50% chamazulenes	Stomachal haemostatic anti-inflammatory
Chenopodium	Whole plant	Essential oil 1% containing 60 to 80% Ascaridol	Antihelminthic
Datura innoxia	Leaves	Alkaloids 0.2 to 0.4% (containing 45 to 55% Scopotamine)	Nervous depressant anti-spasmodic, anti-parkinson
Datura stramonium	Leaves	Alkaloids 0.2 to 0.4% (Atropine, Hyoscyamine and Scopotamine)	"
Ocimum canum	Leaves	Essential oil 0.2 to 0.5% containing 40 to 50% Camphor	Cardiac rubifacient revulsive
Ricinus communis	Latex	Fatty oil 40 to 50%	Purgative
Strophanthus kombe	Latex	Glycosides Strophanthin 8%	Cardiotonic

Table IV gives the list of plants found growing wild in the flora and merits evaluation from the viewpoint of industrial potential.

Table IV

List of plant species growing wild in the flora of Botswana

	Name of species present in the flora of Botswana	Name of other related species industrially used or species which it may substitute	Likely active components or economic phyto-chemical	Possible therapeutic activity or economic use
1.	Aloe robrulutea A. saponaris A. zebrina	A. ferox A. vera A. perryi	Aloe-emodol Aloin	Tonic Stomachic, Laxative
2.	Balanites aegyptica	Dioscorea spp. Solanum spp.		
3.	Cassia abrus C. abbreviata C. biensis C. falcinella C. kirkii C. obovata	C. angustfolia C. acutifolia	Emodins Rhein Sennosides A + B	 Laxative
4.	Chenopodium bontea	Chenopodium ambrosoides and other species	Chenopodium and essential oil (Ascaridole and Safrol)	Anthelmintic
5.	Coryza stricta	Coryza squarosa	Flavanoids	Expectorant
6.	Croton gratissimus	Croton eleuteria	Essential oil	Atonic - As Cascarilla is used
7.	Cymbopogon plurinoides	Cymbopogon citratus	Essential oil/ Citral	As lemon-grass oil
8.	Dioscorea dumetorum D. Sylvatica	Discorea spp.	Disgenine	Synthetic intermediate
9.	Euphorbia candilabrum E. heterophylla E. ingens E. tirucalli	Euphorbia spp. E. resinifera	Resin Euphorbone	Nervous and cardiac Stimulant Vesicant in veterinary practice. Aromatic burning resin

Table IV (cont'd)

	Name of species present in the flora of Botswana	Name of other related species industrially used or species which it may substitute	Likely active components or economic phyto-chemical	Possible therapeutic activity or economic use
10.	Gomphocarpus fruticosus (syn. Asclepias fruticosa)		Glycosides	Cardiotonic (?)
11.	Harpagophytum peglerae H. procumbens			Anti-rheumatic + anti-tumour agent
12.	Lantana rugosa		Steroids [illegible]	
13.	Lippia javanica	Lippia spp.	[illegible]	Flavouring
14.	Lobelia erinus L. minutidentata	Lobelia inflata	Alkaloids (Lobeline)	Stimulate breathing anti-asthmatic
15.	Notholaena eckloniana		Essential oil steroids, flavanoids	
16.	Rhus lancea R. leptodictya R. guartiniana R. pyroides R. undulata	R. aromatica R. glabra R. coriaria and other spp.	Tannins	As tannin agents like Sumach tannin (R. coriaria)
17.	Solanum kwebense S. incanum S. nigrum S. panduraeforme	Solanum spp.	Solasodine	Steroid intermediate
18.	Strychnos coeculoides S. potatorum S. pungens	S. nux vomica	Alkaloids Strychnine and Brucine	Bitter tonic, depressant.
19.	Tagetes minuta	T. signata T. hybrida	Essential oil	
20.	Tarchonanthus camphoratus			
21.	Urginia altissima U. sanguinea	U. marifina syn: Scilla maritima	Glycosides Scillarin A and B	Cardiotonic

6.4 Besides these plants found already growing in Botswana the UNIDO experts identified several well-established species which were recommended for introduction by cultivation, in the eastern part of Botswana. The experts emphasized the need for further botanical evaluation of the flora of Botswana, especially in Ngamiland and Kgalagadi districts. Accordingly UNIDO is currently developing a project together with the Government, to further explore the forest flora of the country with a view to establishing the nucleus of a unit which will assess the possibilities for utilization of the already existing species and cultivating these and several other introduced species for the preparation of pharmaceuticals.

6.5 B. Burundi

In Burundi too, a rich and varied natural flora was encountered by the UNIDO-Romania team. The team's laboratory activities were conducted at the Laboratoire Pharmacologique du Burundi, Bujumbura. At the same time, the facilities of l'Institut des Sciences Agronomiques du Burundi (ISABU) were placed at the disposal of the team. The UNIDO experts were able to initiate work on the culture of several introduced species.

6.6 The Laboratoire Pharmaceutique du Burundi at Bujumbura functions under the Ministry of Health, and has facilities for the pilot-scale production of powders, tablets, pommades, syrups and other forms, together with physico-chemical quality assessment facilities. The production capacity could only meet internal demands, but for any more ambitious production programmes equipment as well as personnel were lacking. In Burundi there was no specific agency or institution committed to activities related to the utilization of medicinal and aromatic plants.

6.7 The team noted the existence of comparatively small cultivations of Cinchona (Cinchona succirubra). The University of Bujumbura had a herbarium which had around 8,000 authenticated species of medicinal and aromatic plants but there was no way to ascertain the numbers and quantities of such plants which were contained in the indigenous forest flora. It was evident though, that the number and quantity were certainly sufficient for rational utilization.

Table V gives an indication as estimated by the UNIDO experts, of the estimated occurrence of 12 well-established species, which have definite use as indicated in established pharmacopoeias. Table VI gives the estimated occurrence of 19 other species which could be utilized after preliminary studies, for the production of pharmaceuticals.

Table V

Indication of the occurrence in Burundi of plants mentioned in well-established pharmacopoeias

No.	Species	Occurrence: mean height above sea level		
		780 - 1,000 m	1,000 - 1,600 m	1,600 - 2,490 m
1.	Chenopodium ambrosiodes	x	x	x
2.	Ricinus communis	x	x	x
3.	Ocimum basilicum	x	-	-
4.	Sesamum indicum	x	-	-
5.	Phytolacca dodecandra	-	x	x
6.	Capsicum frutescens	x	-	-
7.	Datura stramonium	x	x	x
8.	Cinchona succirubra	x	x	-
9.	Eucalyptus globulus	x	x	-
10.	Gomphocarpus fruticosus	x	x	-
11.	Cymbopogon citratus	x	x	-
12.	Catharanthus roseus	x	x	-

Table VI

Indication of the occurrence of other species that warrant investigation

No.	Species	Occurrence: mean height above sea level		
		780 - 1,000 m	1,000 - 1,600 m	1,600 - 2,400 m
1.	Rauwolfia obscura			x
2.	Balanites aegyptica	x		
3.	Cassia aoscus	x		
	C. alata	x		
	C. mimosoides	x	x	
	C. obtusifolia	x		
4.	Erythrococca atrovirens			x
5.	Euphorbia candelabrum	x	x	
	E. dawei	x		
	E. hirta	x		
	E. longecarnuta			x
	E. tirucali	x	x	
6.	Scopolia rhamniphylla		x	
7.	Geranium aculeolatum			x
8.	Ocimum suave			x
9.	Lobelia dissecta			x
	L. giberroa		x	x
	L. halstii			x
10.	Strychnos angolensis		x	
	S. innocua	x	x	
	S. lucens		x	
	S. potatorum	x		
11.	Acacia pentagona			x
	A. polyacantha	x	x	
	A. siberana	x		
12.	Passiflora foetida	x		
13.	Polygala arenaria	x	x	
	P. bakerana	x	x	
	P. capillari	x		
	P. melilotoides	x	x	
	P. persicariifolie		x	
	P. petitiana			x
	P. stanleyana	x		
14.	Plantago palmata		x	x

Table VI (cont'd)

No.	Species	Occurrence: mean height above sea level		
		780 - 1,000 m	1,000 - 1,600 m	1,600 - 2,400m
15.	Solanum aculeastrum	x	x	x
	S. incanum	x		
	S. indicum	x		
	S. nigrum			x
16.	Pimpinella englerana		x	
17.	Discorea cochleari-epiculata	x	x	
	D. dumentorum	x	x	x
	D. prachensilis	x	x	x
	D. quartiniana			x
18.	Cymbopogon afronardus	x	x	
19.	Urginea altissima	x	x	x

6.8 C. Rwanda

The UNIDO experts found in Rwanda an organized effort and dedication towards the study of the traditional pharmacopoeia and the medicinal and aromatic plants used as medicaments. The mobile unit was easily able to establish liaison with the research group of the National University of Rwanda at Butare, and use their laboratories and facilities for the work of the mission. The group had displayed considerable interest in a selection of about 140 remedies which were prescribed by the "guerisseurs" */ for the treatment of about 50 different afflictions of the human body. The group had initiated phytochemical and pharmacological investigations on a few of these remedies. At the present time the research activity confined to the traditional pharmacopoeia and aromatic and medicinal plants centred around activities within the following Rwandese institutions:

- the Faculties of Science and Medicine of the National University of Rwanda;
- the Institut National de Recherche Scientifique (INRS);

*/ Native physicians

- the Institut des Sciences Agronomiques du Rwanda (ISAR);
- a pilot forestation project (Kibuye at Arboretum de Rubavu);
- the hospital of Kibungo: and
- the Laboratoire Pharmaceutique du Rwanda.

The research group already possessed the nucleus of activity and a laudable multidisciplinary approach. It was recognized by the UNIDO experts that assistance should primarily take a form which will help co-ordinate the indigenous activity, and establish a pilot-scale production facility, */ in the country.

The Rwandese had already compiled documentation on the Ethnobotany of the Rwandese flora, 26/ which was made available to the UNIDO experts and which was invaluable to them in their work.

6.9 There were many species of plants, in sufficient quantities, to initiate pilot-scale production of medicaments that were in demand. About 20 such species of medicinal and aromatic plants as recognized by the experts are listed in table VII, while those plants which the experts found growing in Rwanda but which needed further assessment from the point of view of their utilization for the production of pharmaceuticals are listed in table VIII.

Table VII

Utilizable medicinal plants growing in Rwanda

No.	Plant species	Part used	Abundance	Economic products	Ethnomedical pharmaceutical or other usage
1.	Acacia senegal	Bark + wood	aa	Gum arabic	Emulsifier
2.	Agave sisalana	Juice	b	Hecogenin	Synthetic intermediate to cortico steroids
3.	Capsicum annuum	Pods		Capsicum Oleoresin + Capsaicine	
	C. frutescens	Pods		"	"

*/ Based on the proposals that came out of this mission UNIDO has now initiated under UNDP auspices a US$300,000 project in Rwanda.

Table VII (cont'd)

No.	Plant species	Part used	Abundance	Economic products	Ethnomedical pharmaceutical or other usage
4.	Carica papaya	Latex + fruits	b	Papain	Meat tenderiser Gastro enteritis Dyspepsia
5.	Catharanthus roseus	Roots + leaves	b,a	Vimblastine Vincristine Raubasine	Antimitotic in treatment of leukaemia and Hodgkin's disease; Vasodilator Hypotensive
6.	Chenopodium ambrosioides	Whole plant	a	Essential oil: Ascaridol	Vermifuge
7.	Conchona ledgeriana	Bark of stem and root	b	Quinine Quinidine	Antimalarial
8.	Cucurbita pepo	Seeds	b	Cucurbitine	Vermifuge
9.	Cymbopogon citratus	Whole plant	b	Essential oil: Citral	Vitamin A Synthesis Cosmetics
10.	Datura stramonium	Leaves + flowers	aa	Alkaloids: Atropine + Scopolamine	Antispasmodic
11.	Eucalyptus globulus	Leaves	aa	Essential oil: Cineole	Cosmetic Decongestant
12.	Lycopodium clavatum	Pollen	aa	Powder	Skin ailments
13.	Melaleuca leucadendron	Leaves	aa	Essential oil: Oil of Cajeput	Antiseptic, anti-rheumatic preparations and skin ailments
14.	Nerium oleander	Leaves	a	Oleandrin	Coariotonic Diuretic
15.	Ocimum gratissimum	Flowers + stems	a	Infusion Powder	Antispasmodic stomachic
16.	Rheum officinale	Rhizomes	a	Powder; Total extract Chrysophanol	Purgative
17.	Rhus vulgaris	Stem Bark + Leaves	a	Tannins	Anti-haemorrhoidal agent
18.	Ricinus communis	Seeds	a,b	Castor oil	Purgative
19.	Sesamum indicum	Seeds	b	Edible oil Foods	Pharmaceutical carrier, diluent

Key to table: a = abundant
aa = very abundant
b = cultivated species available in sufficient quantity

In Rwanda, the UNIDO experts examined several species of Eucalyptus, which had obviously been introduced into the country and were now being maintained for timber purposes. The laboratory facilities of the mobile unit along with those of the University of Rwanda were used to conduct analyses for the essential oil content in the species growing in Rwanda.

The results of these analyses are recorded in table IX.

Table VIII

Plants which are available in sufficient quantities in Rwanda and warrant further assessment

	Plant	Part used	Likely constituent(s) products	Ethnomedical pharmaceutical or other usage
1.	Abrus precatorius	Roots	Glycyrrhetic acid	for ulcers
2.	Centella asiatica	Whole plant	Asiaticoside	
3.	Cissampelos mucronata	Roots	Hayatine	Muscular relaxant
4.	Commifora africana	Bark	Oleoresin	Antiseptic
5.	Cymbopogon aponardus	Whole plant	Essential oil	Insect repellent
6.	Euphorbia hirta	Whole plant	Juice	Antiasthmatic, anti-amoebic agent
7.	Gloriosa simplex	Rhizome	Alkaloids Colchicine	Anti-tumour agent Anti-rheumatoid
	G. superba	Rhizome	"	"
8.	Lobelia spp.	Whole plant	Lobeline	Respiratory disorders
9.	Melia azedarach	Leaves + bark	Oil, powder	Tonic and variety of uses
10.	Plumbago zeylanica	Roots	Plumbagin	Anti-microbial, anti-fertility agent
11.	Prunus africana	Bark	Total extract	Anti-neoplastic agent
12.	Solanum nigrum		Solasodine	Synthetic intermediate for steroids
13.	Thalictrum rhynochocarpum	Roots	Berberine	Anti-dysenteric
14.	Thevetia neriifolie	Seeds	Peruvoside	Cardistonic
15.	Tribulus terrestris	Whole plant	Diosgenin	Synthetic intermediate for vorticosteroids

Table IX

Quantitative estimations of the essential oil content of Rwandese Eucalyptus spp.

Species		% content of oil in leaves
E. globulus	(fresh)	1
E. globulus	(dry)	3.5
E. citriodora	(partly dried)	1.5
E. cinerea	(fresh)	1.4
E. maidenii	(semi-dried)	2.2
E. smithii	(semi-dried)	1.7

Several pharmaceutical preparations were prepared by the experts in collaboration with the scientists of the University of Butare.

6.10 After the visit of the mobile unit, the Romanian experts were able to assist the Government of Rwanda and UNDP (with UNIDO as executing agency) to formulate a project proposal for: The Establishment of a Pharmaceutical Production Unit Based on Medicinal Plants, and also for research on medicinal and aromatic plants to be conducted at the University of Butare's Centre Universitaire de Recherche sur la Pharmacopoie et la Médicine Traditionelle (CURPHAMETRA). The project which involves UNDP, funding to the extent of US$300,000 is now under way. Equipment including a complete pilot-plant assembly for extraction of medicinal plants and distillation of essential oils will be installed during the course of 1981-1982 and several UNIDO experts will work for brief periods to initiate both production and agronomic activities.

6.11 D. Sudan

The UNIDO mobile unit's one month mission in Sudan commenced in November 1979. Information and data concerning the medicinal and aromatic plants in the flora of Sudan were obtained by the mission from local specialists of the Medicinal and Aromatic Herbs Research Unit (MAHRU), Faculty of Pharmacy, University of Khartoum, and the Industrial Research and Consultancy Institute, Khartoum.

Then the mobile unit itself collected samples and data on medicinal and aromatic plants along the following route: Port Sudan, Wad Medani, Khartoum and environs, El Obeid, Wan, Tombora, Yambio, a linear distance of approximately 2,600 kms.

6.12 The UNIDO experts visited the experimental farm for medicinal and aromatic plants, under the control of the Medicinal and Aromatic Herbs Research Unit; the extent of the farm was 4 ha with possibilities of extension to 60 ha if needed. Irrigation facilities were also available to this farm. Apart from this farm there was no other organized cultivation of medicinal and aromatic plants, nor was there any organization dealing with the harvesting and processing. It was noted that plants were collected by local healers and medicaments processed by them to suit their own needs.

6.13 Among the multitude of indigenous species of medicinal and aromatic plants present in Sudan, table X lists 18 species available in abundant quantity. Many of these species are well-known and, included in recognized pharmacopoeias, these could form the basis of raw material for industrial processing, initially, for local requirements.

There are also a small number of plants which were found to grow abundantly, and on account of the fact that they were related to plants which have been economically utilized they were deemed to merit further investigation. They are listed in table XI.

In addition the UNIDO experts evaluated the possibilities of cultivation of well-known species of medicinal and aromatic plants after introduction of suitable cultures into the country. Table XII lists some of those plants which the experts felt could be introduced for cultivation.

6.14 The UNIDO experts felt that Sudan possessed climatic features which could be taken advantage of for the cultivation of a variety of medicinal and aromatic plants. As the country possessed large areas for cultivation with the added advantage of labour availability there were obvious prospects for the industrial production of plant-derived pharmaceuticals.

Furthermore it was felt that cultivation could also realize export market possibilities. Where the experts felt attention was urgently needed were the following:

- A botanical survey of the flora;
- Organization of cultivation and harvesting of plants for medicinal purposes;

Table X

Well recognized medicinal and aromatic plants found growing in the Sudan in abundance

No.	Name of species	Part used	Phytochemical + pharmaceutical interest	Therapeutic usage
1.	Cassia acutifolia a/	Leaves	Sennosides	Laxative
2.	Ricinus communis b/	Seeds	Fixed oil; Ricin	Purgative
3.	Capsicum frutescens c/	Fruits/ pods	Capsaicine	Local application
4.	Datura stramonium b/	Leaves	Alkaloids	Anti-Parkinson effects; Depressive
5.	D. innoxia d/	Leaves	Alkaloids	"
6.	Rauwolfia vomitoria a/	Roots	Alkaloids	Anti-hypertensive agent
7.	Catharanthus roseus c,b/	Leaves	Alkaloids	Anti-leukaemic agent
8.	Carica papaya b,d/	Latex	Papaine	Gastro-enteritis, Dispepsia, Meat tenderizer
9.	Cucurbita pepo. b/	Seeds	Fixed oil	Anthelmintic
10.	Cucurbita maxima b/	Seeds	Fixed oil	Anthelmintic
11.	Foeneculum vulgare c/	Seeds/ fruits	Essential oil	Carminative/ flavouring
12.	Anethum graveolens c/	Seeds/ fruits	Essential oil	Flavouring
13.	Citrullus colocynthis a/	Seeds/ fruits	Fixed oil	Purgative

Key to Table X: a/ grows spontaneously in specific region
b/ grows spontaneously, widely spread out in all regions
c/ cultivated in certain regions
d/ cultivated generally

Table XI

Medicinal and aromatic plants found growing in Sudan in abundance, which warrant further investigation with regard to their possible utilization

No.	Name of species	Location
1.	Hibiscus subdoriffe [c/]	Central and southern regions
2.	Tamarindus indica [a/]	Central region and southern regions
3.	Acacia nikotica [a/]	Northern and central regions
4.	Solonostema argel [a,c/]	Northern region
5.	Mentha viridis [c/]	Nile valley
6.	Cymbopogon proximus [a/]	Northern and central regions
7.	Lupinus ternais [c/]	Northern and central regions
8.	Balanites aegyptiaca [a/]	Nile valley and central region
9.	Cuminum ciminum [c/]	Northern region
10.	Lawsonia alba [c/]	Northern and central regions
11.	Slavadora persica [a/]	Central and southern regions

Key to Table XI as in Table X

Table XII

Plants which are recommended for cultivation in Sudan

	Essential oil-bearing plants	Alkaloid bearing
1.	Pimpinella anisum	Cinchona spp.
2.	Mentha piperita	Strychnos nux - vomica
3.	Mentha crispa	Strophanthus spp.
4.	Matricaria chamomilla	
5.	Carum carvi	
6.	Coriandrum salivum	

- The setting up of a few more experimental farms particularly one in the Nile valley.

The Sudanese authorities and UNIDO will in the near future be, hopefully, following up these mobile unit recommendations towards developing the industrial production of plant-derived pharmaceuticals.

6.15 E. Tanzania

The Tanzanian lap of the UNIDO mobile unit mission took place during January 1980.

The Tanzanian Traditional Medicine Research Unit (TMRU) located at the Muhimbili Medical Centre played an active collaborating role. Here too the experts demonstrated phytochemical determinations and the preparation of various plant-derived pharmaceutical products. As a consequence of the first exploratory mission to Tanzania in December 1977 UNIDO had programmed to make available about US$5,000 worth of chemicals and supplies to Tanzania to facilitate the work of the mobile unit.

6.16 The present Tanzanian work on medicinal and aromatic plants was confined to the TMRU and the Faculty of Pharmacy, and the Department of Botany of the University of Dar-es-Salaam. These institutions provided the mobile unit's experts with background information on the flora of Tanzania. The Herbarium of the TMRU had compiled a short-list of around 1,000 species of plants used by the local physicians in the treatment of over a hundred varied ailments. The list had been compiled from specialized local publications.

Tanzania is already famed for such well-known spices as Cardamom (Ellectaria cardamomum) and Clove (Eugenia caryophyllata), and well-known medicinal plants such as Cinchona succirubra, and Agave sisalana. Export trade in these and other species already exists. In the case of Agave sisalana, which is used for producing textiles as well as a source of Hecogenin, the concentrated extract is exported.

6.17 In Tanzania the plants that already occur in abundant quantity and can be used as the nucleus of industrial production of pharmaceuticals, on account of their known constituents and use are listed in table XIII. These again, are plants with a ready market demand for their products, in addition to their contribution towards local pharmaceutical use.

Plants available already and which should receive further scrutiny are listed in table XIV.

Table XIII

Utilizable plants of Tanzania

No.	Name of Plant species	Part used	Estimated Abundance	Phytochemical and pharmaceutical interest/ Economic products	Therapeutic usage Ethnomedical use
1.	Acacia senegal	Gum exudate	aa	Arabinose	-
2.	Agave sisalana	Leaves	b	Hecogenin	-
3.	Capsicum frutescens	Pods	b	Capsaicine	Anti-rheumatic
4.	Cinchona succirubra	Bark	b	Alkaloids	Anti-malarial
5.	Chenospodium embroisioides	Whole plant	aa	Essential oil	Anthelmintic
6.	Cola nitida	Seeds	b	Cafeine	Stimulant, Cardiotonic
7.	Citrus aurantium	Leaves, fruits, bark	c	Essential oil	Psychodepressor Antispasmodic
8.	Cymbopogon citratus	Leaves	c	Essential oil	Tonic/flavouring
9.	Datura stramonium	Leaves	a	Alkaloids	Depressant, anti-Parkinsons agent
10.	Eucalyptus globulus	Leaves	b	Essential oil	Decongestant
11.	Eugenia caryophyllata	Buds + stems	b	Essential oil Eugenol	Analgesic
12.	Foeniculum officinale	Fruits	b	Essential oil	Carminative
13.	Gomphocarpus fruitiasus	Seeds	a	Glycosides	Cardiotonic
14.	Ocimum basilicum	Aerial parts	aa	Essential oil	Carminative
15.	Phytolacca dodecandra	Roots	b	Alkaloids	Anthelmintic + laxative
16.	Punica granatum	Root + bark	c	Alkaloids	Taenifuge
17.	Rauwolfia vomitoria	Roots	a	Alkaloids	Nerve sedative Anti-hypertensive
18.	Ricinus communis	Seeds	a,b	Fixed oil	Laxative, rubefiant

Key as in Table X.

Table XIV

Medicinal and aromatic plants found in abundance in the indigenous flora of Tanzania, which merit further investigation as regards utilization for production of pharmaceuticals

No.	Name of species	Plant part used	Use in traditional medicine
1.	Aloe flexilifolia A. graminicola A. rabainensis	Sap of the succulent leaf	Inflammation of glands; testes; enlarged spleen in malaria; stomach ailments
2.	Asparagus africanus	Roots	Bronchial condition, throat infection
	A. racemosus	Roots	Gonorrhea and infections
	A. setacens	Fruits/leaves	Bronchial pneumonia
3.	Balanites aegyptica	Roots	Laxative
4.	Calotropis procera	Roots	Snake bite
5.	Cassia abbreviata	Roots	Malarial fevers
	C. absus	Roots	Stomach disorders
	C. afrofistula	Roots/leaves	"
	C. alata	Leaves	Skin ailments (ringworm) Eliminate placenta
	C. italica	Leaves/roots	Gonorrhea; Laxative
	C. obtusifolia	Aerial parts	Stomach disorders
	C. senna	Roots/bark	Laxative
6.	Centella asiatica	Aerial parts	Syphilis
7.	Discorea esterricus	Leaves	Eye infections
	D. dumetorum	Roots	Bilharziasis/Schistosomiasis
	D. guartiniana	Roots	Plague + fevers
8.	Eucalyptus bicostata	Leaves	Chicken Pox
9.	Euphorbia candelabrum	Stems	Post-partum release of placenta
	E. hirta	Leaves	Asthma
	E. obovalifolia	Wood	Cramps in late pregnancy and delivery
	E. tirucalli	Roots	Snake bite; sterility
	E. usambarica	Roots	Children's ailments

Table XIV (cont'd)

No.	Name of species	Plant part used	Use in traditional medicine
10.	Gloriosa superba	Roots	Abortion
11.	Hypericum peplidifolium	Roots	Infections and indigestion
12.	Iboze meltiflora	Roots	Bilharzia/Schistosomiasis, Pneumonia and Pulmonary infections; Indigestion
13.	Lobelia anceps	Leaves	Inflammations
	L. holstii	Roots	Bronchitis
14.	Passiflora edulis	Roots	Ear infections
15.	Pelargonium alchemilloides	Leaf juice	Eye infections
	P. quinquelobatum	Roots	Diarrhoea in children
16.	Pimpinella keniensis	Roots/leaves	Orchitis (testicular inflammation)
17.	Polygala erioptera	Whole plant	Children's ailments such as coughs, skin rashes and whitlow
	P. paniculata	Extract of fresh roots	Aphrodisiac
	P. stenopetale	Leaves	Eye infections
18.	Rhus vulgaris	Fruits, roots, leaves	Diarrhoea, Gonorrhea, Infertility
19.	Scilla indica	Bulb/Rhicome	Earache
20.	Solanum aculeastrum	Roots	Bronchitis
	S. incanum	Roots	Abdominal pain, dyspepsia
21.	Strophanthus eminii	Roots	Worm infectations, febrifuge
22.	Strychnos spinosa	Roots	Earache
23.	Tamarindus indica	Leaves and stems	Diarrhoea + Dysentery

6.18 Based on the work of the mobile unit, and the observations made by a UNIDO programming mission which visited Tanzania at the beginning of this year, UNIDO has formulated a project for assistance in the production of plant-derived pharmaceuticals in Tanzania. The project is expected to commence during 1983.

6.19 In all the countries visited by the UNIDO mobile unit, a common feature noted by the team was the genuine interest and commitment to utilize the plant resources towards the following ends:

(i) Employment of modern technology in the preparation of medicaments based on the traditional pharmacopoeias, for the health-care needs of the people;

(ii) Utilization of plant resources to prepare exportable pharmaceuticals;

(iii) Enhancing local capability in:

Research
Technology
Quality assessment
Cultivation practices.

It is obvious from the subsequent reactions that the mobile unit's visit gave great impetus to the efforts towards these ends. For instance, in each country the mobile unit was able to demonstrate the preparation of a whole array of pharmaceutical products, depending on available resources of raw materials and facilities (table XV). Many pharmaceutical products already being prepared on a small scale in an ad hoc manner, to suit local traditional pharmacopoeial requirements, could undoubtedly be produced on a pilot-plant scale in all of the countries visited. This aspect, and the necessary and sufficient quality control, stability tests and standardization are discussed later in this review.

7. OTHER ONGOING UNIDO PROGRAMMES IN PROSPECT AND RETROSPECT

7.1 Two of UNIDO's earliest programmes on the development and utilization of medicinal and aromatic plants are in Guinea and the United Republic of the Cameroon (Vide Fig. 1). Both countries are situated on the West African coast and have in common the historical fact that several Cinchona species are indigenous to them, and between the wars the extraction and processing of quinine and accompanying alkaloids on a commerical scale was being carried out by European drug companies, within these countries. The UNIDO projects these two countries are described below.

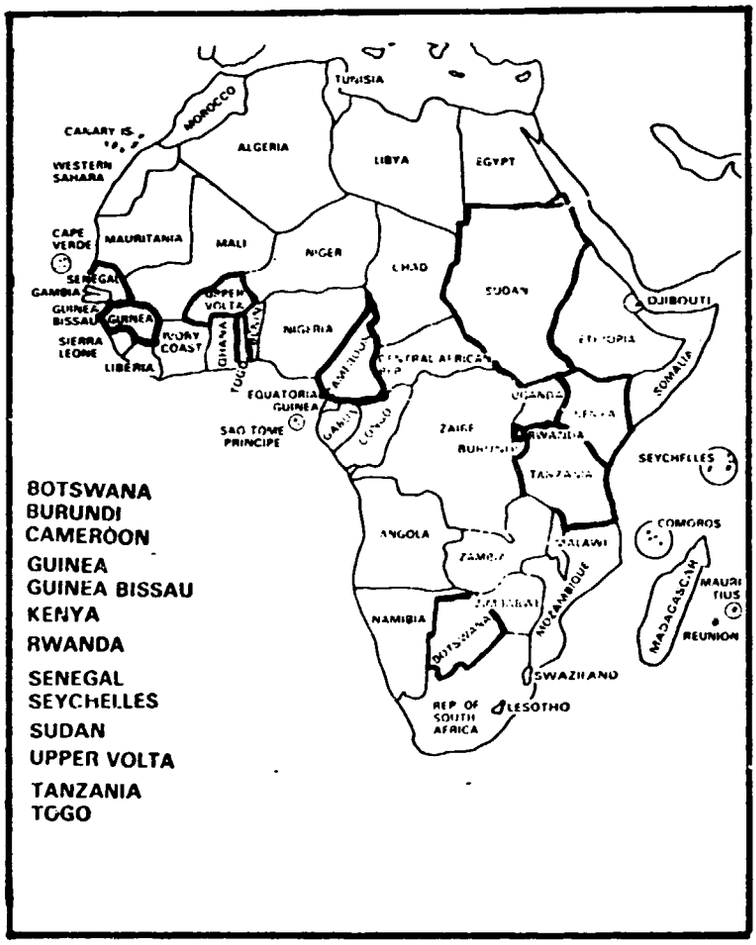


Fig. 1 Location of UNIDO activities on the Utilisation of Medicinal and Aromatic Plants within the African Region.

Table XV

Some examples of pharmaceuticals containing plant-derived products prepared for demonstration by the mobile unit in the various countries visited

1. Tincture cardamomum

   Composition: fructus cardamomi

2. Compound cardamomum tincture

   Comp.: Fructus cardamomi
   Fructus carum carvi
   Cartex cinnamomi
   Cochineal

3. Tincture cinchcnae

   Comp.: Cartex cinchonae

4. Tincture capsici

   Comp.: Fructus capsici

5. Colae tincture

   Comp.: Semen colae

6. Tincture Eucalypti

   Comp.: Folium eucalypti

7. Tincture stramonii

   Comp.: Folium stramonii

8. Coffee tincture

   Comp.: Caffea arabica

9. Anti-rheumatic preparation

   Comp.: Extract of capsicum
   Methyl salicylate

10. Disinfectant of buccal cavity

    Comp.: Benzoi acid
    Dil of Eucalyptus

11. Anti-toussive solution

    Comp.: Tincture stramonium
    Tincture aconite
    Tincture eucalyptus
    Codeine

12. Analgaesic solution

    Comp.: Oil of cajput
    Oil of helianthus

13. Antispasmodic and antiacid powder

    Comp.: Folium stramonii
    Oil of citronella

14. Analgesic and anti-fever tablets

    Comp.: Cinchonae pulvis
    Salicylic acid

15. Dentifrice powder

    Cortex cinchonal
    Charcoal
    Oil of mint

16. Pardiatric syrup sedative

    Tinctura passiflora

17. Tea for stomach cholic

    Flores chamomillae
    Folium menthae
    Fructus foeniculi
    Fructus coriandri

18. Laxative tea

    Folium sennae sine resina
    Folium theae

7.2 A. Guinea

Guinea, ranked as one of the LDCs of Africa is rich in plant species that have been employed in the traditional systems of medicine throughout the entire African region. It is also known that around 80 per cent of the Guinean population live in rural areas. Furthermore 80 per cent of the economically active section of this population are engaged in primary sector industries such as agricultural, farming, herding, hunting and fishing. [27] There are large plantations of such well known medicinal plant species like Rauwolfia, and Cinchona in Guinea, and raw material from them has been extracted and exported in the past.[28,29]

7.3 The pharmaceutical industry in Guinea is a public sector industry and PHARMAGUINEA, the national agency responsible for pharmaceuticals, is engaged in the production of pharmaceuticals valued at over a million dollars each year. Among these are galenicals from medicinal plants and preparations used in traditional medicine. PHARMAGUINEA also possesses a herbarium of medicinal plants and had been engaged in exploratory work on the Rauwolfia species. The percentage of the population utilizing traditional health-care methods is estimated at 60 per cent.

7.4 The medicinal plants found in Guinea and considered [30] as priority-candidates for possibilities of utilization in the preparation of pharmaceuticals within the country are listed in table XVI.

Table XVI

List of medicinal plants recommended as priority candidates for utilization in the production of pharmaceuticals within Guinea

	Name of plant species (part used)	Product possibility	Therapeutic use/ indications
1.	Borreiria verticillata (whole plant)	Extract	Skin infections
2.	Capsicum frutescens (Pods)	Tincture/Extract	Rheumatism
3.	Cassia alata, C.siberiana	Extract	Laxative
4.	Combretum migrantum (Root)	Extract	Intestinal infections
5.	Harungana madagascariensis (leaves, bark, root)	Extract	Fever; Interruption of menses
6.	(Kola)		Tonic, stimulant
7.	Lippia adoensis (leaves)	Extract/Essential oil	Fever, decongestant
8.	Xilopia aethiopica	Tincture; extract	Uterotonic effect

7.5 UNIDO's interest in Guinea with regard specifically to the utilization of its resources in plants, goes back to 1970, when a UNIDO expert [28] studied and reported on the potential for utilizing indigenous plants for the production of both essential oils and edible oils. Since this report, UNIDO has been engaged in rendering sustained assistance in strengthening the capacity and enlarging the scope of activities of the Central Laboratory for Vegetable and Essential Oils (now the Central Analytical Laboratory) at Conakry.

This laboratory's current activities include analytical work on essential oils, fixed edible oils, food and pharmaceutical products, toiletries and cosmetics, and the phytochemical screening of medicinal and aromatic plants.

UNIDO initiated in 1978 under UNDP assistance, a comparatively large assistance programme of development at the central laboratory. Two experts were provided, one a technologist with experience in production and marketing of pharmaceuticals of plant origin and the other an analytical chemist specializing in the quality assessment of edible oils. The entire project which carries a budget of US$260,000, included partially equipping a new laboratory building in Matoto, which has now been accomplished. In addition UNIDO provided a project manager and training facilities for four local scientists during 1979-1980. The phased training programme was conducted in institutions in France and Belgium and the Guinean personnel were trained in the following areas of activity:

- Toxicology of foods and forensic science (1);
- Pharmaceutical analysis and formulation (2);
- Analytical chemistry and methods of quality assessment in food and pharmaceutical products.

The UNIDO expert in chemical analyses has drawn up protocols for the analyses and quality assessment for a variety of items such as essential oils, food products and cosmetics, produced in the country and requiring regular quality control.

The UNIDO Project-Director on site, along with his national counterpart has put forward comprehensive proposals to the Government in regard to the reorganization of this laboratory. [31] The proposals include administrative plans, a plan for the technical and managerial work, as well as a realistic plan of work for the laboratory. Both UNIDO and the Government of Guinea have positive interests in developing the Central Analytical Laboratory in Matoto to serve the people of Guinea as a national laboratory for all analytical work as well as for the R + D activities connected with two other projects, viz: the development of an essential oil industry, and the utilization of Cinchona species and other indigenous medicinal plants.

7.6 At Labé, north of Conakry, the Société Industrielle des Plantes Aromatiques (SIPAR) has been producing, albeit sporadically, various essential oils from indigenous plants. These include those in table XVII. A UNIDO expert sent out in 1979 reported[29,30] on the possibilities for rehabilitation of the SIPAR complex.

Table XVII

Essential oils produced in Guinea at various times

Common name (under cultivation)	Botanical name	Plant part used	Essential oil/product obtained and main constituents
1. Karo Karondé */	Leptochtina senegambica	Flowers	Oil of Karo
2. Jasmin (57 ha)	Jasminium officinale	Flowers	Oil of Jasmine and concrete
3. Bigaradiers (93 ha)	Citrus bigaradia	Fruits + flowers	Oil of Bigarade Neroli oil
4. Bergamot (41.5 ha)			
5. Orange */	Citrus sinensis	Rind of fruit	Orange oil

*/ Grows partially wild, and gathered by peasants for cottage seak distillations as well.

The plantation-cum-factory complex had been initiated in 1928 by the Compagnie Africaine des Plantes à Parfum and was in operation even as recently as 1970. It had been functioning as a State enterprise since 1973. The plantations now are in need of expert agronomic attention with a view to increasing extent and quality, and the factory too is in need of equipment and supplies.

On the basis of the observations made by the UNIDO expert, and the discussions the expert had with leading manufacturing companies in France, a new project has been drawn up by UNIDO which is awaiting consideration for funding. [30 - 33/]

7.7 The Station Autonome de Sérédou is a similar venture which possesses a plantation of Cinchone (mainly C. succirubra, and C. ledgeriana) and a factory for the extraction of quinine and accompanying alkaloids. Again on the basis of reports and evaluations by UNIDO experts a project has been formulated and is under consideration by the Government. The project seeks to utilize the existing plantations and equipment, together with the agronomic expertise and experience of rural cultivators in the surrounding areas, for the cultivation of selected medicinal plants and the preparation of plant-derived pharmaceuticals which are vitally needed in the country.

7.8 B. United Republic of the Cameroon

Cameroon has a great variety of ecological zones from the Sahel in the north down to the equatorial forests in the south. The variety of climatic zones, and the diversity of natural conditions due to geology and relief gives rise to a rich and varied flora. The range of food crops produced in the country [32] bears evidence of this diversity. There are tubers (manioc, macabo, taro and yams), cereals (rice, millet, sorghum, maize), and plantains, beans, groundnuts as well.

7.9 As regards medicinal plants, while a very wide range is available, none are cultivated on a large scale. Collections of wild-growing plants have been organized for the purposes of export. A single member [34] UNIDO mission in 1978-1979 sought to identify problems and examine the feasibility of utilizing the existing flora to produce plant-derived pharmaceuticals in the Cameroon. UNIDO's expert (on whose recommendations UNIDO and UNDP have initiated a comprehensive project of assistance in the utilization of medicinal plants) found that there were several plants growing in the Cameroon, which had established reputations as sources of biologically active constituents (table XVIII).

Table XVIII

Indigenous Cameroon plants which contain therapeutically utilized constituents

Name of plant	Plant part used	Constituent(s)/Therapeutic usage
1. Voacanga africana V. thouarsii	Seeds	Tabersonine - for synthesis of Vincamine
2. Rauwolfia vomitoria	Root bark	Ajmaline, raubasine
3. Pausinystalia yohimbe	Stem bark	Yohimbine
4. Physostigma venenosum	Seeds	Physostigmine
5. Cola nitida	Seeds	Caffeine
6. Theobroma cacao	Seed-coat	Theophylline, Teobromine
7. Pentadiptandra brazzeana	Root	Total alkaloids for treatment of haemorroids
8. Prunus africanum	Bark	Total standardized extract for treatment of prostatic hypertrophy
9. Strophanthus gratus	Seeds	G-Strophanthine

7.10 It has been noted that eight of these nine items are exported, and the extraction and isolation was carried out in Europe and the United States.

The export approximate figures for 1977-1978 were as indicated in table XIX.

Table XIX

Approximate export statistics of some crude drugs from the Cameroon [34]

Drug	Quantity in tonnes
Prunus (Pygeum) africana	900
Voacanga spp.	370
Pausinystalia yohimbe	< 200
Rauwolfia spp.	< 200
Physostigma venenosum	
Cola nitida	5 - 10
Pentadiptandra brazzeana	

As against this the UNIDO expert found that the Cameroon imported approximately 2,725 tonnes of pharmaceutical products per year, valued at US$11-12 million. It is not too optimistic therefore to believe that at least some of this import component could be substituted with locally manufactured plant-derived pharmaceuticals and part of the cost of imports offset by the earnings of locally prepared exportable products as well.

7.11 The UNIDO expert examined the current research facilities in the Cameroon which would form the basis for future development of a pharmaceutical industry based on the utilization of medicinal plants. A Centre d'Etudes des Plantes Médicinales (CEPM) had been created under the leadership of Professor J. Kom Mogto, within the Office National de la Recherche Scientifique et Technique (National Office for Scientific and Technical Research)(ONAREST) now designated Direction Générale à la Recherche Scientifique et Technique (DGRST).

The CEPM has been responsible for an "Inventory of Medicinal Plants of the Cameroon" - an alphabetical list of medicinal plants used in traditional health-care practice by the "guerisseurs", and confined (so far) to the western provinces (Bafoussam-Fomban region).

The data collected has been classified both according to botanical families, as well as therapeutic usage. The authentication of the plants had been carried out at the National Herbarium of Cameroon. This inventory is to be expanded to

cover all seven vegetation zones of the Cameroon and when complete the inventory would represent a commendable accomplishment. The Department of Organic Chemistry of the University of Yaoundé had undertaken during the past few years phytochemical studies on plants such as Holarhena floribunda, Funtamia elastica, and Piper guineanse. However pharmacological evaluation had lagged behind. From the industrial viewpoint the UNIDO expert viewed with satisfaction the work on the Voacanga species where the alkaloid Tabersonine could be isolated. The work had been carried out in collaboration with the Belgian company OMNIUM CHIMIQUE which possessed patented technology for the synthetic conversion of Tabersonine to Vincamine, an alkaloid which is valuable in therapy as a cerebral vasodilator, and about 15 tonnes of which are used annually.

7.12 The UNIDO expert also visited the abandoned quinine factory at Dschang with a view to evaluating the possibility of utilizing the equipment there to extract the seeds of Voacanga spp. to produce Tabersonine. It was noted that nine companies had organized the collection of Voacanga seeds within a broad belt of the central part of the Cameroon. The total amount collected for export annually was estimated at around 400 tonnes and these seeds are processed by factories in Europe, which perform the conversion into Vincamine.

Since the Dschang factory had been out of production, the Cinchona plantations far too aged and not economical to utilize, it was logical to assess as part of the project in the Cameroon the feasibility of rehabilitating the factory for extraction of Tabersonine from Voacanga. Based on the proposal of the expert, UNIDO commissioned an experienced pharmaceutical organization to assess this possibility. UNIDO organized the visit to the Cameroon by experts from this organization during June 1981. Their report will be analysed by the Cameroon Government and by UNIDO experts, prior to formulating any further developments.

7.13 The UNIDO one man mission's initial recommendations also included field trials for cultivation of selected non-indigenous species of medicinal plants which had good prospects of being cultivated on a large scale and utilized for extraction of pharmaceuticals. Several species (table XX) were carefully selected from the list developed at the UNIDO meeting in Lucknow. 35/

As a consequence of this recommendation, UNIDO has now through the courtesy of the Joint UNIDO-Romania Centre fielded in 1981 an agronomist who during the first phase of a two-phase mission, initiated the small-scale cultivation in selected climatic zones in the Cameroon some of the recommended plant species. The UNIDO agronomist-expert returned in October 1981 for the second phase of his mission to evaluate the possibility of large-scale cultivation and reported

the prospects as good. On-site training of local counterpart personnel is an important aspect of the work of this mission, and other activities of the on-going UNIDO project in the Cameroon.

Table XX

List of well known medicinal plants recommended for cultivation in the Cameroon for the production of pharmaceuticals

	Name of plant	Use
1.	Cephaelis ipecacuantra	Treatment of amoebic dysentery
2.	Chenopodium ambroisiodes	Anthelmintic
3.	Digitalis lanata	Cardiotonic drug
4.	Atropa acuminata	Anti-spasmodic
5.	Hyoscymus muticus	Anti-spasmodic
6.	Cassia acutifolia	Laxative

7.14 The need for building up a facility for the pharmacological screening of indigenous plants used in Cameroonian traditional medicine had been particularly emphasized. In accordance with this, ten chosen plants were studied for their pharmacological activity. The pharmacological screening was conducted by the UNIDO expert Finn Sandberg and his colleagues at the Biomedical Centre of the University of Uppsala (Sweden). The procedures employed were based on methods previously developed at Uppsala. [36] This screening procedure involved the observation of 53 parameters in rats. The rats were injected interperitonially with a suspension of the crude extract in 0.25 per cent agar. Graded dosages ranging from 150 to 500 mg/kg were used and observations made at suitably adjusted time intervals such as 5, 15, 30 minutes and 1, 2, 4, 6 and 24 hours.

The main effects observed in several effective, non-lethal doses are summarized in table XXI. Based on these preliminary observations there appears to be a wealth of material for further study and development. The phytochemical facility at the University of Yaoundé in collaboration with ONAREST and the proposed pharmacology team have plants of considerable promise for the future development of pharmaceuticals based on traditional medicine.

Table XXI

Summary of results of pharmacological screening of plants used in traditional medicine in the Cameroon conducted by Finn Sandberg et al at the Biomedical Centre, University of Uppsala (Sweden)

	Plant name (family)	Part used	Pharmacological screening: observations	Preliminary phytochemical indications	Correlation with use in traditional medicine
1.	Alchornia cordifolia (Euphorbiaceae)	leaves	Pronounced decrease in motor activity; dilated pupil; vasoconstriction in ear; lacrimation; minimum lethal dose 400 mg/kg; death after 24 hours.	Presence of indole-type alkaloids	The sedative and anti-cholinergic effects observed can be related to use of leaves against tachycardia.
2.	Annonidium manni (Annonaceae)	bark	Decreased motor activity; muscle relaxation; enophthalmus; hyperemia in the ear and lacrimation; surprisingly not very toxic.	--	The observed vasodilation (hyperemia) and hypotension may be related to its use against heart ailments. The muscular relaxation and decreased motor activity can explain the use of bark against epilepsy and as a sedative.
3.	Fagara macrophylla (Rutaceae)	bark	Pilomotor erection	Presence of alkaloids	
4.	Lophira alata (Ochnaceae)	bark	Decreased motor activity; muscle relaxation; analgesia; enophthalmus; lacrimation; minimum lethal dose 200 mg/kg; death after 24 hours.	--	The analgesic properties observed explain its use against visceral pain and tooth-ache. The muscle-relaxing effect is a basis probably for its use as an anti-convulsive and anti-epileptic agent.

Table XXI (cont'd)

	Plant name (family)	Part used	Pharmacological screening: observations	Preliminary phytochemical indications	Correlation with use in traditional medicine
5.	Nauclea latifolia (Rubiaceae)	bark and root	Interesting central effects: low motor activity interrupted by brief periods of hyper-activity; (the somniferous effect has been observed previously) diuretic effect.	--	In the Ivory Coast the plant is recommended for "maladie du someil". Bark decoction is used as diuretic.
6.	Nauclea pobigiuni (Rubiaceae)	bark and root	Pronounced decrease in motor activity; animals sleepy for over 5 hours; both fail erection and pilomotor erection observed.	--	Use as a sleeping draught.
7.	Pentaclethia macrophyllie (Mimosaceae)	bark	Decreased motor activity; analgesia; dilated pupils; blanching of the ear (peripheral vaso-constriction); minimum lethal dose 200 mg/kg; death after 6 hours.	Presence of alkaloids	Traditional use to calm boisterous patients correlates with observations. Anticholinergic effect has been previously observed.
8.	Piptadeniastrum africana (Mimosaceae)	bark	Pronounced decrease in motor activity; minimum lethal dose 100 mg/kg; death after 8 hours.	--	--

Table XXI (cont'd)

	Plant name (family)	Part used	Pharmacological screening: observations	Preliminary phytochemical indications	Correlation with use in traditional medicine
9.	Spondianthus preussi (Euphorbiceae)	bark	No pronounced effects; minimum lethal dose 150 mg/kg; death after 5 hours.	--	--
10.	Trichilia zenkeri (Meliaceae)	bark	Muscle relaxation; enophthalmus; ptosis; minimum lethal dose 150 mg/kg; death after 2 hours.	--	--

7.15 C. Kenya

Like many other developing nations of Africa, Kenya too is richly endowed with a varied indigenous flora which is extensively used by the traditional systems of medicine.

Preliminary studies carried out at the University of Nairobi confirmed the potential of the country's flora for setting up industries for extraction and processing of medicinal plants and the distillation of essentials oils from aromatic plants. Studies carried out further indicated that the favourable agroclimatic conditions in Kenya made it ideally suitable for the introduction and cultivation of a large number of medicinal and aromatic plants which already have established uses in pharmaceutical and cosmetic industries. Accordingly the Department of Industrial Promotion of the Kenyan Ministry of Industries invited UNIDO assistance in conducting a study on the use of indigenous plant resources for industrial purposes.

7.16 In early 1981 UNIDO fielded an expert, who made such a study and reported [38/] very positively in regard to the possibilities in Kenya for the production of plant-derived pharmaceuticals, and essential oils. The expert reported the existence of several very distinct possibilities from raw material already available in Kenya.

7.17 Among medicinal plant species the following were deserving of consideration:

Cinchona spp.

The production of raw cinchona bark was estimated at around 500 tons per year. This would support an industry with a production of around 25 tons of cinchona alkaloids per year (given an average recovery of 5 per cent). The Kenyan bark is reputed to contain up to 6 per cent alkaloids and so an annual turnover of 37-50 million Kenyan shillings was considered feasible by the expert.

Sisal - Agave sisalana

The plant is grown in Kenya and contains the alkaloid hecogenine which is commercially utilized as the starting material in the synthesis of a number of corticosteroids. Corticosteroids are used in the treatment of rheumatoid arthritis, collagen diseases, ulcerative colitis and allergies. The UNIDO expert noted the presence of a number of plantations of Agave sisalana in the Taita Hills, Thika and Nakuru areas which would provide sufficient raw material for industrial production of hecogenine in Kenya.

Datura stramonium

The expert noted that this plant grew wild in Kenya and there were extensive areas of it in the Rift Valley and western Kenya. The leaves contain the alkaloids hyoscyamine and hyoscine but the quantity (0.4 to 0.5 per cent) is insufficient for their economic extraction. However the main use of strammonium leaves today is as crude extracts and tinctures. There is commercial potential for such.

Kenya possessed several wild-growing Aloe species, such as Aloe secundiflora, and Catharanthus roseus which is also an important drug plant.

There were also several other plants which the UNIDO expert noted were commercially utilizable such as:

Rauwolfia spp.

R. serpentina, R. vomitoria, R. mombasiana, R. canescens, Gloriosa simplex etc.

7.18 Among aromatic plant species growing abundantly in Kenya the expert selected the following for consideration.

Juniper spp.

J. procera - grows as a timber tree and sawdust which is a by-product, yields 2-3 per cent essential oil, known as East African cedarwood oil. The oil has been processed in Kenya for export but operations recently have been abandoned. The expert recorded the possibility of an annual production of at least 200 tons from currently discarded sawdust.

Geranium varieties

The locally grown geranium (Pelargonium graveolens) had been introduced into Kenya and the oil distilled from it is called "mawah oil". More recently strains of geranium from Reunion Islands had been introduced from which around 2-3 tons of good grade geranium oil was produced mainly in the Naivasha area. Production had dropped due to problems of marketing but there was, in the UNIDO expert's view, much potential in this crop, as there was considerable demand for geranium oil of acceptable quality.

Eucalyptus spp.

The two species growing in plantations in Kenya, E. globulus in the high altitudes and E. citriodora in the lake areas, could both yield essential oils utilizable in commerce. The oils of the two species E. globulus rich in

1:8 cineole, and E. citriodora containing citronellal, both have export possibilities and the expert was of the view that production of these oils in Kenya could contribute towards a valuable essential oil industry.

The expert recommended several other indigenously available essential oil bearing species for research evaluation and development. These were the following:

Common name	Latin binominal
African citronella	Cymbopogon nardus = C. afronardus
Mexican marigold	Tagetes minuta
"Nkuri"	Ocimum kilimandscharicum
"Muhugu"	Brachylaena hutchinsii
Lemon grass	Cymbopogon citratus
	Micromeria microphylla

7.19 The UNIDO expert found many indigenous plants, occasionally used in medicine but with constituents which render them valuable as industrial crops. These included those listed (table XXII) which the expert recommended for further evaluation.

Table XXII

List of Kenyan plants with valuable natural products

Plant name	Possible use
Carica papaya (Papaw) (Papaya)	Papain production
Acacia senegal (Gum arabic)	Gum production
Ricinus communis (Castor)	Industrial-scale production of castor oil and "castor cake".
Commiphora spp. (Myrrh)	Essential oils and resins
Melia azadarichta (Neem)	Fixed oil
Pinus spp.	Rosin and turpentine production
P. radiata P. patula	

7.20 The UNIDO expert also studied possibilities for the trials with indigenous plants and the introduction of plant species with recognized industrial products, into Kenya. The species which were recommended for cultivation trials are listed in table XXIII.

Table XXIII

Species of plants recommended for introduction into Kenya

Common name	Latin binominal
Senna	Cassia acutifolia
Periwinkle	Catharanthus roseus
Aloe	Aloe ferox, A. barbadensis
Egyptian henbane	Hyoscymus muticus
Duboisia	Duboisia myoporoides D. leichardtii
Ipecac	Caephalis ipecacuanha
Liquorice	Glycyrrhiza glabra
Discorea yams	Discorea floribunda, D. composita
Belladona	Atropa belladona
Ergot of rye	Clavicaps purpurea
Voacanga	Voacanga africana
Rauwolfia	Rauwolfia vomitoria
Geranium	Pelargonium graveolens
Lemon grass	Cymbopogon citrus
Patchouli	Pogostemon patchouli
Citronella	Cymbopogon winterianus
Jasmine	Jasminum grandiflorum
Peppermint	Mentha piperita
Japanese mint	Mentha arvensis
Lavender	Lavendula spp.
Aniseed	Pimpinella anisum
Coriander	Coriandrum salivum
Dill seed	Anethum graveolens
Carraway	Carum carvi

7.21 In addition to the suggestions made above regarding the assessment plants for industrial utilization, the UNIDO expert surveyed the institutional R + D services available in Kenya for future development. He noted that existing research facilities were minimal and the research work though meritorious was uncoordinated and not geared to the goal of industrial utilization. He recommended institutional measures by which a greater measure of productivity could be attained.

8. PROGRAMME FOR DEVELOPMENT OF MEDICINAL AND AROMATIC PLANT PRODUCTS IN THE ARAB STATES

8.1 During 1976-1978 UNIDO at the request of ACDIMA - the Arab Company for Drug Industries and Medical Appliances - commissioned a team of experts to draft a production plan for the Arab pharmaceutical industry in selected Arab countries. The plan included inter alia the development of plant-derived pharmaceuticals and essential oils. ACDIMA was interested in producing drugs and phytochemicals from plants both for localized use as well as for export. UNIDO provided ACDIMA with the services of a specialized expert on medicinal and aromatic plants and his report 39/ formed the basis of the production plan in the area of plant-derived pharmaceuticals. The report revealed that phytochemicals and plant extracts were widely used as therapeutic agents in many Arab countries, about 20 phytochemicals and over 80 crude extracts being included in formulations regularly marketed.

The expert's surveys recorded only six species of medicinal plants being cultivated in large quantities. A further seven species were in experimental cultivation.

Table XXIV

Medicinal plants available in large quantities in Arab countries

	Name of plant	Active constituents	Location and source	Quantity */ in metric tons
1.	Liquorice (Glycyrrhiza glabra)	Glycyrrhizitic Acid	Iraq	7 728.00
		Liquorice extract	Syrian A.R. (wild)	
2.	Senna pods and leaves (Cassia acutifolia)	Calcium sennosides	Sudan (wild)	1 751.00
3.	Gum arabic (Acacia senegal)	B.P. grade Gum arabic	Sudan (wild)	28 347.00
4.	Ammi majus	Xanthotoxin (Ammodin)	Egypt (wild)	100.00
5.	Ammi visnaga	Khellin	Egypt (wild and cultivated)	200.00
6.	Henbane (Hyoscymus muticus)	Hyoscine, Hyoscymine, Atropine	Egypt	exact figure not known

*/ Estimates based on export of these raw materials in 1975 (Bureau of Statistics, Egypt, Sudan, Syrian Arab Republic, Iran). Chammomile (Matricaria chamomila) is cultivated on large scale in Egypt, but the dried flowers are exported to Europe, and there is no scope for processing this material.

8.2 A detailed survey of the various formulations produced by leading companies in Egypt, Sudan, Syria and Iraq revealed that more than 25 per cent of the trade items marketed by them contained one or more plant product.

This included more than 20 natural products and about 80 different plant extracts. Furthermore, the UNIDO expert estimated the requirements of phytochemicals and crude extracts for the Arab pharmaceutical industry on the basis of actual imports into Egypt during 1975. The major requirements as estimated are summarized in table XXV. These estimates do not include imports, or formulations containing plant-derived substances.

8.3 On the basis of these findings there is evidence that the development of a medicinal and aromatic plants industry in the region would result in considerable savings in imports. The UNIDO expert considering the health needs of the region, the availability of raw material within the different countries and the export possibilities of products, considered several plant drugs as important for a medicinal and aromatic plants industry to be established under the aegis of ACDIMA. These drugs and their sources are listed in table XXVI. It may be noted that this list does not include important alkaloids and other natural products that are presently imported for which no raw material sources exist. Also some Arab countries such as Egypt already have well-developed essential oil industries and ACDIMA could help a country like Egypt to increase the production of aromatic oils which are needed for pharmaceutical use.

8.4 The UNIDO expert was of the view that the Arab countries (which includes a vast area of the Middle East and North Africa) were very rich in vegetable resources which could be exploited for industrial purposes. Because of the wide variety of climate and soil conditions, a variety of medicinal plants - tropical, subtropical, temperate and Mediterranean types - could be profitably cultivated in one or other of the countries of the region.

Seven different plants which were utilized for medicinal purposes had been cultivated on an experimental scale, and these could be cultivated on a commercial scale after pilot scale trials. The plants along with their main active ingredients and region suitable for cultivation are given in table XXVII.

Large-scale cultivation of Ammi majus, Ammi visnaga, Hyoscymus muticus and Cassia acutifolia in Egypt and Sudan, in order to support a sizeable phytochemical industry, should also be undertaken in the view of the expert. The quantity of these drugs available from wild sources would not be sufficient, and no industry could be based solely on vegetable raw materials from wild growth; the quality could not be guaranteed and raw material supply could be exhausted by continuous collection.

Table XXV

Summary of the estimated requirements of phytochemicals and crude drugs in Arab countries

	Name of chemical or extract	Estimated approximate requirements in kg
1.	Steroid drugs	1,665
2.	Codeine derivatives	8,250
3.	Papaverine derivatives	6,180
4.	Caffeine salts	32,067
5.	Ergotamine tartarate	258
6.	Ergometrine maleate	23
7.	Hyoscyamine sulphate	60
8.	Hyoscine hydrobromide	388
9.	Reserpene	38
10.	Colchicine	22
11.	Digitoxin	10
12.	Quinine salts	3,148
13.	Quinidine salts	379
14.	Menthol	6,911
15.	Camphor natural	3,820
16.	Camphor synthetic	6,459
17.	Thymol	24,484
18.	1:8 Cincole	234
19.	Pyrethrum extract	5,000
20.	Eucalyptus oil	6,909
21.	Peppermint oil	11,401
22.	Belladona extract	24,129
23.	Extract buchu.	39,375
24.	Cascara sagrada (dry)	15,000
25.	Extract gentian	69,500
26.	Extract rhubarb	104,970
27.	Extract senega	69,000
28.	Extract lobelia	15,210
29.	Extract hyoscyamus	9,420
30.	Extract ipecac	11,562
31.	Extract Stramonium	2,000
32.	Extract liquorice (liquid)	7,100
33.	Extract liquorice (dry)	6,340
34.	Syrup tolu	48,000

Table XXVI

Phytochemicals required for Arab pharmaceutical industry

	Active constituent	Name of plant source
1.	Steroidal sapogenins and glycoalkaloids (raw material for steroidal drugs)	Dioscorea sp. Solanum lacinatum S. Aviculare Agave sisaliana
2.	Calcium sennoside	Cassia acutifolia C. angustifolia
3.	Xanthotoxin (Ammodin)	Ammi majus
4.	Khellin	Ammi visnaga
5.	Glycyrrhitic Acid Liquorice extract	Glycyrrhiza glabra
6.	Tropane Alkaloids Hyoscine, Hyoscymin Atropine */	Hyoscyamus muticus Datura metel D. stramonium
7.	Opium Alkaloids-Codeine Morphine, Papavarine	Papaver somniferum
8.	Digitalis glycosides Digoxine, lanatosides	Digitalis lanata
9.	Ergot alkaloids Ergometrine, Ergotamine	Claviceps purpurea
10.	Menthol	Mentha arvensis
11.	Euclyptol (Cineol)	Eucalyptus globulus
12.	Pyrethrins	Chrysanthemum - cinerariaefolium
13.	Peppermint oil	Mentha piperita
14.	Eucalyptus oil	Eucalyptus globulus
15.	Gum Arabic	Acacia senegal
16.	Extract Belladona and total Belladona alkaloid	Atropa belladona
17.	Extract hyoscymus	Hyoscymus muticus
18.	Extract Stramonium	Datura stramonium
19.	Psyllium husk	Psyllium Plantago ovata P. Psyllium

*/ Atropine is nowadays obtained from synthetic sources, but can also be manufactured from plants if an economic source like H. muticus is available.

Table XXVII

Medicinal plants which may be cultivated in different Arab countries

	Name of plant	Active constituent	Region suited for cultivation
1.	Belladona (Atropa belladona) */	Belladona extract Total alkaloids	Mountains of Syrian A.R., Iraq, Egypt
2.	Solanum (Solanum lacinatum) S. aviculare	Solasodine	Egypt
3.	Opium poppy (Papaver somniferum)	Codeine, morphine papaverine	Iraq
4.	Peppermint (Mentha piperita)	Peppermint oil	Egypt, Syrian A.R., Iraq
5.	Datura (Datura metel)	Hyoscine Hyoscymine	Egypt Sudan
6.	Stramonium (Datura stramonium)	Hyoscymine Stramonium extract	Egypt, Syrian A.R., Iraq
7.	Digitalis (Digitalis lanata)	Digoxine	Mountains of Iraq and Egypt

*/ A. belladona is a temperate plant and as such optimum yield and alkaloid content is obtained only in temperate areas. If cultivated in Egypt both yield and alkaloid content would be low.

As no Arab country had satisfactory sources of steroidal sapogenins, Ergot alkaloids, Pyrethrins and Menthol, the authentic species of plants used for obtaining these chemicals would have to be introduced and systematically cultivated for the industry. The list of such plant material along with the region suitable for introduction is indicated in table XXVIII.

Table XXVIII

Plants which are recommended for cultivation in Arab countries

Name of plant	Active constituents	Area suitable for introduction
Japanese mint (Mentha arvensis)	Menthol	Egypt, Sudan
Ergot of rye (Claviceps purpurea)	Ergometrine Ergotamine	Mountains of Syrian A.R. and Iraq
Pyrethrum (Chrysanthemum cinerariaefolium)	Pyrethrins	Mountains of Iraq, Syrian A.R. and Sudan
Mexican yam (Dioscorea floribunda)	Diosgenin	Egypt and Sudan

There was no economic alternative source for the first three natural products and very little research work had been done on the cultivation of these plants in Arab states. There was also evidence that Japanese mint could grow well in Egypt.

The Mexican yam Dioscorea floribunda is currently the most widely used source of diosgenin in the world. About 60 per cent of the total requirement of steroidal drugs are obtained from diosgenin isolated from tubers of this plant and related species like D. composita and D. spieuliflora found growing wild in Mexico and other Central American countries. D. floribunda had been cultivated successfully in India, Mexico and the USA (Puerto Rico) and the climatic as well as soil conditions were considered ideal for growth of this plant in the light soils of Egypt and Sudan. As steroidal drugs consisting of corticosteroids, sex hormones, anabolic steroids and oral contraceptives are derived from compounds obtained from vegetable sources, introduction of the authentic species of plant was essential for the development of the pharmaceutical industry in Arab countries.

Another natural product in this category was the glycoalkaloid, solasodine isolated from leaves and fruits of Solanum lacinatum and S. aviculare. Considerable research work had already been done in Egypt on S. lacinatum especially by the Medicinal Plants Section of the National Research Centre at Cairo, and the Memphis Company. The plant contains about 1.5 per cent solasodine which has been used commercially to a very limited extent in East European countries and USSR.

In Sudan the expert observed an interesting raw material growing throughout semiarid and humid parts of the country. The common "Helig" tree (Belanite aegyptica) in Sudan forms approximately 25 per cent of the tree population. It is distributed widely in clay and sandy soils where the rainfall exceeds 350 mm annually. It grew along the rivers and streams in association with Acacia senegal. Although most of the parts of the tree contain saponins, the mesocarp (the fleshy portion of the fruits) contains 1-1.5 per cent total sapogenin which mainly consists of diosgenin, and yamogenin. The fruit of the tree which has a sweet arid taste is eaten by children all over Sudan and the dried fruits, often called soapnuts, are used for washing clothes by rural folk. The seed of the Belanite fruit had been found to contain more than 40 per cent of a fixed oil of good quality which could be used as an edible oil and in the soap industry. The seed oil has been used in cooking for several centuries. The cake left after removal of oil would be a rich source of a protein, the nutritive value of which had been found to be comparable to soyabean protein.

Considering all the qualities of this fruit as a potential raw material for medicine and food, the UNIDO expert saw the immediate need to work out technology for manufacture of diosgenin, fixed oil and protein from this plant. The raw material was available in appreciable quantities, and the only cost involved was the labour used in the collection of the fruits. The dried fruit was available at 50 Sudanese pounds per ton and the cost would come down to about 30 pounds per ton if the collection was organized on a large scale. The Industrial Research and Consultancy Institute has already taken up the project. However the need for assistance to develop a viable technology was evident.

In addition to the plants mentioned above there was good possibility for cultivation of Catharanthus roseus and Cymbopogon citratus (lemon grass) in Egypt and Sudan.

During the expert's discussions with scientists in Sudan it was mentioned that Rauwolfia vomitoria (a good source of Reserpine) was found growing wild in certain parts of southern Sudan. Cultivation of this species was recommended.

8.5 The UNIDO expert noted that some kind of phytochemical industry existed only in Egypt and Iraq. The industry which was reasonably well developed in Egypt could be classified into two distinct categories. The first category of industry which was in a fairly advanced stage of development was the "aromatic plant industry" producing essential oils and oleoresins used in perfumery, cosmetics and food preparations. There was one large state-owned company, and several other private units which produced geranium (Pelargonium-graveolens) oil, jasmine (Jasminum-grandiflorum) concrete and absolute, small quantities of peppermint (Mentha piperita) oil, spearmint (Mentha spicata) oil, bitter orange oil, neroli oil, fennel oil, carraway oil, thyme oil, garlic oil and a number of other food flavours. Egypt was a major exporter of geranium oil and jasmine concrete. The production statistics of important essential oils in Egypt is presented in table XXIX.

The total production has been estimated on the basis of the area under cultivation and the known yield of oil per acre.

The expert noted the dire need of research and development services to improve the agrotechnology, as well as distillation equipment. The second category of industry based on plants, which was not so advanced, was the medicinal plant industry. There was one company, which had an outfit for isolation of ammodin (xanthotoxin) - 500 kg annually from Ammi majus seeds and khellin (1,000 kg annually) from Ammi visnaga seeds.

Table XXIX

Production of important essential oils in Egypt (1977)

Name of the oil	Area under cultivation in Feddan	Estimated production of oil in tons
1. Geranium oil	11 000	210.00
2. Jasmine concrete	2 876	11.54
3. Peppermint and spearmint oil */	446	2.0
4. French basil oil	75	1.50
5. Bitter orange oil	80	0.50
6. Neroli oil	80	0.50
7. Marjoram oil, rosemary oil, rose concrete, aniseed oil, fennel oil, dill oil, thyme oil, cumin oil, garlic oil		small quantities

*/ Only a part of peppermint herb is distilled for oil and a major portion is exported as dried herb for medicinal tea.

Source: Department of Economics and Statistics, Ministry of Agriculture and the Cairo Company of Food Flavour and Essences.

One other company made extracts from plants. Approximately 60,000 litres of crude extracts were prepared. The most important extracts being: liquorice extract, belladona extract, valeriana extract, gentian extract, rhubarb extract and a number of minor plant extracts and tinctures. The company in collaboration with the National Research Centre had also produced solasodine on a pilot-plant scale. However, the commercial production had not commenced due to prohibitive costs. As only crude extracts were being produced there was an idle capacity of at least 50 per cent.

In Iraq the only industrial unit "The Samara pharmaceutical complex", under the State Drug Company of Iraq, had a large size (four batteries of seven extractors) solvent extraction plant with all the accessories. The plant, which was imported from the USSR some time ago was expected to process more than two dozen medicinal

plants suggested by Soviet experts. A farm for production of various plants was begun in 1961, but it was closed down after initial experiments were completed on about 40 medicinal plants. The equipment was currently being used to produce a small quantity of crude extracts mostly for consumption in the company's own formulations. This included: 1.6 tons of belladona, 5.6 tons of liquorice, 5.3 tons of valeriana roots and small amounts of minor vegetable drugs like ginger and cardamom. Thus the plant had an idle capacity of about 80 per cent. The size of the plant was sufficient to supply crude extracts to four other Arab countries. The UNIDO expert felt that the medicinal plant farm at Abughrab could be reactivated so that the crude drugs produced at the farm could be processed at Samara to supply vegetable drugs to the Syrian Arab Republic, Lebanon, Jordan, Saudi Arabia and Kuwait.

8.6 Considering the available raw materials, present and future requirements and the products already manufactured by the existing industry, the expert concluded that a large sized phytochemical industry to fulfil all the requirements would be a feasible proposition.

He suggested that ACDIMA should take immediate action for manufacturing the following chemicals from the raw material already available in commercial quantities:

(i) Calcium sennoside from senna leaves and pods (C. acutifolia) available in Sudan;

(ii) Glycyrrhizitic acid and liquorice extract and powder from liquorice (G. Glabra) available in Iraq and the Syrian Arab Republic;

(iii) Xanthotoxin (Ammodine) from Ammi majus, available in Egypt;

(iv) Hyoscine and Hyoscymine from Hyoscymus muticus, available in Egypt and Sudan.

8.7 There was considerable demand for senna glycosides in the world and at present all the senna collected from wild growth in Sudan was being exported to European and Scandinavian countries. Systematic cultivation of this plant in Sudan would give beneficial results.

In the case of liquorice it was currently collected from the desert areas of Iraq and the Syrian Arab Republic and exported in crude form. There is considerable demand for liquorice extract and powder all over the world and the expert felt that the entire quantity (approximately 30,000.00 tons) could be processed in Arab countries. In addition to the concentrated extract, glycyrrhizitic acid could also be produced from the roots. There was appreciable demand for this chemical, as it is being used widely for treatment of peptic ulcers.

Some xanthotoxin (Ammodin) was being produced by the Memphis Company but the quantity (500 kg) was small. The demand for this chemical has increased considerably during recent years because of its use for the treatment of psoriasis and as an ingredient of suntan lotions.

There was also a sizeable market for hyoscine and hyoscymine in the Arab countries and an acute shortage of hyoscine in the international market (present price approximately US$800 per kg). The raw material (H. muticus) is found growing wild all over Egypt and some parts of Sudan. The expert recommended that initially the processing could commence with the existing raw material but in order to have a consistent supply of good quality material an acceptable strain of the plant would have to be cultivated on a large scale. Datura metel could also be used for processing if sufficient quantities can be obtained by organized cultivation. Production of khellin from A. visnaga in the expert's view could be left to the Memphis Company as they had the capacity to meet any increase of demand for the chemical. In addition to the above four plants, ACDIMA, in the UNIDO expert's view, should consider the possibility of refining and bleaching the large quantity of gum arabic (A. senegal) exported from Sudan in crude form. Sudan had the monopoly of this gum in the world, and it could fetch much better prices if the crude product was refined, bleached and exported.

The UNIDO expert recommended the production of plant-derived pharmaceuticals to include the cultivation of the necessary plants for the production of the following:

Diosgenin from Mexican yam (F. floribunda)
Solasodine from Solanum sp. (S. lacinatum)
Menthol from Japanese mint (M. arvensis)
Codeine, morphine and papaverine from opium poppy (P. somniferum)
Ergotamine and ergometrine from ergot of rye (C. purpurea)
Belladona alkaloids and extract from belladona (A. belladona)
Peppermint oil from peppermint (M. piperita)
Euclyptol from eucalyptus (E. globulus)
Citral from lemon grass oil (C. citratus)
Digoxine from digitalis (D. lanata)

Later, it was logical that the industry would take up production of formulations based on phytochemicals. The manufacture of steroidal drugs from diosgenin would also be a future possibility.

8.8 The UNIDO expert recommended a method of approach to ACDIMA for the establishment of a pharmaceutical industry for the production of plant-derived drugs and essential oils for the Arab countries. This included the following steps:

The setting-up of an organization under ACDIMA for the production of plant pharmaceuticals;

The development of suitable agrotechnology for the production of a variety of plants for industrial production;

The acquisition of land in Egypt, Sudan, Syria and Iraq for setting up farms for cultivation;

The development of mechanisms for collection and produce, providing seed and planting material to farmers as well as extension services;

The commissioning of suitable processing units with trained personnel and modern equipment;

Continuing R + D services.

9. WORKSHOPS AND TRAINING PROGRAMMES

9.1 One of the premier requirements in developing countries, for the purpose of inaugurating projects on medicinal and aromatic plants would be the building up of a scientific and technological competence within the individual country. The multidisciplinary requirement of such a competence stretches across a wide spectrum of subject areas and involves levels of activity that range from that of the farmer who cultivates the crops to that of the highly skilled professional scientist or technologist (vide fig 2). This remains the most difficult single task to accomplish in almost all developing countries. Yet it is in many ways the most crucial to the success of any project. UNIDO programmes have tended to be very conscious of this requirement and apart from the formal training programmes within individual projects, three different types of events were held in the recent years to meet this requirement. The three events are the following:

I. A technical consultation on production of drugs from medicinal plants in developing countries;

II. An in-plant group training programme in the field of medicinal plants;

III. A workshop on the essential oil industry.

I. THE TECHNICAL CONSULTATION ON THE PRODUCTION OF DRUGS FROM MEDICINAL PLANTS IN DEVELOPING COUNTRIES

Lucknow, India 13-20 March 1978

9.2 At several meetings on pharmaceuticals, developing countries have expressed interest in the promotion, development and production of drugs derived from medicinal plants. In response, UNIDO organized the Technical Consultation on the Production of Drugs from Medicinal Plants in Developing Countries. This Consultation was under the joint auspices of UNIDO, the Government of India and the Central Drug Research Institute of India (CDRI) at Lucknow. Background papers for the Consultation were prepared by UNIDO's specialist consultants and reviewed at UNIDO Headquarters, Vienna. Experts invited from the various countries were also requested to present country papers on the status of production and use of drugs from medicinal plants in their respective countries.

A paper was prepared by UNIDO's Secretariat which set out the guidelines for the formulation of a Plan of Action for the Sector.

Finally the Consultation proposed a series of recommendations for future development of the Medicinal Plants and Pharmaceutical Industry in the Developing Countries.

The Report of the Consultation [35/] gives the summarized proceedings, a summary of the main technical papers and summaries of the country presentations.

9.3 During the discussions at the Consultation, it was positively felt that countries that grew medicinal plants should be encouraged to enter into the production of drugs that clinical evidence had shown to be effective. The level of production would depend on the infrastructure within each country, its flora and the available level of technology.

Three levels were recognized:

A. Countries with no facilities for research and development pilot plants or industrial production;

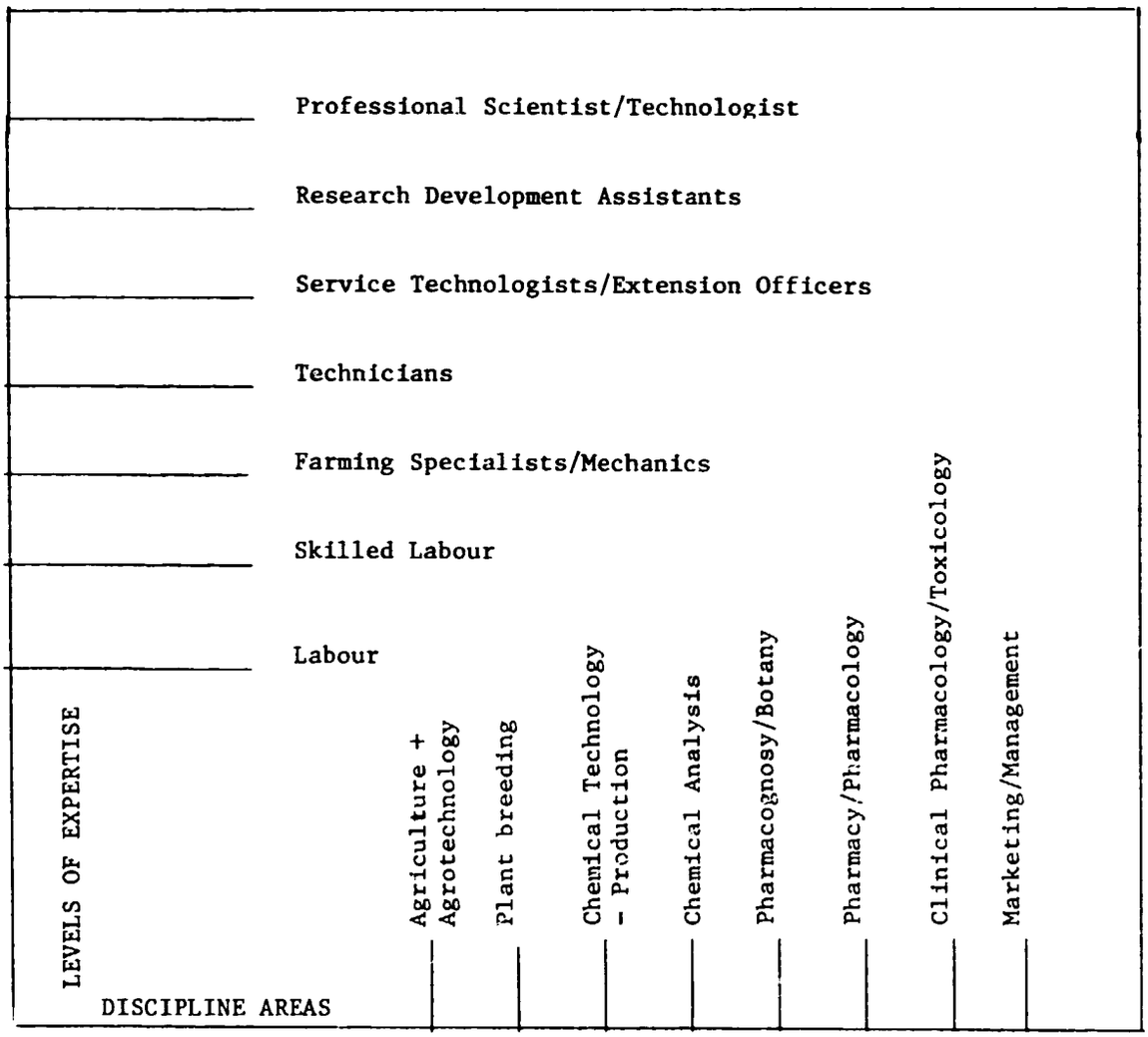
B. Countries whose facilities are limited to production of extracts;

C. Countries with facilities for pilot scale or industrial production of active principles from medicinal plants.

9.4 It was the opinion of the Consultation that UNIDO should emphasize the production of plant drugs used in both traditional and modern systems of medicine; however particular attention should be given to plant products that were accepted in modern medicine, were widely used in health programmes and were of large economic value.

Fig. 2

Levels of expertise/Discipline areas



9.4 It was also noted at the Consultation that in order to facilitate and accelerate the establishment of a pharmaceutical industry based on medicinal plants the developing countries should be urged to co-operate with each other on: the transfer of technology; the training of personnel; and the supply of equipment and planting material.

9.5 During the Consultation it was revealed that the production process for many of the important plant products was not covered by patents; hence patents would not be a barrier to production. Accordingly the opinion was expressed that medicinal plants for which there existed an international demand should only be exported in some processed form and not as raw material.

9.6 Caution was expressed in respect to the need to organize the export of plant-derived products so as to avoid creating a glut in the market and the need therefore to conduct detailed techno-economic studies to assess particular market requirements.

It was also noted that the production of drugs from medicinal plants could only be successful if attention was paid to the quality of the products and their conformity to specifications. A well-equipped quality control laboratory was therefore a basic prerequisite for a production facility. Adequate quantities of raw material of acceptable quality must be available and hence the need to organize cultivation, collection and storage of plant material in an acceptable manner. The Consultation noted the success of UNIDO's mobile unit mission to the countries of Africa and Asia and observed that such missions were a suitable means of transferring technology for the production of extracts, for training personnel in production and control methods in countries lacking such expertise.

9.7 The following are the titles of the specialized lectures delivered by UNIDO consultants to the Consultation:

1.	An integrated approach to research on medicinal plants. Doc. ID/WG/271/2	N. Anand
2.	Medicinal plants for curing diseases other than communicable, tropical and infectious. Doc. ID/WG/271/4	F. Sandberg
3.	Plants of the African Pharmacopoeias used in the treatment of tropical diseases. Doc. ID/WG/271/1	J. Kerhars

4. Industrial requirements for processing of medicinal plants. Doc. ID/WG/271/2 — E. Bombardelli

5. Drugs derived from medicinal plants. — UNIDO Secretariat

9.8 The Consultation also prepared the following lists of medicinal plants:

(i) A list of the medicinal plants found in various regions: Africa, Asia and Latin America, whose active principles are used in modern medicine (Annex I);

(ii) An additional list of plants used mainly in traditional medicine in Africa, Asia and Latin America (Annex II);

(iii) A restricted list of the plants that are comparatively widely used for the production of medicines classified by therapeutic groups (the WHO List of Essential Drugs was used as a guide) (Annex III);

(iv) A list of plants that are not necessarily used as drugs but are the source of products used in the pharmaceutical industry and for which there is a demand in the international market (Annex IV);

(v) A list of plants on which R + D is well advanced in certain countries and that are likely to be introduced into clinical practice (Annex V);

9.9 The following countries were represented at the Consultation: Algeria, Burma, Cuba, India, Madagascar, Mexico, Nepal, Pakistan, Rwanda and Thailand.

II. THE IN-PLANT GROUP TRAINING PROGRAMME IN THE FIELD OF MEDICINAL HERBS

Bucharest, Romania 23 June - 18 July 1980

9.10 Through the initiative of the joint UNIDO-Romania Centre, the first UNIDO training programme in the field of medicinal plants took place in Bucharest.

The programme was attended by eight trainees drawn from Botswana, Cameroon, Guinea, Lebanon, Nepal, Tanzania and Turkey. The participants were accompanied by UNIDO staff member Prof. Finn Sandberg.

9.11 The training programme included 25 theoretical lectures and 10 practical demonstrations - held in the laboratories of two research institutions, the Faculty of Pharmacy in Bucharest, and an experimental station for medicinal plants. In addition there were six conducted study visits to industrial medicinal plant processing units where detailed explanations of the technological sequences were given to the participants. Visits were also organized to two medicinal plant cultivation farms and three botanical gardens. The participants were also treated

to a demonstration on the economic mapping of medicinal plants in two forest areas.

At the conclusion of the programme, [42] the participants had, in addition to a well-planned theoretical background, the practical knowledge gained from the planned visits. They became acquainted with the sequence of operations - as conducted in Romania - for the conversion of medicinal plants into finished pharmaceutical products viz:

- gathering of authenticated plants from the spontaneous flora;
- cultivation in special forms and plant breeding;
- primary processing;
- secondary processing on industrial scale;
- quality assessment of products.

9.12 The training programme concluded with a round-table discussion (attended by 17 specialists connected with the industry including: professors, management officials etc.) and various issues raised by the trainees were discussed. The issues discussed fell into four categories:

- Introduction of medicinal plants, cultural practices and technical assistance in the economic mapping of the spontaneous flora;
- Collaboration in research and analytical work on medicinal plants;
- Processing of medicinal plants and prospects of bilateral collaboration;
- Marketing aspects.

9.13 A unique feature of the programme was an evaluation session where all participants were involved.

The success of the programme was revealed in the reports made by the participants and their responses to the specific questions asked them.

9.14 A second group-training programme planned on similar lines, will take place during 1982. This training programme will be for the Francophone countries.

9.15 As a result of these training programmes and in response to demands from developing countries, UNIDO plans to produce a series of manuals relating to methodologies in the industrial utilization of medicinal and aromatic plants.

III. THE UNIDO/ESCAP WORKSHOP ON THE ESSENTIAL OIL INDUSTRY

Lucknow, India 21 November - 2 December 1981

9.16 This workshop was organized jointly by UNIDO, the Government of India (Department of Chemicals and Fertilisers/Council of Scientific and Industrial Research) with the collaboration of the Economic and Social Commission for Asia and the Pacific (ESCAP). It was a sequel to a two-man UNIDO-ESCAP mission which visited six countries in Asia in 1976 to report on the essential oil industry. 41/

9.17 UNIDO's primary objective in regard to the essential oil industry is to encourage the development of the industry in the many developing countries that produce essential oil-bearing crops and exotic aromatic plants. The workshop was therefore designed to accent the production aspects of essential oils inclusive of the following:

- Cultivation of aromatic plants on a systematic basis for processing, and plant breeding methods;
- Technology and quality assessment of essential oils and related products;
- Commercial and economic considerations.

UNIDO was also interested that the workshop served as a means of planning and initiating programmes of technical co-operation among developing countries in the essential oils industry since some developing countries had already made considerable progress in the development of the industry.

Accordingly although the original concept in the UNIDO-ESCAP Report 41/ was that the workshop be only a regional one, the present workshop was designed to include a few observers from other regions, with a view to the holding of future workshops in different geographic regions.

9.18 The staging of the present workshop was greatly facilitated by the offer of the Government of India to host the workshop. The main contribution of the Government of India came through the Central Institute for Medicinal and Aromatic Plants which was responsible for the local organization of the workshop. In addition the Government of India hosted all participants to a study tour of several R + D institutions which were located in Mysore, Bangalore, Bombay and Baroda.

9.19 The workshop took the form of expert presentations made by several specialists as follows:

(i) Overview of the essential oil industry in developing countries;

(ii) Technological aspects in the production of essential oils;

(iii) The assessment of quality in essential oils;

(iv) Export potential of essential oils in the context of world trade;

(v) Role of research and development in the essential oil industry;

(vi) Considerations for the further development of an industry dealing with essential oils and aromatic chemicals;

(vii) Prospects for development of essential oil bearing crops by genetic manipulation;

(viii) The development of the essential oil industry in developing countries.

9.20 These presentations form the basis of the several chapters of the report on the workshop. 40/

Besides these the report contains summary country status reports on the essential oil industry for:

Afghanistan, Bangladesh, Cyprus, Egypt, Ethiopia, Guyana, India, Indonesia, Pakistan, Sri Lanka and Thailand, which were based on information provided by the participants from these countries.

9.21 At the conclusion of the workshop, a series of recommendations were made by the participants for follow-up action by UNIDO. The discussions at the workshop generated some general observations regarding the development of the essential oil industry in developing countries.

These were the following:

(i) Socio-economic characteristics. The nature of the industry is such that it would be an attractive proposition for countries planning their economies with factors such as:

- rural sector developments;
- import-substitution and development of agro-based industry;
- achieving scientific and technological competence in selected areas

as some of their desired goals.

The industry is also attractive to agencies within the United Nations system as it lends itself to the global development objectives already enunciated by them. Further, the industry is ideally suited to be initiated into developing countries although the products are primarily utilized by the industrial nations. There are however a plethora of problems and concerns on which future workshops of this kind may deliberate.

(ii) Cultivation aspects of aromatic plants

Although the spontaneous flora within the developing countries may yet contain a considerable number of unknown sources of perfumery and flavour materials, and the screening of the wild flora of a country for such is of prime importance, aromatic plants for industrial use must ideally be systematically cultivated.

Accordingly the following considerations bear relevance:

- Selection of appropriate plant species and procurement of suitable planting material. Maintenance of herbarium vouchers of plant specimens for authentication;
- Introduction of modern plant breeding techniques. Study of the special techniques applicable to aromatic plants;
- Studies on plant diseases and plant pests and methods to combat such;
- Studies on the most economic methods of maintaining the nutrients in the soil and its quality, with minimum use of fertilizer;
- Problems of irrigation;
- Studies on the methods and conditions for harvesting each species of aromatic plant, and the optimum post-harvest preparation of raw material for distillation or extraction, in relation to both quality and yield of oil;
- Genetic improvement of crop varieties.

(iii) Technological aspects

The technology concerning the production of essential oils is well known. In fact quite simple and elementary distillation outfits are known to produce - in capable hands - very acceptable products. However many countries attempting to initiate industrial utilization of aromatic crops could certainly benefit from the experience of other countries who have longer experience with the technological needs. There are several factors here that merit consideration, such as the following:

- Decisions regarding the appropriate type of distillation or extraction unit, and location of such;
- Methodology of procurement of technological expertise appropriate to a given situation;
- Interlinks between the production process of the raw material, and the processing requirements i.e. optimization of the time and capacity of the distillation unit in relation to the available raw material;
- Fabrication of still units in developing countries; optimization of conditions and operational parameters;
- Central supporting R and D services for quality control of products.

(iv) Managerial aspects

The managerial aspects of the production of essential oils relate to management of farms, distilleries and the marketing process, within the country. The methods adopted will vary much with the country and its special features. In general terms all or some of the following factors may need consideration in most instances:

- Availability of adequate extension services as regards agronomic and technological needs. Methods by which such extension services are made to reach farmers, operators of field distillation units and those who collect and transport essential oils to centres of marketing;
- Measures to ensure adequate control of authenticity and quality of raw material used in distillations;
- Availability of prompt maintenance facilities for distillation assemblies;
- Training of all grades of personnel in the industry.

(v) Storage and marketing of produce

One of the most important needs is adequate storage and marketing systems for products. It is established that market price fluctuations and variations in demands for products present considerable problems to producers in developing countries. Hence the factors below emerge as some needing consideration depending again on the country and the circumstances:

- Procurement of appropriate storage vessels and ensurement against contamination and adulteration;
- Dissemination of information regarding market demands quality pricing factors etc.;
- Organized systems of central collection and primary assessment of produce, to enable farmers to promptly dispose of their produce;
- Creation of incentives such as capital support, pricing and marketing guarantees and means of transportation of products from remote field areas.

(vi) Support agencies and regulatory functions

It is true in practice that the essential oil industry in several countries where it has in recent times flourished has enjoyed the benefit of support agencies and several regulatory advantages. The factors below are some of those considered very necessary for the development of the industry.

- Creation of agencies and practices to ensure the development of the Essential Oil Industry as an income generating operation for rural populations;

- Establishment of information centres for data on exports, imports, producers, wholesalers, cultivating agencies, distillers etc. and accessible extension services;
- Regulatory assistance in the promotion of the use of naturally produced essential oils in preference to imported synthetic substances wherever possible. R and D services to assist such utilization;
- Agencies capable of rendering capital support assistance to producers of essential oils.

(vii) Aspects of collaboration among developing countries

The industry, as revealed by the sample of country status reports, is in various stages of development in the countries represented at the workshop. There is unlimited scope for collaboration among the developing countries either on a bilateral basis or through the agency of UNIDO. The collaboration could take several forms some of which are outlined below:

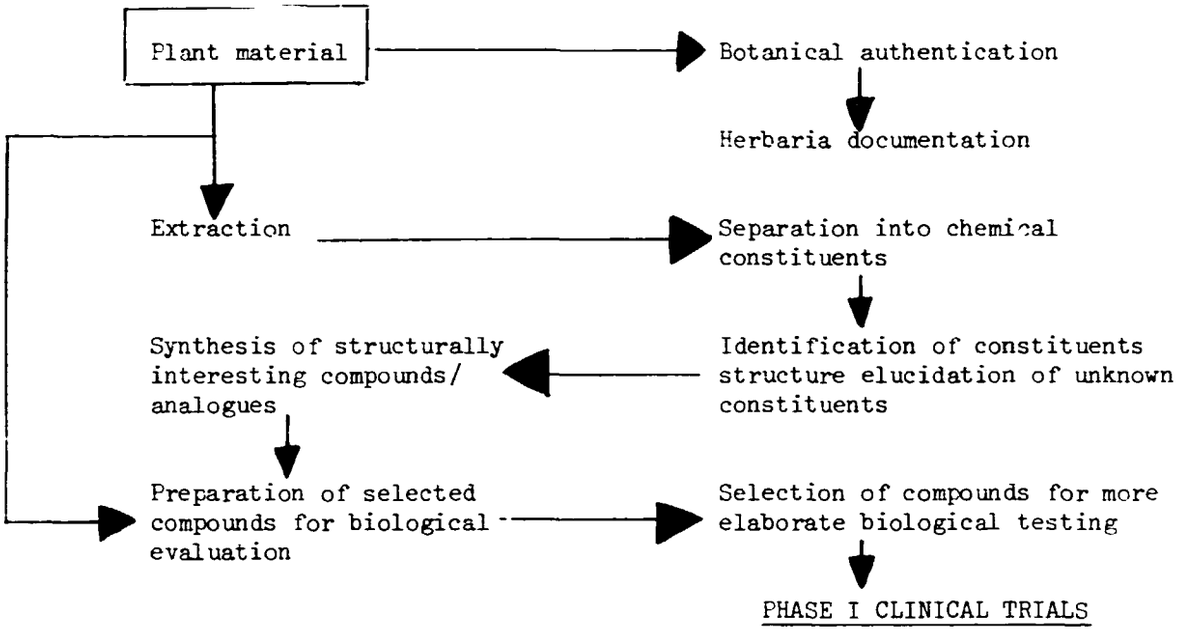
- Interchange of planting material, of essential oil-bearing crops;
- Exchange of information on various crops, technology and methods of extraction, fractionation, purification, formulation of products, marketing practices etc.;
- Exchange of personnel between R and D institutions for training and gaining expertise;
- Loan of experts from the countries where the industry is more developed to those where the industry is in the initial stages;
- Information on best methods of procurement of suitable technology as regards cultivation and distillation;
- Testing of products from developing countries at institutions in other developing countries.

In general there was felt a strong need to develop a form of bulletin or other information source on a regular basis to developing countries which were interested in the essential oils industry, as the need for information on agronomic aspects, marketing, technology etc. was clearly there.

10. SOME CONSIDERATIONS IN THE DEVELOPMENT OF PLANT-DERIVED DRUGS, WITH PARTICULAR REGARD TO THE NEEDS OF DEVELOPING COUNTRIES

STRATEGIES OF DRUG DEVELOPMENT

10.1 Plant extracts are the most simple and traditional form of therapeutic agents. Throughout the ages and in all parts of the world this form of therapeutic agent is widely used. However, in the development of modern research on plants reputed to possess biological activity, the preferred sequence of operations has been the following. [42 - 45]



10.2 In the sequence of events the two main operations are:

(i) The separation of the chemical constituents and the isolation of pure compounds followed by structural elucidation, synthesis of the natural products and their structural analogues;

(ii) The quantitative bioassay of the compounds in a variety of animal species to evaluate efficacy as well as any possible toxicological or teratogenic manifestations, prior to launching into clinical evaluation.

10.3 The methodology of isolating the "active" constituents as pure compounds brings with it certain constraints. Generally speaking organic chemists will tend to find such compounds that lend themselves to ready isolation, and purification by crystallization, as this makes for comparatively rapid structure elucidation - an exercise which is attractive as a means of intellectual fulfillment. It is just likely that compounds, which present more formidable problems of isolation may g undetected and these may be the very ones with biological activity. Isolation methods, monitored by animal bioassays have come into reckoning relatively recently and these techniques serve as guides to the isolation of active constituents. 47/ However, bioassay methods are time consuming and expensive and can only be sparingly employed.

10.4 In this scheme of drug development which is the main strategic line traversed by the drug producers of the industrialized countries the costliest and by far the most time consuming operations are the testing for toxicology and the overcoming of regulatory barriers. Even if a herbal remedy succeeds in its passage through this operational sequence, the cost in money and time would be prohibitive to developing nations.

10.5 The use of extracts

On reflection it must be realized that 80 per cent of the world's population use crude plant extracts as therapeutic agents. It is also well documented that plants are a major source of bioactive agents, and given both the increasing poverty and health-care needs of developing countries, as well as the ever increasing cost of pharmaceuticals a dichotomous situation presents itself: there is a wealth of drug potential in the plant-kingdom [47-50] that can greatly ameliorate the health of the world's poor, leaving aside the economic benefits of a drug development strategy based on medicinal plant crops. Yet the strategy of drug development hitherto adopted is clearly not the one to fit the supply.

What is needed therefore is a concerted plan of action to introduce the concept of utilizing plant extracts, and develop the extracts into modern drug formulations with the care and the rigour demanded in such a situation.

10.6 While, as has been noted previously, chemically pure compounds are not always to be preferred to extracts having complex compositions, there are no obvious general guiding principles to decide this - not yet - at this stage of the world's knowledge. However it is true that the isolation of a pure, active chemical compound is the acknowledged goal of many researchers and particularly the majority of the drug development agencies. A chemically pure compound has obvious advantages; it could be readily identified and characterized; it could be synthesized, and, given the ingenuity and skill of modern organic chemists, the molecular structure could be modified to make analogues of greater efficacy and less undesirable side effects. But this process - modern drug development - takes about 5-10 years in time, and several million dollars in funds, before even a Phase I clinical trial can be envisaged. [51]

The developing countries could afford neither time needed nor the money, given their current dire situation in health-care needs.

10.7 From the developing country viewpoint, advantage may be taken of the fact that extracts need not be always behind pure compounds as effective medicaments; there are indeed reasons - clinical ones - where they may be preferable, for often, they are known to be endowed with greater activity when co-existing constituents may increase solubility and bioavailability. [52]

There are often reasons too, from the point of view of large-scale preparations. Extracts will often contain groups of compounds closely similar in chemical structure (anthraquinones, saponins, peptides, polyphenols, terpenoids, quassins etc.) and the separation of these from an industrial standpoint would be disproportionately costly, and would not increase effectiveness of the drug. Another argument towards the employment of plant extracts as medicaments is the combined result of recent progress in pharmacy, chemical technology and analytical methods. The pharmaceutical industry is today in a position to utilize extracts in a variety of forms presenting them as tablets, capsules, syrups, granules, emulsions etc. all more concentrated and more suitable than the traditional decoctions and infusions.

They can be in standardized and stabilized form and the ingredient - content, can be assessed in modern analytical terms.

Already there exist in the market many such drug preparations; some common ones are: senna, cascara, frangula, valeriana, rauwolfia etc. These preparations contain a determinable and high percentage of the active ingredients and it does not always make sense therapeutically or economically to isolate the active ingredients, for the purpose of medication.

10.8 Selection of plant species

In initiating a programme for production of pharmaceuticals from plants the first requirement is the selection of a priority list of plant species to be utilized for pharmaceutical productions. This selection may be from the species found in the spontaneous flora of a country and currently being used in traditional therapeutics. A critical evaluation of the ethnomedical literature is a prerequisite. 47/ The list may also include plant species of established medicinal value that may be introduced into cultivation. The former selection necessitates an "economic mapping" 20/ of the spontaneous flora of the country concerned and certain aspects of plant identification or authentication, taxonomic and chemotaxonomic research. The latter selection would require experimentation in plant agronomy and genetic research which could eventually lead to the production of viable nurseries for the plant species introduced into cultivation. Eventually all plant species employed for production of pharmaceuticals - for reasons of uniformity in quality and availability of a continued raw material supply - need to be systematically cultivated.

10.9 Selection of pharmaceutical preparations

The number of pharmaceutical preparations being produced from plants in the traditional manner in most countries presents a range too wide to be undertaken systematically in a factory. Obviously some selection has to be made on the basis of such parameters as the following:

- Treatments for the most common ailments;
- Treatments for ailments which are unique to a country or locality;
- Utilization of plant material available in abundance, within a country or locality;
- Utilization of plant species readily cultivable in the country or region;
- Possibilities of export markets for processed products;
- Possibilities of extensive local utilization of products;
- Availability of infrastructural requirements: trained manpower, equipment etc.

In many developing countries, given that assistance from international organizations is forthcoming and the infrastructure is available, a start could be made in the harnessing of plant-derived medicines for health-care needs as well as economic benefit.

10.10 Preparation of extracts

Production facilities for preparation of extracts will largely depend on the circumstances within a given country. During the UNIDO Technical Consultation (ref. 9.2) [35/] a model assembly of basic requirements for the preparation of crude extracts from plants was presented. The complete list of equipment requirements for a multipurpose phytochemical processing plant was also listed.

Such an assembly will afford the basic facilities for production of pharmaceuticals from plant material as an initial venture. Besides these facilities, an essential requirement of the preparation of extracts would be the fullest possible knowledge of the chemical characteristics of the plant material. This would mean that even if the plant (or combination of plants) has not been fully and exhaustively worked on and the chemical constituents identified structurally, some preliminary chemical research will have to precede processing. Such preliminary work would enable the selection of suitable solvents for extraction and temperatures and conditions etc. This presupposes the presence within the country of a research facility in analytical chemistry or organic chemistry of natural products. The building up of such a facility for this and other reasons should commend itself in many instances, to aid giving organizations.

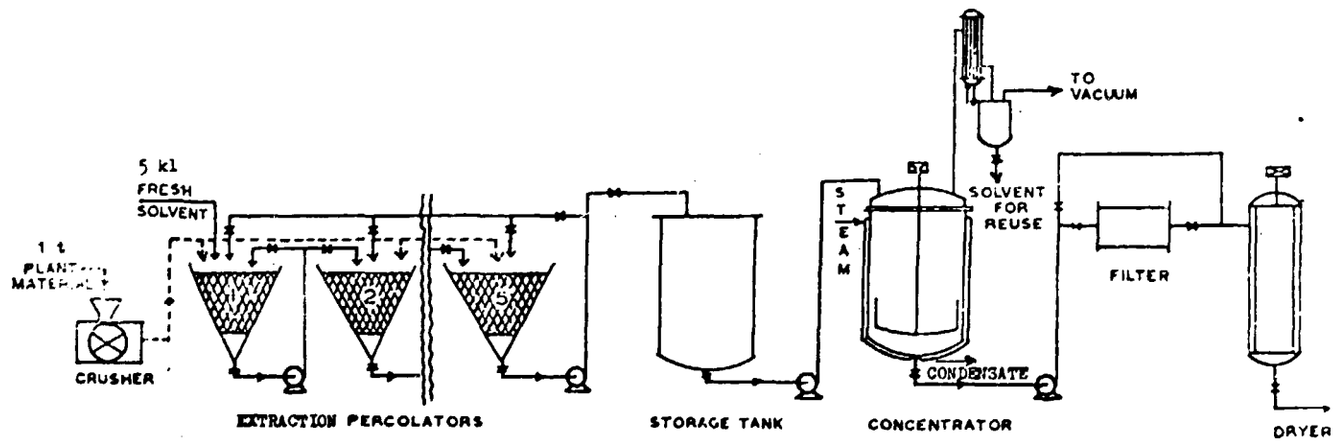
Fig. 3

A model unit for the preparation of plant extracts

The sequence of unit operations involved in processing 1 ton (t) of material per day is indicated in the flow chart below. Depending on the nature of the desired final product, the concentrate obtained can be processed further.

Only the major process equipment is shown in the flow chart. The complete list of equipment for the unit is as follows:

Item	Capacity	Number required
Process equipment		
Weighing balance		1
Hammer mill with sieving arrangement	100 kg/h	1
Percolator, stainless steel	1 500 l	5
Circulation pump, stainless steel, head 10 m	500 l/h	8
Storage tank, stainless steel	3 000 l	1
Concentrator, stainless steel, jacketed with agitator	500 l	2
Shell-and-tube heat exchanger, stainless steel, surface area 2 m^2	250 l	2
Receiver, stainless steel		1
Solvent recovery plant		1
Filter		1
Dryer		1
Service equipment		
Boiler, pressure 10 bar	300 kg/h	1
Vacuum pump, water-ring type, vacuum up to 0.06 bar	80 m^3/h	2
Chilled-water circulation unit	20 t	1
Analytical instruments		
pH meter		1
Thin-layer chromatography equipment with ultraviolet lamp		1
Spectrophotometer, ultraviolet		1
Centrifuge, laboratory model		1
Soxhlet apparatus with bath		1
Vacuum pump, oil		1
Vacuum oven and muffle furnace		1
Microscope		1



Flow chart for a multipurpose phytochemical processing plant
(capacity 1 t/d)

Quality assessment of extracts and standardization

10.11 The quality assessment of extracts produced must be conducted not as a final step but as a continuing process. This means that commencing with the procurement of the authentic type of plant material, its pretreatment in the established manner, all steps of the extraction process must be conducted under controlled conditions that are conducive to reproduceability.

The quality assessment of plant extracts can now be carried out utilizing modern analytical techniques, [52-55] but it would be unrealistic to expect in the analysis of extracts the exactness of data, which arise from the analysis of pure chemical compounds. The nature of the material does not permit such exactness, and the same can be said to be true in the quality assessment of food products.

10.12 Basically, there are three types of analytical tests that could be conducted on an extract:

tests to determine physical characteristics;

tests to determine qualitatively and quantitatively the presence of selected constituents; and

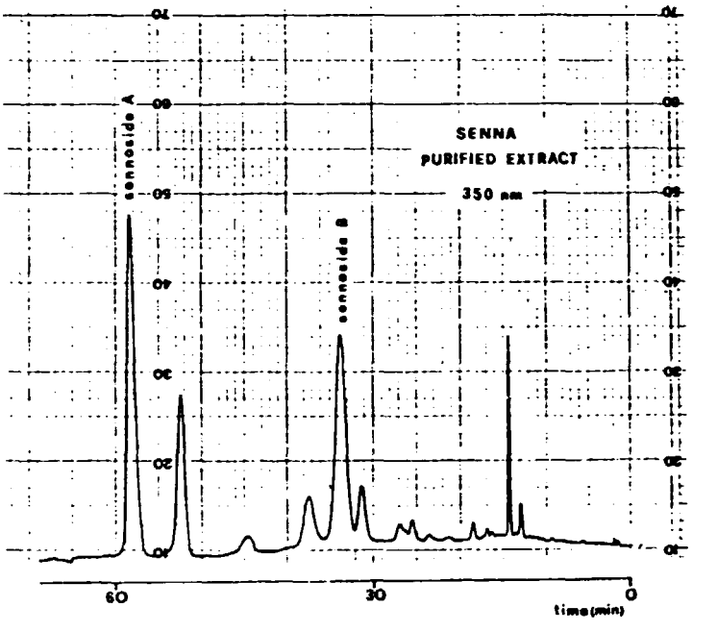
tests for potential impurities and microbial content.

The physical characteristics may be determined by such classical tests as appearance, pH, solubility, solvent content, ash, etc. such tests are described for pharmaceuticals in the various pharmacopoeias and in the Handbook of the Association of Official Analytical Chemists, of the United States. Chromatographic methods are supreme in the qualitative standardization of an extract.[52-55] Firstly it is possible by these methods to ensure that the extract has not been denatured by the extraction process. This would be so if the chromatographic pattern of a fresh extract is unaltered when the finished product is made (fig. 4). [52]

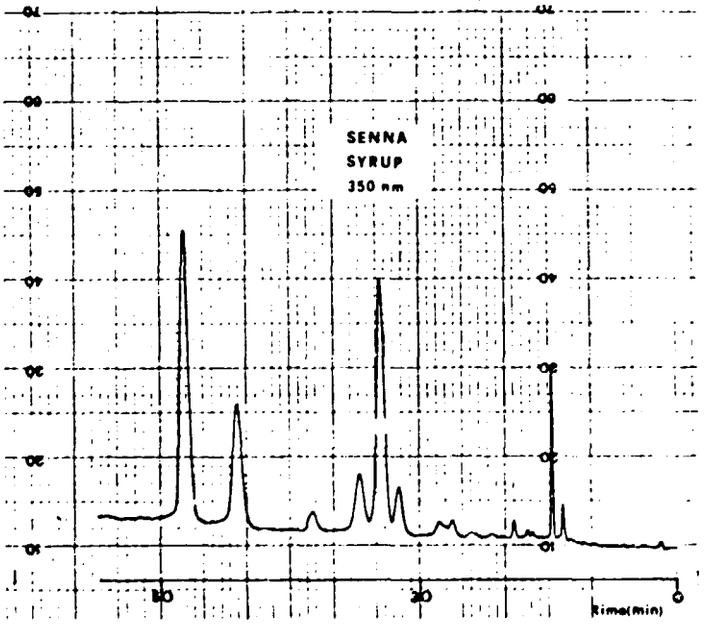
Secondly it is possible to identify selected important constituents and obtain a quantitative estimate of their presence in the original extract as well as the final preparation. The other classical techniques would be able to determine quantitatively compounds for which there existed specific chemical reactions that could be quantitatively monitored. Chromatographic methods (HPLC, TLC, GLC) enable the quantitative estimation of several specific compounds when needed.

Fig. 4

Analysis of senna (Cassia acutifolia delite) extracts by high pressure liquid chromatography (HPLC) 52/



Chromatogram of Senna (purified extract).



Chromatogram of a syrup containing Senna (purified extract).

Pharmaceutical formulations

10.13 In the traditional systems of medicine, plant-derived drugs are prepared in the crudest formulations such as total aqueous extracts, or powders with no ambitions for storage of the product. In rare instances alcoholic extracts and syrups are made and in several countries such preparations are stored for many months.

It is in this field of formulations for storage and distribution that a very distinct contribution could be made by the application of modern science and technology.

When a pharmaceutical technologist is committed to work with extracts whose physical characteristics and chemical nature are known, he may adapt the pharmaceutical form of the product to suit the extract. As a result he may be able to develop formulations that are physically and chemically stable and furthermore can be subjected to standardized dispensation.

The employment of extracts with well-defined characteristics and the use of modern instrumental techniques of quality assessment will enable the production of traditional medicines in a variety of modern formulations such as syrups, capsules, tablets, injections, ointments, granules for making up just prior to use, which will be a great boon to developing nations.

Assessment of efficacy

10.14 This is one of the most difficult and controversial issues in the entire subject of pharmaceutical development from plants. If, as has been pointed out previously, the elaborate and rigorous methods of drug development now applicable in the industrialized world, which have evolved to control the modern flood of synthetic drugs are to be employed the situation becomes intractable. On the other hand the dangers are too evident in the simple belief and trust that plant remedies have been in use for thousands of years. There are too many instances of plant drugs containing substances known to be distinctly toxic to man. On the other hand there are instances where particular traditional preparations overcome such toxicity.

10.15 Traditional systems of medicines have always based their therapeutics on an array of concepts that differ so much from those of Western medicine. These concepts have received scant attention in terms of scientific assessment and have generally tended to be lightly tossed away by Western practitioners and drug development agencies. In general the multi-component prescriptions or poly-prescriptions, characteristic of traditional medicine, in the Chinese systems, in Ayurveda, Unani, and Siddha, and Sowa Rigpa systems of South Asia, as well as in the African systems, are administered in the form of

"decoctions". The underlying therapeutic rationale is the "hollistic approach" where it is contended that a whole drug, or a group of drugs would be more effective than a single component. This could be rationalized in several ways: by postulating synergistic activity and complementary activities where one component counteracts the ill effects of another component; by solubility factors where an increase of solubility increases bioavailability or the decrease in solubility of a toxic constituent renders the preparation as a whole less toxic.

Furthermore, the concept of therapeutics itself differs considerably in the traditional systems which basically disregard symptomatic treatment. For example, both the Ayurvedic system, and in the Chinese systems, the guiding principle of treatment depends on the regulation of the homeostatis of a body and the restoration of the diseased body to a normal state. Thus it must be recognized that scientific assessment of efficacy by the existing methods of pharmacology has its limitations when applied to traditional systems of medicine.

It follows thus, that a greater utilization of medicinal plant preparations would call for enhanced research efforts with a new approach towards the assessment of efficacy, and an understanding of the mechanisms of action of the composite preparations employed.

10.16 A recent example that has received attention along these lines, is the case of the Aconitum species, widely used in traditional medicine in Japan and China, and, a species known by previous phytochemical work, to contain the highly toxic alkaloids mesaconitine and hypaconitine as major constituents. The question begs itself: Why then is it used in the traditional system of medicine, and further why are toxic manifestations and fatalities not reported?

Japanese researchers Hikino et al. [56] recently studying this problem found that when the raw tubers of the Aconitum spp. were processed in the traditional way - by boiling for about an hour - most of the poisonous aconitines were hydrolysed into the relatively far less toxic benzoylaconines.

For example the raw tubers of Aconitum japonicum contained the toxic alkaloids hypaconitine, mesaconitine and aconitine to the extent of 0.35 per cent. After the tubers had been heated the content of toxic alkaloids was reduced to 0.04 per cent. Furthermore, the raw tubers had an oral LD.550 in mice of 0.54 g/kg of crude drug equivalent, and after processing as described the oral LD. 50 value increased to 195 g/kg reflecting a decrease in toxicity of over 400-fold.

There are many cases where such explanations of mechanisms could be obtained if modern research was designed to search for interpretations of the empirically established results, instead of the prejudice-laden approach, lacking in scientific objectivity itself, that has often tended to dominate approaches in this field hitherto.

Pharmacological examination of extracts

10.17 The pharmacological examination of extracts also presents a variety of problems in comparison to examination of pure compounds and these problems are not dissimilar to the problems encountered in analysis. The standardized extracts even as such do not always display sharply defined bioactivity. The many substances present can interfere, modify, or render latent the manifestations of bioactivity. When the pharmacologist embarks in devising bioassays, the ethnomedical information, as well as the analytical parameters could act only as a guide. The pharmacologist has also to be sensitive to the many different manifestations of biological activity that are likely to show up. However recently, there are indications that pharmacological work on extracts are of great interest and present challenging problems, for which solutions though difficult are well within the realm of possibility. 56-58/

Perspectives in research on the preparation of standardized and stabilized plant-extracts

10.18 Given the objective in simple terms, of the preparation of qualitatively and quantitatively standardized total or purified plant extracts, research work must take on the following stages:

(a) Botanical and agronomic studies on the plant species used;

(b) Identification of the bioactive or characteristic principles of the plants used; this may be done on the basis of studying the existing literature if the plant or its species has already been chemically investigated;

(c) Development of suitable analytical methods for assessment - both qualitatively and quantitatively - of a variety of constituents to enable the control in terms of quality of both crude plant material and the extracts to be produced;

(d) Studies on the best method of extraction, both with respect to choice of solvent and technology;

(e) Studies to develop the most appropriate pharmaceutical formulation of the extract - liquid, dry granules, syrup etc. - that would ensure the optimum stability, facile presentation and quality assessment;

(f) Comparative pharmacological and clinical studies on prepared pharmaceutical formulations and original traditional preparations.

10.19 Following the correct botanical authentication of the plants it will be found that in many instances there is already a wealth of information on the constituents of plants employed in the traditional systems of medicine. Equally the literature abounds with data on the chemical composition of essential oils derived from aromatic plants. There are many computer data-bases that have collated such information on plant-derived natural products. 59/ In the event that the literature reveals no previous work on a plant in question, then doubtless, chemical work should be undertaken, and this is then the type of research which will have a direct bearing on the pharmaceutical needs of developing nations.

A knowledge of the chemical characteristics of the plant material used lends itself to the development of the following:

- Suitable analytical techniques for assessment of quality with respect to the presence/absence of active ingredients, or of desirable/undesirable constituents;
- Analytical monitoring of the agronomic techniques used in the propagation of the plant species by cultivation. Clones may be selected which possess enriched amounts of the desirable constituents and comparatively less of the undesirable ones;
- Analytical monitoring of the extraction process, as well as the stages in formulation of products;
- Control of stability and effectiveness of standardization.

10.20 Analytical chemistry in the past few decades has made spectacular progress with the introduction of new and sensitive instrumentation. New separation techniques such as gas-liquid, thin-layer and high performance liquid chromatography have enabled fantastic separations of plant constituents. The development of a range of modern spectroscopic methods have made possible the detection and estimation of minute quantities of material and these two developments, in concert, have revolutionized concepts and procedures of analytical quality control. The result is that in modern pharmaceutical formulations, the pharmacist is able to work with extracts that have well-defined characteristics, and with methods of control that enable him to develop formulations that are physically stable. Furthermore, the pharmacist is now able to adapt the formulation methods, to the characteristics of the extract. So the way is open to undertake now (and indeed on behalf of all developing

nations) the complex yet essential task of preparing plant-based pharmaceuticals up to the most modern scientific and technical requirement. It is a reassuring thought therefore that pharmaceutical formulations can now be developed that are stable with respect to the content of their active or characteristic principles, constant in their technological characteristics and reproduceable industrially.

10.21 For the reasons discussed before, the pharmacological examination and biological standardization of plant extracts does not present quite the same formidable problems as a few decades ago. All variations of chemical constituents of an extract due to either botanical variability, or geographical variations from plants grown in different regions, or variations due to extraction techniques could be monitored by the new analytical techniques. The material now presented is more uniform and specific bioassay techniques have to be devised to assess the activity of the product, in each case. In several pharmaceutical firms today that deal with products from plant extracts such bioassay methods have been successfully worked out, which help control quality of the preparation in pharmacological terms. However it must be argued, that there appears to be little justification for the insistence in many quarters of rigorous and at times irrelevant tests for toxicology and efficacy. In the case of synthetic drugs these requirements are quite another matter. It must be remembered in the case of plant extracts that we are dealing with material that is substantially already "in clinical use" in the world and has been so over the millenia.

List of annexures

Annex I

A list of the medicinal plants found in various regions: Africa, Asia, Latin America, whose active principles are used in modern medicine

Name of plant	Part of the plant used	Product	Availability: Cultivated	Availability: Wild	Region: Africa	Region: Latin America	Region: Asia	Method of production a/	Market potential: Local	Market potential: Export	Trend
Acacia arabica/ Acacia senegal)	Stem	Gum		+	+				+	++	Steady
Aconitum sp.	Root	Total extract		+			+	C	+	+	Down
Acorus calamus	Rhizome	Essential oil and crude drug		+			+	A	+	++	Steady
Aesculus hippocastanum	Seeds	Aescin and total extract	+	+			+	C	+	++	Up
Agave sisalana	Juice	Hecogenin	+		+	+	+	D	+	++	Steady
Aloe sp.	Leaf juice	Aloin	+	+	+	+	-		+	++	Steady
Ammi majus	Seeds	Xanthotoxin	+	+	+		+	D	+	++	Up
Ammi visnaga	Fruits	Visnagin, khellin		+	+	+		C	+	++	Steady
Amomum subulatum	Fruits	Essential oil	+	+	+		+	A	+	++	Up
Amomum xanthioides	Fruits	Essential oil	+	+	+		+	A	+	++	Up
Andira araroba	Stem wood	Total extract		+	+	+		C		+	Steady
Anethum sp.	Fruit	Essential oil	+			+	+	A	+	+	Steady
Anise	Fruits	Essential oil	+		+		+	A	++	++	Steady
Artemisia maritima	Flowering tops	Santorin		+	+		+	D	+	+	Steady
Atropa belladonna	Leaf and roots	Total alkaloids	+				+	C	++	++	Steady
Berberis aristata	Root, stem bark	Berberine		+			+	B	+	++	Steady
Berberis asiatica	Root, stem bark	Berberine		+			+	B	+	++	Steady
Berberis lycium	Root, stem bark	Berberine		+			+	B	+	++	Steady
Betula alnoides	Stem bark	Crude drug		+			+		+	+	Steady
Capsicum annum	Fruits	Capsaicin oleoresin	+		+	+	+	D	+	+	Steady
Carica papaya	Fruit juice	Papain	+		+	+	+	B,C	+	+	Up
Carum carvi	Fruit	Essential oil	+		+		+	A	+	++	Steady
Cassia acutifolia	Leaves and pods	Sennosides		+	+	+	+	C	+	++	Up
Cassia angustifolia	Leaves and pods	Sennosides	+				+	C	+	++	Up
Cassia italica	Leaves and pods	Sennosides		+	+			C	+		
Catharanthus roseus	Leaves and roots	Vinblastine, vincristine, raubasine	+	+	+	+	+	D	+	++	Steady
Centella asiatica	Whole plant	Asiaticoside	+	+	+		+	C	+	++	Steady
Centella acuminata	Roots	Emetine	+			+	+	D	+	++	Up
Cephaëlis ipecacuanha	Roots	Emetine	+			+	+	D	+	++	Up
Ceratonia siliqua	Fruit	Total extract	+	+	+			C	+	++	Steady
Chenopodium ambrosioides	Flowering top and whole plant	Essential oil	+	+	+	+	+	A	+		Steady
Cinchona sp.	Stem and root bark	Quinine, quinidine	+	+	+	+	+	D	++	++	Up
Claviceps purpurea		Ergotamine, ergotoxine, ergometrine	+			+	+	D	++	++	Steady
Cola nitida	Seeds	Total extract	+	+	+	+		B	++	++	Up
Combretum micranthum	Leaves	Total extract		+	+		+	C	+	++	Up

a/ A - steam distillation; B - water extraction; C - Alcohol extraction; D - extraction with ther solvents.

Annex I (cont'd)

Name of plant	Part of the plant used	Product	Availability: Cultivated	Availability: Wild	Region: Africa	Region: Latin America	Region: Asia	Method of production a/	Market potential: Local	Market potential: Export	Trend
Commiphora mukul	Resin	Gum		+			+	D	++		
Costus speciosus) Costus citratus)	Rhizome	Diosgenin		+		+	+	D			
Cymbopogon flexuosus	Leaves	Essential oil, citral	+		+	+	+	A	+	++	Steady
Datura sp.	Leaves	Atropine									
Derris elliptica	Root	Rotenone	+	+	+		+	D	+	++	Up
Digitalis lanata	Leaves	Digoxin and lanatosides	+		+			C,D	++	++	Steady
Dioscorea sp.) Dioscorea) leichartii)	Tubers	Diosgenin	+	+	+	+	+	D	++	++	Steady
Duboisia myoporoides	Stem	Hyoscyamine, hyoscine	+	+	+	+	+	D	++	++	Steady
Ephedra gerardiana	Whole plant	l-Ephedrine		+			+	D	++	++	Steady
Ephedra vulgaris	Whole plant	l-Ephedrine		+			+		++	++	Steady
Ephedra nebrodensis	Whole plant	l-Ephedrine		+			+	D	++	++	Steady
Eucalyptus globulus	Leaves	Essential oil	+		+	+	+	A	++	++	Steady
Glaucum flavum	Leaves	Glaucine		+	+		+	C	++	++	Steady
Glaucum simplex	Rhizome	Colchicine		+	+		+	D	++		
Gloriosa superba	Rhizome	Colchicine		+	+		+	D	++	+	Steady
Glycyrrhiza	Rhizome	Total extract		+			+	B	++	++	Steady
Heracleum candicans	Roots	Xanthotoxin		+	+		+	D	+	++	Steady
Hibiscus sabdariffa	Flower	Dried flowers	+		+	+	+		+	++	Up
Holarrhena floribunda	Stem bark	Conessine and total alkaloid	+	+			+	D	+		
Hydnocarpus kurzii	Seeds	Fixed oil, hydnocarpic acid		+			+		+		
Hydnocarpus wightiana	Seeds	Chaulmoogric acid									
Hyoscyamus sp.	Root	Hyoscyamine and other alkaloids		+	+				+		
Lippia chevatiari	Whole plant	Camphor and essential oil		+	+			A	+	+	Steady
Lobelia pyramidalis	Leaf, flowering top	Lobeline and total extract		+			+	D	+		
Mentha sp. (Japanese mint) Mentha piperita)	Whole plant	Essential oil	+		+	+	+	A	++	++	Up
Mucuna pruriens	Beans	l-Dopa	+	+	+	+	+	B	+	+	Steady
Omoba echinata	Seeds	Fixed oil			+				+		
Papaver somniferum	Capsule and latex	Morphine, codeine moscapine papaverine	+			+	+	D	++	++	Up
Rauwolfia sp.	Whole plant	Total extract	+	+	+	+	+	C	+	+	Steady
Rauwolfia yohimba	Stem bark	Yohimbine and total extract		+	+			D	+	+	Steady
Physostigma venenosum	Seeds	Physostigmine, stigmasterol		+	+			D	+	++	Steady
Physochlaina praealta								C,D			
Pilocarpus sp.	Leaves	Pilocarpine		+		+		D	+	+	Steady

Annex I (cont'd)

Name of plant	Part of the plant used	Product	Availability: Cultivated	Availability: Wild	Region: Africa	Region: Latin America	Region: Asia	Method of production a/	Market potential: Local	Market potential: Export	Trend
Plantago ovata	Seeds, husks	Isphaghula, psyllium	+				+		++	++	Up
Podophyllum hexandrum (Podophyllum emodi)	Rhizome	Podophyllin, podophyllotoxin		+			+	D	+	++	
Polygala senega	Roots	Resin		+	+				+	+	Up
Prunus africana	Stem bark	Total extract		+	+			C	+	++	Steady
Psoralea corylifolia	Seeds	Psoralen		+			+	D	+	+	Steady
Rauwolfia heterophylla Rauwolfia serpentina Rauwolfia vomitoria	Roots	Reserpine, ajmaline, deserpidine, rescinnamine, reserpiline		+	+			D	+	+	Up
Rhamnus purshiana	Bark	Crude extract		+		+		C	+	+	Steady
Rheum emodi	Rhizome	Total extract	+	+	+		+	C	+	+	Steady
Rheum palmatum	Rhizome	Total extract	+	+	+		+	C	+	+	Steady
Ricinus communis	Seeds	Fixed oil	+	+	+	+	+		+	++	Steady
Solanum sp.	Berries	Solasodine	+	+	+	+	+	D	+	+	
Sterculia setigera	Bark exudate	Gum		+	+		+		+	+	Steady
Strophanthus gratus	Seeds	Strophanthine, strophanthidine		+	+			D	+	+	Up
Strophanthus kombe											
Strychnos nux vomica	Seeds	Strychnine		+	+		+	D	+	+	Steady
Tabernanthe iboga	Stem bark	Ibogaine		+	+			D		+	
Taraxacum officinale	Root	Resin and total extract		+		+	+	D	+	+	Steady
Thevetia neriifolia	Seeds	Peruvoside	+		+	+	+	D	+	+	Steady
Urginea indica Urginea scilla	Bulbs	Proscillaridine		+	+	.	+	C	+	+	Steady
Valeriana officinalis Valeriana wallichii	Rhizome	Total extract	+	+		+	+	C	+	+	Steady
Voacanga thouarsii Voacanga africana	Seed	Tabersonine		+	+			D		+	Up
Vinca [illegible]	Leaves	Vincamine	+	+	+	+	+	D	+	+	Up

Annex II

An additional list of plants used mainly in Traditional Medicine, in Africa, Asia and Latin America

ADDITIONAL LIST OF PLANTS USED MAINLY IN TRADITIONAL MEDICINE IN AFRICA, ASIA AND LATIN AMERICA

Name of plant	Part of plant used	Type or use of drug
Acacia catechu		For ulcers, boils, indigestion and throat pain
Acacia senegal	Gum	In diarrhoea
Aconitum heterophyllum		Antiperiodic, antidiarrhoeal, antirheumatic
Achyranthus aspera		In leprosy
Acorus calamus		Antispasmodic, carminative, antitussive
Ajuga bracteosa		Antidiarrhoeal
Albizzia lebbeck		Antitussive
Alangium digitata		
Aegle marmelos		Antipyretic, stomachic, antidiarrhoeal
Alchornea cordifolia		Antimalarial
Allium sativum	Bulb	Anti-infectious
Aloe barbadensis		
Alpinia galanga	Rhizome	Anti-infectious
Alpinia officinarum	Rhizome	Anti-infectious
Alstonia scholaris		Antimalarial, febrifugal, antidiarrhoeal
Althaea officinalis		Antidiarrhoeal, antidysenteric
Amomum xanthoides		For tincture of cardamom, antitussive
Anacardium occidentale	Bark	Antidysenteric
Andrographis paniculata	Plant	Antidysenteric
Anisomeles ovata		Carminative
Annona muricata		
Areca catechu	Seed	Anti-infectious
Artemisia abiutlium	Flower	
Artemisia herbealba		
Asimum sp.		Antimalarial

Name of plant	Part of plant used	Type or use of drug
Asiacuosi deo asparms moris (fresh)		Anthelminthic
Asparagus racemosus	Root	Antidysenteric
Asparagus racemosus		Refrigerant, diuretic, antidiarrhoeal
Atrocarpus lakoloha	Bark	Anthelminthic
Averrhoa carambola	Flower	Anthelminthic
Azadirachta indica	Bark	Antimalarial
Azadirachta indica	Oil	Antiseptic; in rheumatism
Baliospermum montanum		Antifilarial
Bauhinia malabarica	Plant	Antidysenteric
Bergenia ligulata		In fever, diarrhoea and pulmonary infection
Berberis aristata / Berberis asiatica		In diarrhoea and jaundice
Bidens fulosa		
Bidens pilosa		Antimicrobial
Blumea balsamifera		As camphor
Boarhavia diffusa		Hypertensive, antidiuretic
Boerrhavia diffusa		In uterine bleeding
Butea frondosa		Anthelminthic
Carrophyllus aromaticus		For toothache; carminative
Carthamus tinctorius	Flowers	Stimulant
Carum copticum (Ajowan)	Fruit	Stomachic, carminative
Cassia tistula		Laxative
Catharanthus roneus		
Celosia argentea	Seed	Anthelminthic
Centella asiatica		In skin diseases
Cephaelis ipecachuana		In amoebiasis
Chenopodium ambrosiodes		Bilarzia
Cimunum cyminum	Fruit	Anthelminthic
Cinchona sp.		Antimalarial

Annex II

Name of plant	Part of plant used	Type or use of drug
Cinnamomum camphora		For rheumatism
Cinnamomum iners [1]	Leaf oil	Antidiarrhoeal
Cinnamomum tamala	Bark	Aromatic, stomachic
Coleus aromaticifolius	Root	Antidysenteric
Curculigo orchioides	Root	Anthelminthic
Curcuma [illegible]		Carminative, stomachic
Coleus kalmanoschari		Antimicrobial
Cyperus tuberosa	Rhizome	Tonic, antidiarrhoeal, ophthalmic
Cucurbita pepo	Seeds	Anthelmintic
Curculigo orchioides		For asthma, gonorrhoea; as diuretic and tonic
Curcuma comosa	Rhizome	Blood circulation regulator
Cyperus rotundus	Bulb	Anti-infectious
Cyperus scariosus		Antidiarrhoeal, anti-inflammatory
Datura fastuosa		
Datura stramonium		
Derris pinnatus		Antimalarial
Desmodium gyroides	Root	Astringent, tonic
Desmodium triflorum	Plant	
Dichrocephala tuberculatus	Resin	For ulcers
Embelia ribes		Anthelmintic
Eriolaena gerardiana		Antiasthmatic; for inflammation of bronchi
Garcinia cumini	Bark	Antidysenteric
Garcinia indica	Seed	
Garcinia malaccensis	Bark	
Gentiana odoratum	Herb	Haemostatic
Euphorbia thymifolia		Antidysenteric
Ferula foetida		For gastric disorders

(cont'd)

Name of plant	Part of plant used	Type or use of drug
Garcinia pedunculata	Dried fruit	For indigestion
Gentiana kurroo	Rhizome	Bitter tonic
Gentiana sp.		Antipyretic
Glycyrrhiza glabra		Colitis
Gremmatophyllum speciosum	Bulb	Anthelminthic
Hagenia abbysinca (Taenia, Botigocephalus)		For ophthalmic disorders of children
Helictropum indicum	Herb	For ulcers; diuretic
Holarrhena antidysenterica	Bark	Antidysenteric
Iboza riparia		Antimicrobial, antimalarial vermifuge
Iris nepalensis		Diuretic, in bilious obstruction
Ixora coccoinea	Root	Anti-infectious
Juniperus sp.	Fruit	
Lansium domesticum	Seed	Anthelminthic
Linaria ramosissima		Antimalarial
Lobelia pyramidalis		Antispasmodic
Mallotus philippinensis		Anthelminthic
Matricaria chamomila		
Melia azadarach	Leaves	Anthelminthic
Mentha citrata		
Mesua ferrea		Stomachic, expectorant, paste for bites
Millingtonia hortensis		For hypertension
Mimosa pudica	Leaves, roots	For haemorrhoids
Mirabilis jalapa		Wound dressing
Momordica charantia		Hypoglyaricht
Murraya paniculata	Leaves	Anthelminthic
Mustard		Oil for massage and ointments
Myristica fragrans		Carminative; for nausea and vomiting

Annex II (c

Name of plant	Part of plant used	Type or use of drug
Nardostachys jatamansi		Carminative; for cholera and hysteria
Nutmeg		Carminative, stomachic
Ocimum basilicum		Antidysenteric
Ocimum sanctum		Hypoglycemic, expectorant
Orchis lanata		Tonic
Pandanus odorus	Leaves (fresh)	Anti-infectious
Pergularia daemiavacana	Roots	Antitumoral
Phyllanthus emblica		Refrigerant, diuretic and laxative
Phyllanthus madraspatensis		Antidysenteric
Picrorhiza scrophulariaefolia		Antipyretic, stomachic
Pinus sp.	Resin	Carminative, expectorant; in asthma and bronchitis
Piper betle	Leaves	Anti-infectious
Piper nigrum		Stomachic, antitussive
Piper longum		Antifilarial, antipyretic
Piper longum	Rhizome	Stimulant, tonic
Plantago major		Antidysenteric
Plumbago rosea	Root	Stimulant in rheumatism
Plumbago zeylanica		Antifilarial
Podophyllum hexandrum		For liver and gall bladder
Portulaca oleracea	Leaves	Anti-infectious
Pouzolzia pentandra	Leaves	Anti-infectious
Punica granatum	Fruit	Anti-infectious
Quisqualis indica	Seed	Anthelmintic
Rauwolfia serpentina		Hypnotic, sedative, hypertensive
Rheum emodi		Purgative; in diarrhoea
Rumex vulgaris		Hemnionoides
Salvia cordifolia		For leprosy

ont'd)

Name of plant	Part of plant used	Type or use of drug
Sapindus mukrolli		Spermicidal
Securidace longipeduneculata		Molluscicidal
Securinega virosa		Polyvalent
Smilax peguana	Rhizome	Antisyphilitic
Stemona collinsae	Plant	Anthelminthic
Stemona curticli		
Stemona minor		
Stemona tuberosa		
Streblus asper	Seed, bark	Anti-infectious
Strophanthus sarmentosus		Trastone, sactone
Swertia chirata		Antimalarial, antipyretic, anti-infectious; for diarrhoea, jaundice
Swertia moorcroftiana		
Tamarindus indica	Pulp	Laxative
Taraxacum officinalis		Diuretic; for chronic disorders of kidney and liver
Terminalia arjuna		
Terminalia belerica		Laxative, antipyretic; for dropsy, haemorrhoids
Terminalia belerica	Fruit	Bitter tonic, astringent
Terminalia chebula		Antidysenteric
Thapsia garganica		Rubefiant
Tinospora cordifolia	Plant	Anthelminthic
Tinospora cordifolia	Stem	In diabetes
Trachespermum ammi		Antispasmodic; in cholera
Valeriana wallichii		Carminative; in nervous disorders
Vernonia amygdalina		Vermifugal, antiviral
Veronia anthelminticum		Anthelminthic
Veronia cinerea		Antifilarial, antipyretic
Vitex glabrata	Leaves	In diabetes
Zanthoxylum armatum		In dyspepsia and cholera
Zingiber officinalis		Antidysenteric

Annex III

A restricted list of the plants that are comparatively widely used for the production of medicines classified by therapeutic groups

Therapeutic Group	Essential		Second category	
	Plant	Active constituent	Plant	Active constituent
Anaesthetics	-	-	-	-
Analgesics, antipyretics, non-steroidal anti-inflammatory drugs and antigout drugs	Papaver somniferum	Morphine Codeine	Aesculus Hippocastanum Aesculus indica	Aescine and total extract
	Gloriosa superba	Colchicine		
Antiallergics	-	-	-	-
Antidotes, chelating agents, cholagogue			Combretum micranthum	Extract
Anti-epileptics	-	-	-	-
Anti-infective				
Antiprotozoal	Cephaëlis ipecacuanha	Emetine	-	-
	Cinchona sp.	Quinine	-	-
Anthelmintic	-	-	Chenopodium ambrosioides	Ascaridol, total extract
	-	-	Artemisia maritima	Santonin
Antimigraine	Claviceps purpurea	Ergotamine	-	-
Antineoplastic	Catharanthus roseus Catharanthus lanceus	Vinblastine Vincristine	Podophyllum hexandrum (P.emodi) Prunus africana	Podophyllotoxin and total extract Total extract (specific for prostate enlargement)
Antiparkinsonism	Mucuna pruriens	L-Dopa		
Blood and haematopoietic system	-	-	-	-
Cardiovascular				
Antihypertensive	Rauwolfia serpentina Rauwolfia vomitoria Rauwolfia confertifloratum	Reserpine	Rauwolfia sp.	Deserpidine
	Catharanthus roseus Catharanthus lanceis	Raubasine Vincamine	Ammi visnaga	Visnagin
	Vinca minor Voacanga africana a/ Voacanga thoursii a/			
Anti-arrhythmic	Cinchona sp. Rauwolfia serpentina and other species	Quinidine Ajmaline		
Cardiotonic	Digitalis lanata	Digoxin and lanatosides	Strophanthus gratus	Strophanthin
			Thevetia narifolia	Peruvoside
	-	-	Urginea scilla (Scilla maritima)	Proscilliaridine Rutin or bioflavanoids
Dermatological preparations	Ammi majus	Xanthotoxin	Psoralea corylifolia	Psoralen
	Centella asiatica	Asiaticoside	-	-
Diagnostic agents	-	-	-	-
Diuretics	Theobroma cacao	Theophylline		
Gastrointestinal drugs				
Antispasmodics	Dubois a myoporoides Duboisi. leichartii	Total alkaloids atropine or hyoscyamine		
	Atropa belladonna Atropa acuminata Datura sanguinea Datura stramonium Datura metel Hyoscyamus muticus Hyoscyamus niger Physochlaina praalta			

a/ Providing raw material for drug production.

Annex III (cont'd)

Cathartics	Cassia angustifolia Cassia italica Cassia acutifolia	Sennosides mixture or sennosides A,B	Rheum sp. Aloe sp.	Total extract Aloin
Laxatives	Plantago ovata	as such and products		
Anti-ulcer	Glycyrrhiza glabra	glycyrrhetic acid and extract a/		
Antidiarrhoeal	Berberis aristata	Berberine	Ceratonia siliqua	Total extract
Hormones	Dioscorea deltoidea Dioscorea floribunda Dioscorea composita Costus speciosus	Diosgenin a/		
	Solanum laciniatum Solanum khasianum Solanum xanthocarpum	Solasodine a/		
	Agave sisalana	Hecoginin a/		
Immunologicals	-	-	-	-
Muscle Relaxants (peripherally acting) and antagonists	Physostigma venenosum	Physostigmine		
	Chondrodendron tomentosum	d-Tubocurarine		
Ophthalmological preparations	Pilocarpus sp.	Pilocarpine		
	Physostigma venenosum Duboisia myoporoides	Physostigmine Atropine a/ (as homotropine)		
Oxytocics	Claviceps purpurea	Ergometrine		
Psychotherapeutic			Rauwolfia serpentina Rauwolfia confertiflorata Rauwolfia vomitoria	Reserpine and crude extract
			Valeriana wallichii Valeriana officinalis	Valepotriate and total extract

a/ Provides raw material for drug production.

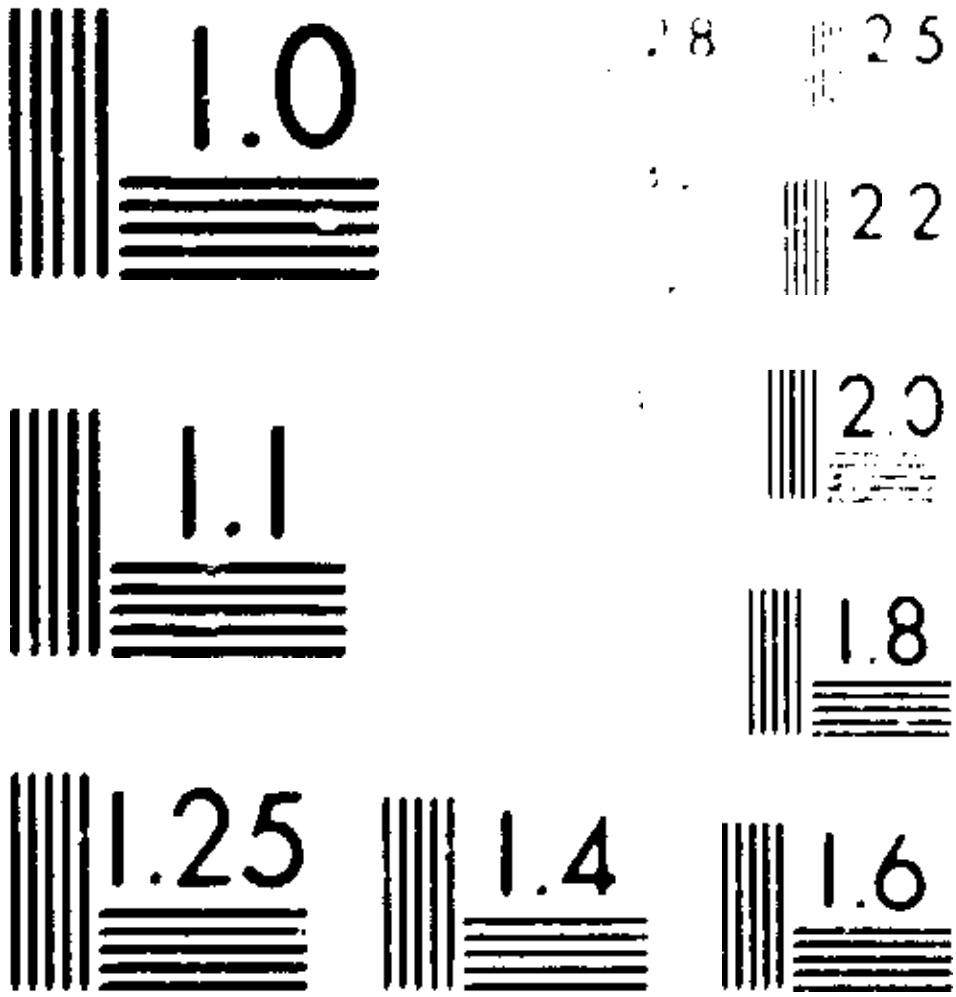
Drugs acting on the respiratory tract	Ephedra gerardiana (Ephedra vulgaris)	Ephedrine	Glycyrrhiza glabra Glycyrrhiza uralensis	Total extract
	Ephedra nebrodensis		Glycyrrhiza violacea	
	Theobroma cacao	Theophylline a/ (as aminophylline)	Glaucum flavum	Glaucine
			Polygala senega	Total extract
	Papaver somniferum	Codeine		
Solutions correcting water, electrolyte, and acid-base disturbances	-	-	-	-
Vitamins and minerals	-	-	-	-

a/ Provides raw materials for drug production.

Annex IV

A list of plants that are not necessarily used as drugs but are the source of products used in the pharmaceutical industry and for which there is demand in the pharmaceutical industry

Acacia senegal (A. Arabic)
Carica papaya Ananas
Chrysanthemum cinerariaefolium
Cola nitida
Cymbopogon flaxuosus
Derris elliptica
Eucalyptus sp.
Mentha sp.
Passiflora sp.
Ricinus communis
Soyabean (for sitosterol)
Sterculia setigera
Sugar-cane press mud (for stigmasterol)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Annex V

A list of plants concerning which R and D is well advanced in certain countries, and are likely to be introduced into clinical practice

Plant	Part of plant used	Properties
Annona muricata	Seeds	Oxytocic
Alpinia siamensis	Rhizome	Antibacterial, insect repellant
Adhatoda vasica	Leaves	Oxytocic
Asclepias curassavica	Seeds	Cardiotonic
Brucea amarissima	Fruit	Anti-amoebic
Casimiroa edulis	Seeds	Hypotensive
Chenopodium foetida C.Graveolens	Leaves	Antiparasitic
Coleus forshoklii	Roots	Hypotensive
Commiphora mukul	Resin	Hypolipidaemic
Derris trifolia	Root	Antispasmodic
Echinops spinosus	-	Vasoconstrictor
Ipomoea pescaprae	Plant	Antihistaminic, anabolic
Peretia hebeciada	Roots	Laxative
Ruta chalepensis	Leaves, stem	Oxytocic
Streblus asper	Seed	Antibacterial, antiseptic
Sapindus mukorosii	Seeds	Spermicidal
Zingiber cassumunar	Rhizome	Muscle relaxant, analgesic

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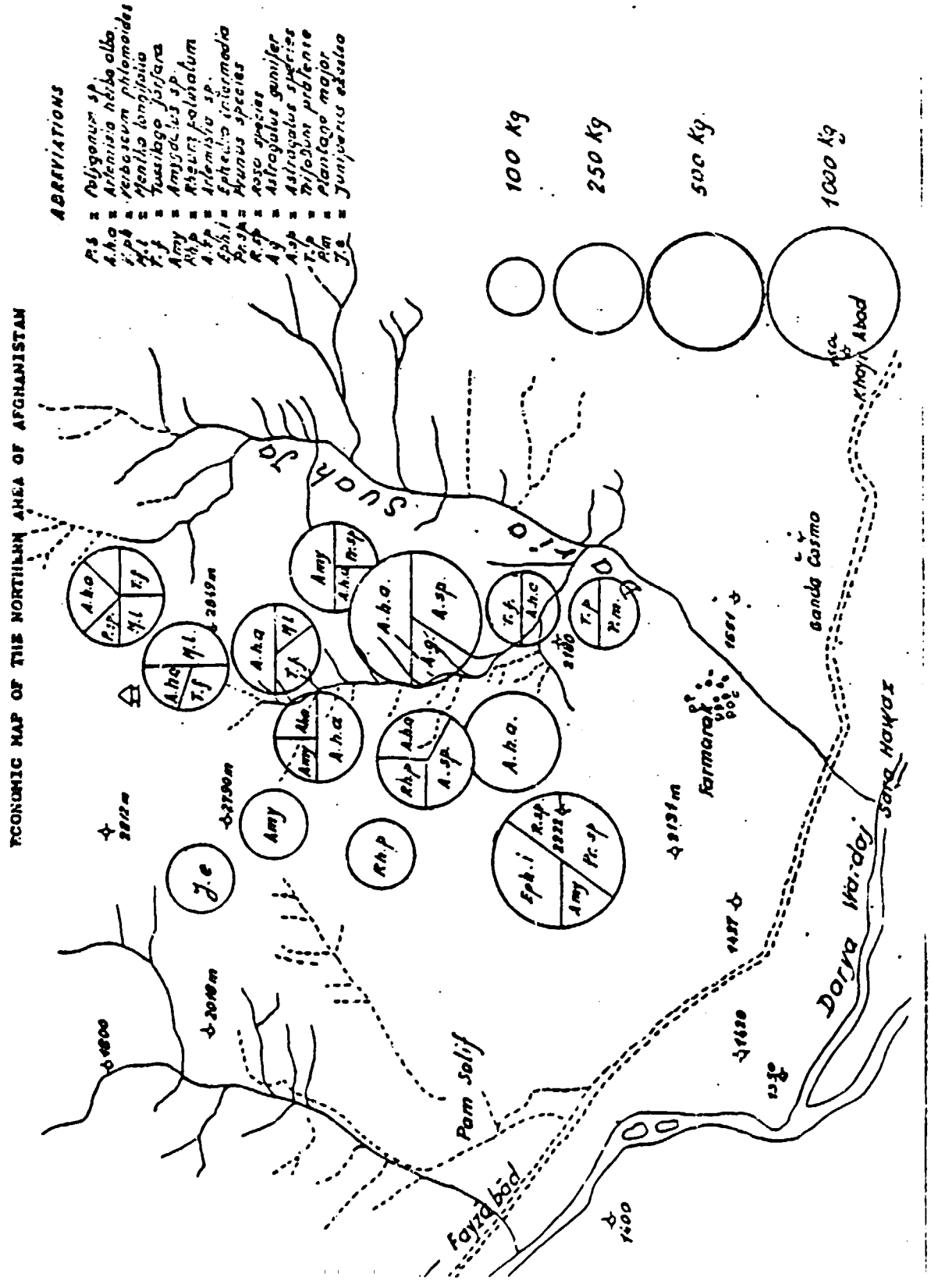
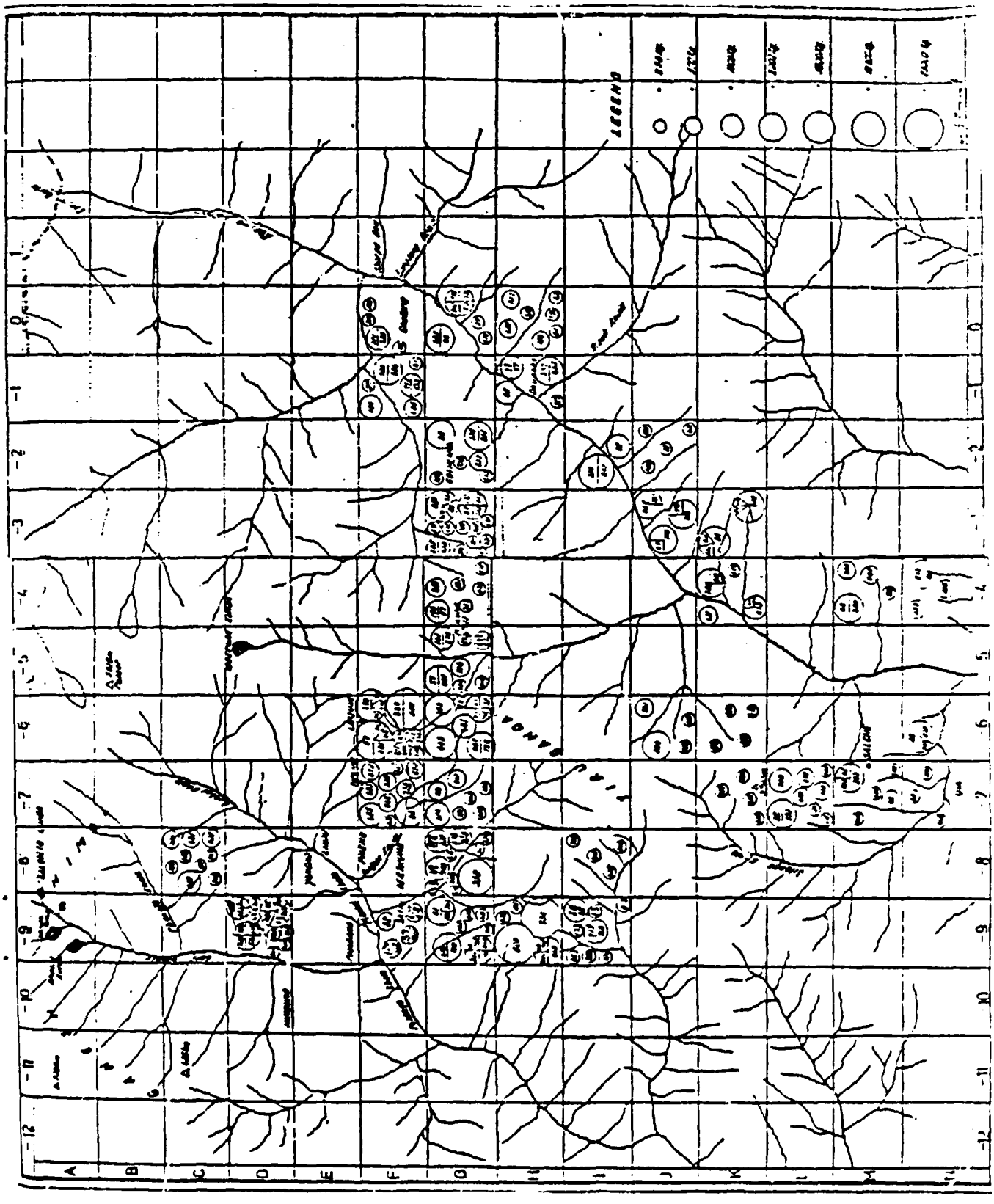
Map 1

Economic map of an area relating to the growth of medicinal plants within the spontaneous flora in Afghanistan



Map 2

Preliminary results of the "economic mapping" of medicinal and aromatic plants in Nepal



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