ICAR

Vision 2030

Directorate of Medicinal and Aromatic Plants Research

Boriavi, Anand 387310, Gujarat, India
www.dmapr.org.in

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Printed : July 2011

Edited by
Dr. Satyabrata Maiti, Director, DMAPR

Compiled by
Dr. Satyanshu Kumar, Principal Scientist, DMAPR
Dr. Manish Das, Senior Scientist, DMAPR

Directorate of Medicinal and Aromatic Plants Research (DMAPR)
Boriavi, Anand

Published by the Director, Directorate of Medicinal and Aromatic Plants Research, Indian Council of Agricultural Research, Boriavi, Anand 387310, Gujarat, India.

Printed at Anand Press, Anand 388001, Gujarat, India
0091-2692-253933, anandpress@gmail.com

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डा. एस. अय्यप्पन
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SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि मंत्रालय, कृषि भवन, नई दिल्ली 110 014
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE, KRISHI BHAVAN, NEW DELHI 110 114
Tel.: 23382629; 23386711 Fax: 91-11-233844773
E-mail: dg.icar@nic.in

FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climatic change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective VISION-2030 documents highlighting the issues and strategies relevant for the next twenty years.

The medicinal and aromatic plant sector is witnessing sea changes in the recent past due to high demand in the international market for alternative medicines and also facing numerous challenges such as sustainable supply, quality raw drug free from pesticide residue and heavy metal contamination on one hand and over exploitation of forest flora on the other. The research programmes of Directorate of Medicinal and Aromatic Plants Research (DMAPR) at Anand focus on varietal improvement, development of good agricultural practices, quality assessment, supply of quality planting material, etc. It has articulated strategies for achieving sustainability in quality raw drug supply based on science led innovations.

It is expected that the analytical approach and forward looking concepts presented in the 'Vision 2030' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

Dated the 7th July, 2011 **(S. Ayyappan)**

New Delhi

Preface

The Vedic chant ॥ सर्वे सन्तु निरामयः ॥ *"Sarve Santu Niramaya" meaning "Let all be free from diseases" has been the part of prayers of for ages. Not only Hinduism, every major religion has focussed and worked for freedom from disease and pain. Taking the cue from our Vedic wisdom, we set our vision on "Health for all" and wish to continue our research for achieving this goal by assuring quality raw drug production and supply for ever increasing population of the world.*

Medicinal plant sector is having a long supply chain starting from either cultivation or collection to marketing, raw drug distribution, primary and advanced processing, drug development, drug validation, drug introduction in the market, etc. those are handled by several stakeholder players. Success of the sector thus depends on the efficient functioning like symphony in an orchestra.

ICAR contributes in this sector in the very basic link of quality raw drug supply by research in its core competent area of agriculture such as varietal improvement, development of good agricultural practices for assuring quality raw drug supply, quality assessment, quality supply of planting material, etc. The emerging challenges and opportunities demand for an innovation driven research system using modern tools of ICT, biotechnology, molecular biology, biochemistry, etc to link with all the stake holders in the entire MAP supply chain.

I am pleased to present the DMAPR vision 2030 document which highlights the present scenario, future challenges and the strategies to address those in the raw drug production sector with science led innovations keeping sustainability of quality raw drug material supply for the industries in forefront. I am confident that this document will provide a direction to influence the sector with the power of science in achieving the sustainable growth of quality raw drug supply keeping pace with growing world market demand. I am sure that this forward looking approach and innovative strategies will put the ICAR as front runner in the sector.

I take this occasion to express my gratitude to Dr. S. Ayyappan, Secretary, DARE & Director General, ICAR and Dr. H. P. Singh, Deputy Director General (Horticulture) for their encouragement, interest and support in the activities of the DMAPR in particular and the sector in general. My thanks to Dr. Umesh C. Srivastava, Assistant Director General (Hort. II) and Ms. Shashi Prabha Razdan, Deputy Secretary for considerate handling the matter of DMAPR at the headquarters. I thank Dr. Satyanshu Kumar and Dr. Manish Das for compiling information of the sector from various sources which has given me more freedom in accepting and rejecting while editing. The efforts of my other colleagues in fine tuning the document at the end by their valuable comments and suggestions are also well appreciated. Thanks to Mr. Srinivasa Rao for providing the relevant photographs from digital photo library of DMAPR which have been included in this document and Mr. Suresh Patelia, Private Secretary for assistance.

Jai Hind!

Anand
July 11, 2011

Satyabrata Maiti

Preamble

The use of plants for preparations of medicines and in health care is by and large the largest use of plants in terms of the number of species specifically targeted. Plants provide the predominant ingredients of medicines used in most traditional systems of healing and also have been the source of inspiration for several major pharmaceutical drugs development. India is known for its various traditional system of medicines which have been developed and practised from time immemorial. A large number of traditional healing systems such as Ayurveda, Siddha, tribal medicines, folk medicines, etc. are widely practised for treatments of very complex and complicated diseases like cancers to simple requirement of primary health care.

As per the WHO estimate about 80 percent of the world population are depending greatly on these traditional health care systems for their primary health care needs. Modern medicines are yet to be accessible to mass for various obvious reasons. The scale of trade in medicinal and aromatic plants (MAP) ranges from local to international.

Basic health care system in most of the developing countries is unfortunately either absent or not sufficient at the most elementary level. MAP provide an opportunity to millions to have access to low cost primary health care that is needed. Many traditionally known plants are having astonishing medicinal value and these can be successfully used to prevent and cure several human illness.

Recently, renewed interest has been created for remedies of many devastating diseases such as cancer, AIDS, etc. from traditional plant based medicinal plants. There is a new surge of demand for MAP as raw drug which is steadily and constantly increasing world wide. However, decision makers usually have little awareness of the significance of trade and consumption of medicinal plants, or of the problems of un-sustainability and sometimes harmful impacts on natural habitats of wild collection. Hence, much of the trade is unrecorded or poorly documented in official statistics. This fact demands benchmark standards for sustainable use of biological diversity from the nature. That would save species from over exploitation and extinction.

Gradually supply of MAP from natural forest is restricted. Commercial cultivation of MAP is another option to ease out the pressure on forest and therefore, slowly but steadily expanding and progressively

becoming popular among farmers. Consumers of traditional drugs are increasingly becoming quality conscious. Under these conditions, cultivation is left as only solution of MAP for steady and quality raw drug supply. This fact is slowly realized by the industries and phenomenon of contract farming is surfacing in the national scenario. Cultivation using Good Agricultural Practices is going to be order of the future.

India being a front runner in use of medicinal and aromatic plants (MAP) over centuries because of its strong traditions of Indian System of Medicines (ISM) for health care and also large number of ISM, folklore and tribal medicine practitioners, Indian Council of Agricultural Research (ICAR) rightly recognized the growth potential of this newly emerging herbal sector because of revitalization of our traditional knowledge and created a National Research Center for Medicinal and Aromatic Plants at Anand, Gujarat in 1992 which has been reorganized as Directorate of Medicinal and Aromatic Plants Research (DMAPR) with backward linking the All India Coordinated Research Project on Medicinal & Aromatic Plants and Betelvine (AICRP-MAPB) which is contributing as outreach programme of the DMAPR in State Agricultural Universities.

The DMAPR has been working for sustainable production and utilization of major agriculturally important medicinal and aromatic plants through research and development to meet the present day demands and to address future national and international challenges.

The population of India is predicted to cross 150 crores by 2025 when the main challenge before the country would be not only food, nutritional and health security. Hence, the programmes of agriculture sector in general needs a clear vision to meet the challenges ahead, while addressing the present day demand. The present situation on future challenges call for a systematic and continued accelerative efforts in research of medicinal and aromatic plants directed towards sustainable quality production for maintaining the socio-economic and ecological balance.

Attempting preparation of a perspective plan, Vision 2030 is a difficult task in this fast changing environment of modern science when developments are happening in an exponential rate. However, we have tried our best to put the concerns related to MAP in the perspective of Indian agriculture in this document. It is expected that it would serve the purpose for which this vision has been prepared and to fulfil the goal, required support will come forth from the future policy makers.

'DMAPR Vision 2030' document describes key challenges and opportunities in the MAP sector in the next two decades for developing an appropriate strategy and a roadmap to articulate role of the Directorate of Medicinal and Aromatic Plants Research under the aegis of ICAR in shaping the future of the Indian agricultural research in the MAP sector for growth, development and equity.

Agricultural scenario *vis-à-vis* medicinal and aromatic plants

Global population is projected to increase from present 6.8 billion to 8.3 billion by 2030 and 9.3 billion by the middle of this century. It is expected that demand for better health care continue to grow with rising population. At the same time demand for more food grain, fresh water, energy and industrial raw material is also expected to increase which will have adverse consequences on the land and other natural resources availability. Climate change is another area of concern due to heavy industrialization and it would bound to have adverse effect on total food production as well as to create newer health concern.

Even now, more than half of the total global population does not have access to primary health care services and many new devastating diseases are being reported from many parts of the globe. Although, medicinal plants provide an opportunity to millions to have access to low cost primary health care facility, commercial cultivation of these plants is not very popular among the farmers. Raw drug supply from forest is also gradually being restricted. At the same time, demand of quality raw drugs of many traditionally known plants is also rapidly increasing. Under these circumstances, commercial cultivation of medicinal plants is left as the only solution for quantity as well as quality assurance. This fact is being realized and new avenues like contract farming and forest farming are explored as sustainable way to ensure the steady and constant supply of quality raw drugs. Presently, organized cultivation of about 70 medicinal plants is in practice and superior performing varieties are lacking in majority of these cultivated medicinal plants. A well planned and organized countrywide planning is required for the commercialization of medicinal and aromatic plants.

MAP and economy

Over the last two decades, there has been a tremendous growing interest in all traditional systems of medicines mainly because of inadequacy in treatment of some of the deadly and painful diseases such as cancer, HIV, AIDS, rheumatic arthritis, etc., by the modern medicine. Medicinal plants have been incorporated in seamless fabric of diet in our traditional food habit and medicines which often connected through a comprehensive traditional theory of disease control. Currently commercialization of this concept has started in the form of developing a new line of products called "functional food" which contains medicinal plant as ingredients added to health foods. Interest in collection, production and marketing of MAP as phytochemicals, pharmaceuticals, nutraceuticals, herbal remedies, food supplements, perfumes and cosmetics, food flavouring agents, etc., has increased many folds in recent years. However, increasing global demand for herbal medicines is facing a problem of dwindling supply of medicinal plants due to over-harvesting and habitat loss. The international market of medicinal plants worth over 60 billion US$ per year, which is growing at the rate of 7% per annum and is estimated to touch US$ 5 trillion by 2050. The present export of herbal raw materials and medicines from India is about US$ 100-114 million per year. India is one of the major exporters of crude drugs mainly to six developed countries viz. USA, Germany, France, Switzerland, U.K. and Japan, who share 75–80% of the total export market. Department of Ayurveda, Yoga & Naturopathy, Siddha and Homeopathy (AYUSH) has released data on export of herbal and AYUSH products which uses mainly MAP have witnessed two fold increase in export over a period of just five years (Fig.1.) which indicates the growing market worldwide.

Contribution of MAP to the global economy and human welfare is now widely recognized. However, the greatest difficulties in assessing their importance as resource are

- Lack of information about the species being used, their identification, availability and distribution
- Lack of information about their cultivation/collection and harvest especially in terms of Good Agricultural and Collection Practices (GACP)
- Lack of post harvest handling technologies
- Non availability of quality standards and procedures for monitoring of raw materials and final products

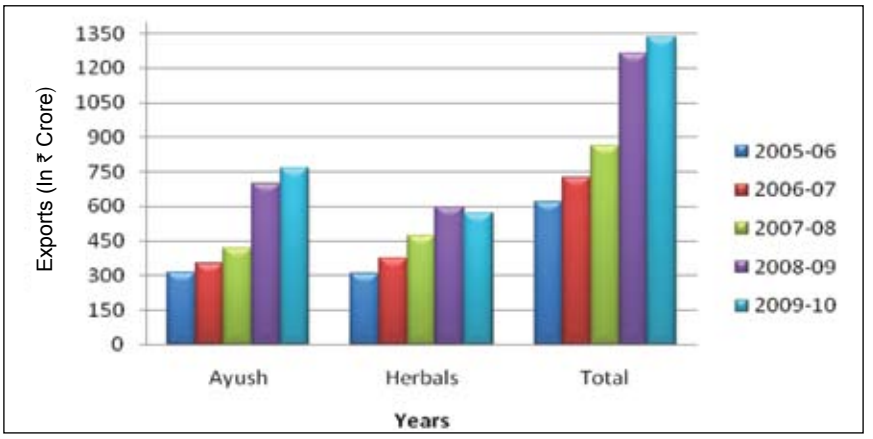


Fig.1. Herbal and AYUSH products trade statistics (2005-10): Source: DGCIS, Pharmexcil Research

- Non availability of trade statistics in case of both cultivated and collected species
- Uneconomic / unscientific price structure
- Unstable market
- Confidentiality

In recent years, there has been a concentrated effort to gather this information. However, much needs to be done for meeting the stringent conditions put by the regulated markets of developed countries.

Role of MAP in smallholders' agriculture

Medicinal and aromatic plants (MAP) as a whole are undeniably high value natural resource providing additional income to a large section of deprived and under privileged populations, particularly, forest dwellers and a number of tribes whose livelihood depend on MAP of forest resources. Increasing cost of food grain cultivation due to yield plateau and market price fluctuations are some of the factors which have driven the farmers towards cultivation of MAP. It is also considered that MAP cultivation is less risky in terms of incidence of insect pests and diseases. Further, some of the MAP can also be cultivated in degraded, eroded, problematic (saline / alkaline / acidic), marginal and sub-marginal soil and also as intercrop with plantation crops and fruit orchards. Therefore, it would be ideal crop for small farm holders who can not afford the cost of high input in terms of fertilizers and pesticides to grow traditional food crops or commercial crops like cotton, sugarcane, etc. However, small farm holders have to assure the volume of production from a given area for marketing and transportability of produce by forming clusters. DMAPR has the responsibility of serving the small farm holders of MAP by providing good agricultural practices for production and supply of

quality raw drug to the industries. The main policy focus of the future in MAP should be promotion and development of sustainable agriculture, with an emphasis on small farm holders.



Advantage of MAP in mitigating climate change in agriculture

It has been projected by the Inter-Governmental Panel on Climate Change that by the end of this century, global temperature is likely to increase by 1.8^0 to 4.0^0 C, leading to more frequent hot extremes, floods, droughts, cyclones and recession of glaciers. These changes put more threats on livelihood security of farmers, thereby, requiring increased adaption of crops able to withstand in changed climate. Hence, development of cultivars which can sustain the impact of climate change is required. MAP basket is having a large number of species which are having different climatic requirements. Use of MAPs in managing the adversity of climate change would be an better options than the traditional crops, since a large number of species of MAPs are having diverse climatic requirement.


Water Lily in flooded conditions


Ashwagandha in dry land conditions

In addition, many of them

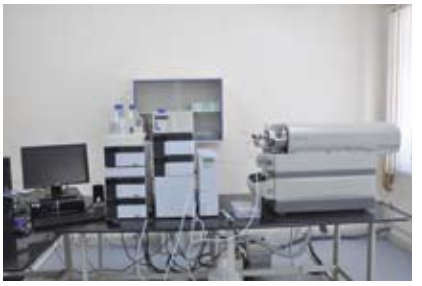
- are largely tolerant to drought and floods
- have low incidence of pest attack
- have lower cost of cultivation as compared to the traditional crops, since most of them are not high input responsive
- could be raised as inter-crop, mixed crop, companion crop thus can add to diversification and also overcome economic loss caused due to adverse climatic conditions
- can provide better returns at a time as compared to traditional crops in marginal and sub-marginal lands

Technology landscape

Frontier cutting age technologies such as information technology (IT) and biotechnology are expected to generate new opportunities to broaden the horizon of agro technology of medicinal and aromatic plants. Application of biotechnology have shown the promise in MAP sector in the following areas:

- Mass multiplication of high value medicinal and aromatic crops where multiplication ratio is low through conventional methods
- Marker assisted breeding for developing varieties
- DNA fingerprinting of MAP germplasm to protect the intellectual property right (IPR)
- Proper identification of species by molecular markers
- Detecting adulteration of raw drug by PCR technique
- *In vitro* production of active principle in cell lines
- Bio-synthesis pathway engineering

Mass multiplication in tissue culture



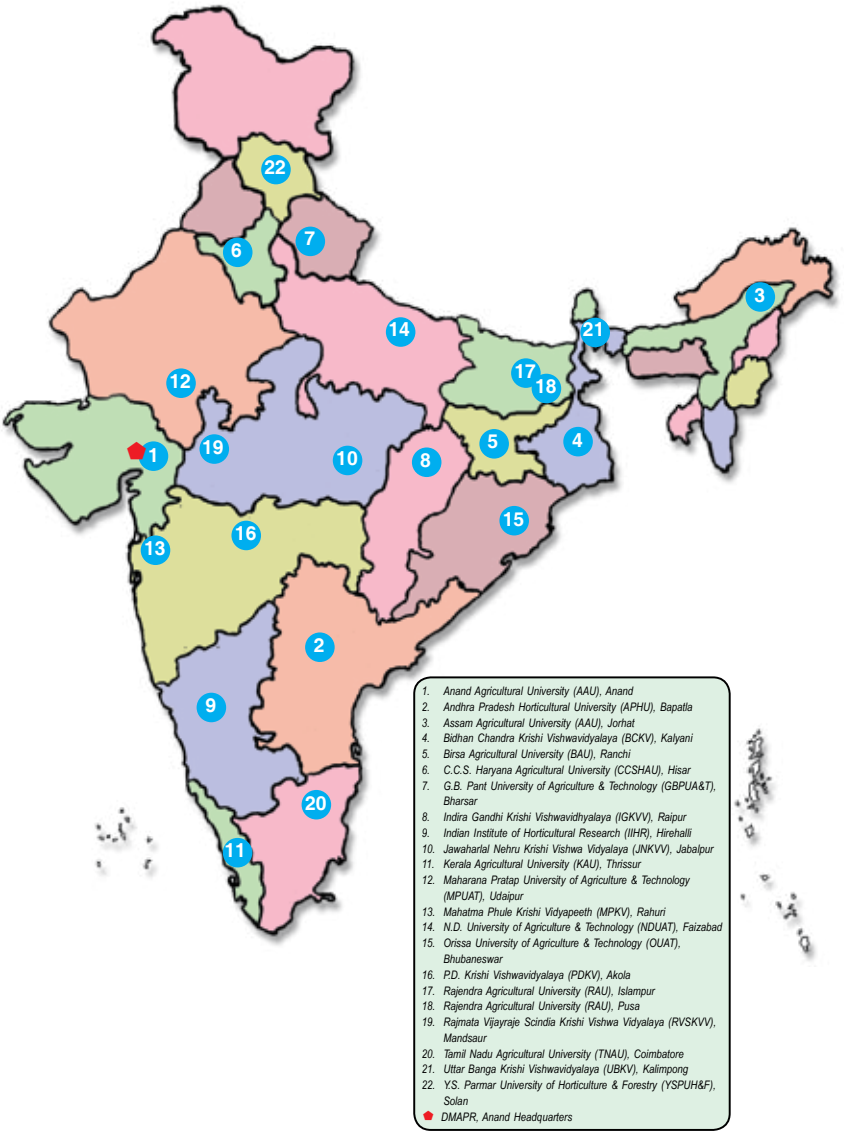
Liquid Chromatograph - Mass Spectrometer

Role of GACP as agri-business

GACP video toolkit

Compliance to quality standards is necessary to consolidate our position in the world herbal market and towards this; adoption of good agriculture and collection practices (GACP) by farmers and collectors is an important starting point. The adoption of GACP in medicinal plant sector will improve livelihood by adding premium price to the produce and also generating additional employment in rural sector for the educated youth. Further, implementation of GACP will improve the efficacy of herbal medicines in the market; ensure that MAP resources are extracted from the wild in sustainable manner, and strengthen the position of the farmers and collectors in the market place.

Fig. 2. Centres of AICRP on
Medicinal & Aromatic Plants and Betelvine



Medicinal and aromatic plants research system: Indian Council of Agricultural Research

The Indian Council of Agricultural Research (ICAR) established National Research Centre for Medicinal and Aromatic Plants (NRCMAP), Boriavi, Anand, in 1992. The same has been rechristened as the Directorate of Medicinal and Aromatic Plants Research in the 11th plan by reorganizing it with backward linking the All India Coordinated Medicinal & Aromatic Plants and Betelvine (AICRP-MAPB) (Fig. 2).

The Directorate has been working for enhancing, sustainable production and utilization of major agriculturally important medicinal and aromatic plants through research and development to meet the present day demands and to address future national and international challenges. The DMAPR is also aggressively working to bring more and more MAP under cultivation so as to assure quality supply of raw drug encompassing research on various facets of cultivation such as varietal development through plant breeding and biotechnology, crop management through physiology, horticulture and soil science programmes, plant protection for managing pests as well as supply of residue free and heavy metal free safe material, quality assessment and control by its phyto-chemistry programme and supply of quality planting material and finally to develop GACP protocol by integrating all the knowledge of various fields. The Directorate has well defined mandates and mandate crops for its basic and strategic research at the head quarters at Anand, Gujarat as well as in its out reach programme, AICRP-MAPB which is operated through its 22 centres distributed through out the country in major agro-climatic zones. AICRP-MAPB is persuading research on location specific problems and contributing in downstream research activities.

Mandate

- Development of appropriate production, protection and processing technologies for important MAP through basic, strategic and applied research
- Germplasm enhancement of various MAP
- To act as a National Repository of the genetic resources of selected important MAP
- To coordinate research under the All India Coordinated Research Project on Medicinal & Aromatic Plants and Betelvine (AICRP-MAPB)
- To act as information data bank on MAP
- Transfer of technologies developed by the DMAPR for the farmers through cooperation with the developmental agencies.

DMAPR Mandate crops

Aloe
(*Aloe barbadensis*)

Ashwagandha
(*Withania somnifera*)

Gilo
(*Tinospora cordifolia*)

Guggal
(*Commiphora wightii*)

Isabgol
(*Plantago ovata*)

Safed musli
(*Chlorophytum borivilianum*)

Senna
(*Cassia angustifolia*)

Lemongrass
(*Cymbopogon flexuosus*)

Palmarosa
(*Cymbopogon martinii*)

Mandate crops

DMAPR

- Aloe (*Aloe barbadensis* Mill.)
- Ashwagandha (*Withania somnifera* Dunal)
- Giloe [*Tinospora cordifolia* (Willd.) Miers ex. Hook]
- Guggal [*Commiphora wightii* (Arn.) Bhandari]
- Isabgol (*Plantago ovata* Forsk.)
- Liquorice (*Glycyrrhiza glabra* Linn.) *
- Safed musli (*Chlorophytum borivilianum* Santapau & Fernandes.)
- Senna (*Cassia angustifolia* Vahl.)
- Lemongrass (*Cymbopogon flexuosus* Nees ex. Steud Wats.)
- Palmarosa (*Cymbopogon martinii* Stapf. Var. motia)

*Worked for about 15 years and thereafter replaced with Giloe in 11th Plan

AICRP-MAPB

- Aloe (*Aloe barbadensis*)
- Arjun (*Terminalia arjuna*)
- Asalio (*Lepidium sativum*)
- Ashwagandha (*Withania somnifera*)
- Ashoka (*Saraca asoca*)
- Atis (*Aconitum heterophyllum*)
- Babchi (*Psoralia corylifolia*)
- Bala (*Sida cordifolia*)
- Ban kakri (*Podophylum hexandrum*)
- Betelvine (*Piper betle*)
- Bhui Amlaki (*Phylunthus amarus*)
- Brahmi (*Bacopa monnieri*)
- Chirayita (*Swertia chirayita*)
- Coptis (*Coptis teeta*)
- Dodi (*Leptadenia reticulata*)
- Coleus (*Coleus forskohli*)
- Giloe (*Tinospora cordifolia*)
- Hypericum (*Hypericum perforatum*)
- Indian Valerian (*Valeriana jatamansi*)
- Isabgol (*Plantago ovata*)

- Kalmegh (*Andrographis paniculata*)
- Kawach (*Mucuna pruriens*)
- Kutki (*Picrorrhiza kurroa*)
- Lal Chitrak (*Plumbago rosea*)
- Lemongrass (*Cymbopogon flexuosus*)
- Long pepper (*Piper longum*)
- Madhunashini (*Gymnema sylvestre*)
- Makoi (*Solanum nigrum*)
- Mandokaparni (*Centella asiatica*)
- Opium poppy (*Papaver somniferum*)
- Palmarosa (*Cymbopogon martinii*)
- Safed musli (*Chlorophytum borivilianum*)
- Shankhpushpi (*Convolvulus microphyllus*)
- Shatavari (*Asparagus racemosus*)
- Senna (*Cassia angustifolia*)
- Vach (*Acorus calamus*)
- Tulsi (*Ocimum sanctum*)

Achievements

1. The effort on collection, conservation, evaluation and documentation of germplasm of medicinal and aromatic plants is a continuous process. In this endeavour the existing germplasm has been augmented and now the germplasm collections have reached up to 2450 accessions from 43 MAP species and are conserved in field gene bank of the Directorate and its AICRP centers. Further, 276 accessions of Betelvine (*Piper betle*) are also being maintained.

Ocimmum spp. in field gene bank

Guggal in field gene bank

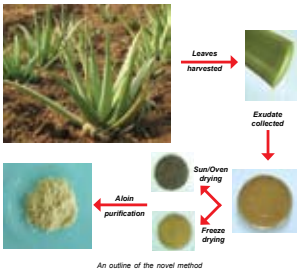
2. The DMAPR has established a Medicinal Plant Botanical Garden in an area of about 21 ha which maintains more than 100 tree species, 65 shrubs, 51 creepers and about 167 herbs. The

botanical garden is a member of Botanical Gardens Conservation International (BGCI), UK.

3. The project has developed about 36 varieties of medicinal crops and eight varieties of aromatic crops. It has also introduced many exotic species for cultivation.
4. Eleven elite germplasm viz, two each in *Chlorophytum borivilianum* (INGR 04114 and INGR 04113) and *Aloe barbadensis* (INGR 06023 and INGR 06024), three in *Hypericum perforatum* (INGR 10074, INGR 10075, INGR 10076) and one each in *Tinospora cordifolia* (INGR 06025), *Andrographis paniculata* (INGR 07041), *Centella asiatica* (INGR 08105) and *Plantago ovata* (INGR 08104) were developed and registered with NBPGR, New Delhi.
5. Under the basic research, reproductive biology of some of the important medicinal plants Aloe (*Aloe barbadensis*), Ashwagandha (*Withania somnifera*), Giloe (*Tinospora cordifolia*), Guggal (*Commiphora wightii*), Indian Gentian (*Gentiana kurroo*) and Shankhpushpi (*Convolvulus microphyllus*) have been studied and information have been generated.
6. Good Agricultural Practices (GAP) for six medicinal and aromatic plants have been developed and further being refined. Further, work on developing GAP in other medicinal and aromatic plants are in progress.
7. *In-vitro* mass multiplication protocols for Aloe (*Aloe barbadensis*), Safed musli (*Chlorophytum borivilianum*) and Liquorice (*Glycyrrhiza glabra*) have been standardized.
8. Protocols for extraction and estimation of active principle components from various MAP have been standardized. Morphological and biochemical characterization and chemical finger printing have also been done for some species.
9. Screening method for resistance against soft rot of Aloe has been established by doing artificial inoculation technique.
10. Two process patents have been filed: (i) "Method of preparing aloin" in 2008 which is a new aloin extraction method for preparation of pure aloin from Aloe (*Aloe barbadensis*). Aloin (aloin A) is the major active principle in Aloe. It is a pharmaceutically important compound and utilized for the production of various drug intermediary compounds. The new method is easy to perform and can be used for extraction of aloin of high quality from fresh, sun dried, oven dried or freeze dried leaf exudates. The method is also quicker, efficient (recovery up to 90%) and cost effective (most of the solvent used can be

recovered for reuse). Aloin purity of more than 90-95% can be achieved by this method hence, suitable; (ii) "Improved gum tapping in Guggal" in 2009 which is a process of gum taping by using a bacteria which has not only improved the gum yield per plant but also improved the efficiency of tapping at will at any period of the year.

Improved Guggal gum tapping



Improved Aloin extraction method

11. The DMAPR has developed some useful software packages like "Medicinal and Aromatic Plants References Information System", "Traders Information System in Medicinal & Aromatic plants", "Digital Photo Library of Medicinal & Aromatic Plants" and "Digital Herbarium of Medicinal & Aromatic Plants in India". A web based network on herbal garden in India has been created and hosted at www.herbalgardenindia.org by the ARIS cell of DMAPR with funding from NMPB.
12. A good agricultural and collection practices (GACP) training toolkit for medicinal plants have been developed in collaboration with Food and Agriculture Organization (FAO) which comprises of a) Trainer's Manual, b) GACP video, (c) Illustrated cause-effect training tool and (d) Illustrated booklet for the benefit of quality assurance of raw drug.
13. The DMAPR also helped the friendly neighbouring country, Bhutan in developing strategic road map for research and development of medicinal, aromatic and dye plants in Bhutan.
14. Developed GAP and GFCP certification national standards with the help of National Medicinal Plant Board and Quality Council of India.

DMAPR Vision 2030

The Directorate of Medicinal and Aromatic Plants Research (DMAPR) with its outreach programme All India Coordinated Research Project on Medicinal & Aromatic Plants and Betelvine (AICRP-MAPB) is marching towards targeted goal of "Health for all" by planning, coordinating, implementing and monitoring of research and development programmes for achieving the objectives of the Directorate with backward integration through AICRP and forward integration by DMAPR activities.

Vision

॥ सर्वे सन्तु निरामयः ॥

Provide "Health for all" to ever-increasing world population through ensuring quality raw drug production and supply.

Mission

To contribute for sustainable production of quality MAPs through development of new varieties, good agricultural practices, quality assessment methodologies and using frontier cutting age technologies such as IT and Biotechnology.

Focus

- To identify plants which need attention of agricultural scientists and to collect, maintain and evaluate the identified plants and develop improved varieties.
- To carry out those basic researches on the chosen crops, which are useful to develop their Good Agricultural Practices (GAP).
- To develop various quality testing parameters (Physical, chemical and molecular) of raw drugs.
- To develop various certification parameters for issuing certificates such as Non GMO, GACP, quality planting material, quality parameters, microbial load, pesticide residue and phytotoxin as well as heavy metal free produce.

- Conservation of MAP in field gene bank and their utilization.
- To coordinate the research activities of the AICRP centres on Medicinal & Aromatic Plants and Betelvine located in various agro-climatic zones of India.
- To provide quality planting material and technical know-how generated for further testing and refinement by the centres of the AICRP-MAPB and DMAPR.
- To develop partnership between this Directorate, with NGOs and farmers' associations/progressive farmers interested in promoting the use of herbal medicines.

Harnessing green technology

A solid shift to green technologies in world farming is a vital agenda of United Nations if endemic food crises are to be overcome and production to be boosted to support the global population. The DMAPR will be putting its whole hearted efforts to develop, use and promote the green technology for a sustainable production system of MAP. The green technology is more necessary for MAP cultivation because of their use in health care system which requires zero pesticide residue limit to be a safe drug. The DMAPR will also continue its efforts for broadening cultivation basket of MAP considerably by carefully deciding the species keeping role of green technology and small farm holders in steering wheel.

Potential of genetic – resource enhancement

The number of medicinal and aromatic plants that need our attention is exorbitant. However, limited germplasm availability and variability within the existing germplasm pool of MAP species are a common phenomenon.The availability of improved varieties with desirable traits is also limited in medicinal and aromatic plant species. To address the future needs research will be undertaken for

- enhancement of MAP germplasm and their characterization
- development of core collection of the germplasm.
- varietal development – development of high yielding and high quality varieties with desirable chemical profiles

Many therapeutically important medicinal plants have fallen in the list of Rare, Endangered and Threatened (RET) category due to over exploitation and over harvesting from the nature without considering their regeneration ability and hence require systematic conservation

efforts. Cultivation efforts will bring the endangered species in *ex-situ* conservation.

Power of biochemistry and biotechnology

Power of biochemistry and biotechnology will be harnessed to understand sequence of substrate and the respective enzymes involved in the biochemical pathways leading to the synthesis of given metabolites in plants. These will help us to know the biochemical and molecular mechanisms of up regulating or down regulating expression of genes and enzymes controlling the synthesis of metabolites. *In vitro* synthesis of bio-molecule will release the pressure on natural resources and save the species in their natural habitat. This knowledge also help us to develop new varieties with better bio-molecule productive efficiency.

Synergies of frontier sciences

Frontier sciences like information and communication technology (ICT), remote sensing, geographic information system (GIS) and global positioning system (GPS) will be integrated with the related disciplines of agronomy, soil science, plant protection, post harvest management, etc. in the ongoing and future research projects for development of Good Agricultural Practices. Development of ICT based decision support system tools will be attempted for crop scheduling, weeds, nutrient, water and pest management for increasing the productivity per unit area.

Management of natural resources

Standardization of technologies leading to improved carbon sequestration and soil health, development of technologies for enhancing nutrient and water use efficiency and understanding nutrient dynamics studies and organic cultivation of major MAP would be targeted in the future research programme.

Post-harvest and value addition

Post-harvest-storage technology for reducing post-harvest loses and development of MAP based products will be developed. It will minimize the post-harvest losses. Best drying methods, drying time, storage conditions and primary processing, etc. will be standardized for major MAP. Value addition will be done by:

- Monitoring of pesticide and heavy metal contamination
- Monitoring quality of raw material available

- Fixing quality standards of raw drug material
- Developing chemical finger printing for individual species to avoid adulteration.
- Developing a referral laboratory for the preferred chemical standards

Technology transfer

The success of cultivation of MAP using green technology such as GAP and also success of good quality raw drug supply through implementation of GACP would largely depend on how effective technology transfer system we have to take these developments in to the grassroots level workers such as farmers and collectors. Development of various technology transfer tools will be attempted and also demonstrated through organizing training programme for various stakeholders. Attempt also will continue to transfer technologies developed in the DMAPR and assess their impact by using modern ICT tools.

Strategy and framework

The Directorate critically analyzed the strengths; weaknesses, opportunities, and threats (SWOT) of the MAP sector in India *vis-à-vis* the constraints and challenges as mentioned above during the year 2010. After exhaustive review of the ongoing research activities, following programmes have been identified for the future years. Successful completion of the programmes would help in emergence of stronger MAP sector in the country. The strategies identified will be implemented through the following nine research programmes.

1. Management and enhancement of MAP germplasm.
2. Breeding for improved MAP varieties.
3. Water management.
4. Nutrients dynamics studies and organic farming in MAP cultivations.
5. Development of good agricultural practices (GAP) through integrated plant production and protection techniques
6. Basic and applied research on quality of MAP
8. Production of quality seed/planting material of MAP through conventional and hi-tech systems.
9. Development of post-harvest technology of MAP and also a limited product development.

Research strategies

Crop improvement

- Introduction of superior germplasm.
- Germplasm enhancement for quality and high yield.
- Identification of high quality and high yielding genotypes.
- Studies of floral biology and breeding behaviour.
- Search for source of resistance to biotic and abiotic stresses.
- G x E interaction to identify best location for best performance.
- *Ex-situ* conservation of medicinal plants in field gene bank.

Crop production

- Basic research for developing good agricultural practices (GAP) in medicinal and Aromatic plants taking into account individual location and species.
- Developing integrated crop management module including integrated nutrient, water and pest management protocols.
- Biosynthetic pathway of secondary metabolites production.
- Developing organic farming system.

Quality management

- Monitoring of pesticide residue and heavy metal contamination in the market produce/sources.
- Monitoring of quality of raw drug material available in the market.
- Fixing of quality standard of raw drug material.
- Developing chemical finger printing for individual species to avoid adulteration.
- Developing a referral laboratory.

Crop protection

- Standardisation and development of integrated pest management (for both disease and insect pest).
- Developing forecasting models.

Biotechnology

- Micropropagation of species which have multiplication problem.
- Use of marker assisted breeding for varietal development.
- Use of molecular markers for detection of adulterations in raw drug trading.
- Developing different molecular techniques for genetic finger printing to protect IPR.
- Studies on biosynthetic pathways of biomolecules and their genetic regulation systems.

Post harvest management

- Development of post harvest management system.
- Development of storage technology for reducing post harvest loses.
- Limited product development for food supplement and nutraceutical.

Partnership development

The Directorate will be developing Public Private Partnership models with private sector organizations, NGOs and farmers' associations/ progressive farmers interested in cultivation of medicinal and aromatic plants following green technology.

Epilogue

The DMAPR is committed to bring a change in the vast canvas of quality raw drug availability by bringing demand-driven, technology-led, environmental-friendly green production technology to assure the quality of produce free from pesticide residue, heavy metal and mycotoxin with low microbial load. Implementation of GACP and certification of GACP produce will not only transform the future supply scenario of quality ISM medicines but also it will generate employment in the rural sector for the educated youth. We firmly believe that the DMAPR will take a lead role to develop location specific species-wise GAP protocol through its forward and backward linking research activities in DMAPR and AICRP-MAPB. In this sector investment from the private sector is bare minimum and majority of the farmers are looking forward to the ICAR-SAU system for the technology generation to fulfil their aspiration for uplifting their economic status by MAP cultivation. The DMAPR will also develop research strategies to respond to the fast changing demand in the supply sector with newer species in a participatory mode with the industries and by introducing a culture of responsibility, accountability and integrity in the work culture.

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch

Anand Press, Gamdi, Anand - 388 001 • Ph: (02692) 253933 • anandpress@gmail.com