SUSTAINABLE DEVELOPMENT OF MEDICINAL AND AROMATIC PLANTS SECTOR IN INDIA: AN OVERVIEW

AJIT ARUN WAMAN* AND POOJA BOHRA*

Use of plant-based medicines for primary healthcare is widespread amongst the developing countries of the world. A number of systems viz. *Ayurveda, Unani, Homeopathy, Siddha, Tibetan, folklore etc. have commonly been used by the rural people in our country for treating various ailments. Considering the potential of these therapies and freedom from side effects, people living in urban areas as well as western countries have started relying upon them. This has caused an upsurge in the demand for the raw materials, and the stocks of a number of species have started dwindling in wild. In order to assure uninterrupted supply to the industries, without compromising with the basic rights of the tribes/ rural people, a sustainable approach is the need of the hour. Present report explores possible measures to conserve the biodiversity of medicinal and aromatic plant wealth in India and its sustainable use for the welfare of human beings.*

Introduction

India is one of the mega-biodiversity countries blessed with diverse agro-climatic conditions, which is known to host vast plant biodiversity. About 22 agro-biodiversity hotspots have been notified by the Protection of Plant Varieties & Farmers' Rights Authority (PPV&FRA), India. This biodiversity has formed the basis for a number of plant based healthcare systems. Approximately 17,000 types of native flora have been reported from India, of which more than 7,500 *i.e.* 44% are known to possess medicinal properties[1]. A large number of plant species have been employed in the natural drug industry *e.g.* 2,000 to 2,500 in India as against 5,700 in China, 1,400 in Sri Lanka and 700 in Nepal[2]. The number of species used in the Indian Systems of Medicine varies depending upon the system[3] *e.g.* Ayurveda (2,000), Siddha (1,121), Unani (751), Homeopathy (482) and Tibetan (337). As about 80% of the global population relies upon plant-based medicines and majority of the raw material supply comes from the wild, it is of utmost importance to form a viable strategy to ensure sustainable development of the sector so that the biodiversity is not misused or abused. At present, of the 800 widely used species in the industry; only about 20-25 are being cultivated on commercial scale. Considering the growing potential, the National Medicinal Plants Board, New Delhi has prioritized 32 species of medicinal and aromatic plants for promotion in India (Table 1).

Since time immemorial, this biodiversity has been conserved and utilized in a sustainable manner for the well-being of the society. Sustainability here indicates judicious utilization of available biodiversity in such a way that, what has been given to us by the Mother Nature through our ancestors, should be passed onto generations after generations without any deterioration. The traditional knowledge of plant wealth for curing variety of ailments has been documented and the plant-based therapies have gained popularity in the recent past[4]. Ayurveda, Unani, Siddha, Homeopathy and folk medicines are not only serving the rural mass in the underdeveloped regions, but are being demanded by the elite class people living in the urban areas. A number of efforts were made to document

* Division of Horticulture and Forestry, ICAR-Central Island Agricultural Research Institute, Port Blair- 744101, Andaman and Nicobar Islands, India

*Corresponding author's e-mail: ajit.hort595@gmail.com.

TABLE 1. List of Medicinal Plants Prioritized by National Medicinal Plants Board

Sl. No.	Common name	Scientific name
1.	Amla	*Emblica officinalis*
2.	Ashok	*Saraca asoka*
3.	Ashwagandha	*Withania somnifera*
4.	Atis	*Aconitum heterophyllum*
5.	Bael	*Aegle marmelos*
6.	Bhumi amalaki	*Phyllanthus amaraus*
7.	Brahmi	*Bacopa monnieri*
8.	Chandan	*Santalum album*
9.	Chirata	*Swertia chirata*
10.	Daru haridra	*Berberis aristata*
11.	Giloe	*Tinospora cordifolia*
12.	Gudmar	*Gymnema sylvestre*
13.	Guggal	*Commiphora wightii*
14.	Isabgol	*Plantago ovata*
15.	Jatamansi	*Valeriana jatamansi*
16.	Kalihari	*Gloriosa superba*
17.	Kalmegh	*Andrographis paniculata*
18.	Kesar	*Crocus sativus*
19.	Kokum	*Garcinia indica*
20.	Kuth	*Saussurea lappa*
21.	Kutki	*Picrorrhiza kurroa*
22.	Makoy	*Salanum nigrum*
23.	Mulethi	*Glycyrrhiza glabra*
24.	Patharchur	*Coleus forskolii*
25.	Pippali	*Piper longum*
26.	Safed Musali	*Chlorophytum borivilianum*
27.	Sarpagandha	*Rauvolfia serpentina*
28.	Senna	*Cassia angustifolia*
29.	Shatavari	*Asparagus racemosus*
30.	Tulsi	*Ocimum* spp.
31.	Vatsnabh	*Aconitum ferox*
32.	Vai vidang	*Embelia ribes*

the important information available on medicinal plants in India. For example, the exhaustive volumes by Kirtikar K.R. and Basu B.D. are an excellent guide to the botanists and other researchers, traditional practitioners, growers, drug collectors and all allied stakeholders related to the medicinal plants.

As per the estimate by World Health Organization (WHO), about 80% of the global population is dependent on the traditional systems of medicines for primary health care and the present demand for medicinal plants is nearly US $14 billion per annum, which could reach to about US $5 trillion by 2050. Demand of raw material in herbal industries is increasing at the rate of about 20% per annum[3]. Trade of herbal plant based products in India is estimated to touch about US $1 billion every year[5].

To reap maximum benefits from ever-increasing demands, a number of companies have been set up in India and abroad. The huge requirement of raw materials for running these companies has resulted into an acute pressure on the forests, as majority of the medicinal plants are being collected from wild. In the desire of gaining more and more profits, the sustainability aspect has been completely ignored and a large number of species are on the verge of extinction due to over exploitation and destructive harvesting practices[6]. Though a number of initiatives have been taken up to manage the biodiversity in more meaningful way, the holistic approach comprising of all the possible measures needs to be adopted. The present report concerned an integrated approach for overall development of medicinal and aromatic plants sector in India.

Development of Databases and Trade Statistics

Except for a few species that are commercially cultivated, majority of the raw material supply comes from the wild[7]. The collectors ask the gatherers to explore the forests without maintenance of any record. Unlike other agri-horticultural crops, organized data about the area under cultivation, total production/ collection, volume of material traded/ exported is lacking, which acts as a major impediment in understanding the real time situation of the MAPs sector. This broken link between demand and supply creates confusion amongst both the parties *i.e.* buyers and growers. Proper targeting of both domestic and international niche markets is not possible in the absence of a valid database and market information system. Collaborating various stakeholders including researchers, producers/ collectors, processors, exporters etc. for developing such a database could improve the overall efficiency of the production and marketing channels. Recently, a number of organizations including some NGOs have started such compilations and co-ordination amongst them could result in development of a robust system for trading MAPs locally as well as globally.

Germplasm Conservation and Utilization

***In Situ* Conservation:** According to Walter and

Gillett[8], eight percent of the world's flora is threatened. In the absence of conservation measures, more and more species are being added into the list. In a number of places including the tribal dominating areas, the tradition of conserving native flora in the form of sacred groves is prevalent. However, in the recent past, areas under these have been reduced drastically. In order to eliminate the chances of genetic erosion and to preserve the variability generated through ages, there is an urgent need to promote the conservation of local diversity. Employing tools such as Geographical Information System (GIS) based tools for ecological niche modelling would be highly beneficial for conservation of endemic species.

***Ex Situ* Conservation:** Extensive explorations need to be carried out, and field gene banks and medicinal gardens need to be established for preservation of natural diversity[7]. The concept of Home gardens could not only encourage the use of traditional medicines for curing common ailments but will also help in conservation of some species[9]. A number of organizations, local parks, schools etc. have been encouraged to develop herbal gardens in their surrounding and more than hundred registered herbal gardens have now been developed in different parts of the country (www.herbalgardenindia.org). *In vitro* gene banks with short and long-term storage facilities need to be established. The necessary protocols need to be standardized for achieving high recovery of the regenerants. Cryopreservation of various species needs to be optimized to provide protection against unforeseen calamities under field condition/ natural habitats[10].

Diversity Assessment and Crop Improvement: The natural variations amongst the medicinal plants in developing countries have not been studied in detail[11]. The germplasm obtained from explorations thus need to be evaluated and characterized for various morphometric, phyto-chemical, molecular and post harvest quality attributes. A number of Indian Council of Agricultural Research (ICAR) and Council for Scientific and Industrial Research (CSIR) institutes, and state agricultural universities have undertaken the characterization work on various species such as aloe (*Aloe barbadensis*), kalmegh (*Andrographis paniculata*), brahmi (*Bacopa monnieri*), safed musli (*Chlorophytum borivilianum*), palmarosa (*Cymbopogon martinii*), gudmar (*Gymnema sylvestre*), cow hedge (*Mucuna pruriens*), opium poppy (*Papaver somniferum*), rose geranium (*Pelargonium graveolens*), glory lily (*Gloriosa superba*), betel leaf (*Piper betle*), ashwagandha (*Withania somnifera*), makoi (*Solanum nigrum*), chirayita (*Swertia chirayata*), chitraka (*Plumbago zeylanica*) etc.[6].

Further crop improvement activities could be based on the utilization of such germplasm through conventional and non-conventional breeding techniques. Identification of chemotypes having desired levels of bioactive molecules would be of merit. A recent study has suggested presence of morphological, anatomical and biochemical variability in the genotypes of gudmar (*Gymnema sylvestre*) collected from different ecosystems of India[12]. This variability could be used for identification of desirable types and subsequent development of cultivars. A number of improved varieties have been developed through mutation breeding in medicinal plants e.g. Aisiri of medicinal coleus (*Plectranthus barbatus*) released from University of Agricultural Sciences, Bengaluru.

Crop Improvement for Present and Future Challenges/ Climate Resilience: Due to a number of factors, large proportion of our country's area has suffered from problems of soil and water salinity, heavy metals/ pesticides, submergence/ flooding, presence of rocky strata, frequent droughts and extremities of temperature and rainfall. The crop improvement should target such problematic areas to facilitate land utilization in a better way, without competing for the areas reserved for food crops. For instance, development of CARI Rakshak cultivar of noni (*Morinda citrifolia*) could be a boon for the areas affected with problems of salinity[13].

Improved Crop Production Technologies

Good Agricultural Practices: The concept of good agricultural practices is especially pertinent in the cultivation of MAPs as the overall quality of the final drug is decided by the methodologies adopted for production. GAPs have been developed in a number of medicinal plants including aloe, asparagus, betel leaf, makoi, ashwagandha, mandukparni, mamejo, kalmegh, isabgol, safed musli, and aromatic plants such as rose geranium, lemongrass, palmarosa, patchouli, sweet wormwood, vetiver and tulsi[6]; however they need to be standardized for newly identified as well as underutilized plant species, to improve their acceptance by the commercial firms.

Rapid and Reliable Multiplication: Lack of availability of quality planting material is one of the major concerns in the promotion of MAPs cultivation. For collection of drugs, plants are harvested following unscrupulous practices, thereby hampering natural reproduction in wild[14,15,16]. This is particularly serious in case of species in which roots, bark, flowers and fruits are used as drug. Plus types identified in the germplasm need to be multiplied in large number to provide the growers with the superior quality planting material. Vegetative

propagation and micropropagation protocols need to be perfected to ensure uninterrupted supply of planting material. In case of *'low price- high volume'* crops, cost effective micropropagation options need to be explored for production of planting material at affordable price[4].

Development of Location Specific Agro-techniques: Not all the crops and varieties can perform equally in all the locations. The cropping pattern of the area should be studied thoroughly and appropriate MAPs need to be identified to complement the cropping systems by means of intercrop, mixed cropping and high-density multi-storied cropping systems. For instance, in the areas such as Andaman and Nicobar Islands, wherein coconut/ arecanut cropping systems are dominant, shade loving rhizomatous plants could be effectively cultivated, while the waterlogged rice growing belts of our country could support growth of moisture loving crops like *Acorus calamus*.

Promotion of Organic Cultivation: There is an increasing trend about the health awareness amongst the consumers, both in domestic and international markets[17]. To produce raw material with desired quality *i.e.* optimum levels of bioactive molecules, free from residues of pesticides and heavy metals, the package of practices for organic cultivation of the major MAPs need to be standardized on priority basis, especially in the export-oriented crops. For example, combined application of organic manures and bio-fertilizers on yield and recovery of bioactive molecules has been reported[18] in an industrially important medicinal plant, stevia (*Stevia rebaudiana*).

Mechanization and Automation in Crop Cultivation: MAPs, being a group of highly diversified species, exhibit great variations in the growth patterns. Cost effective hand operated tools and high end implements need to be developed to carry out various operations such as planting, inter-culture, harvesting, grading, post harvest processing *etc.* for each crop. For example, modified knives for peeling of wood barks without causing injury to the inner parts of plant, modified spade like tools for lifting of underground corms and rhizomes, modified cereal graders for grading of seedy MAPs etc.

Eco-friendly crop protection practices

The plant protection chemicals could alter the chemical constituents of the MAPs if used in improper manner. Also, presence of resides of harmful chemicals in the product could result into serious consequence. Hence, eco-friendly methods need to be optimized for effective control of major pests and diseases in various crops. Emphasis needs to be given for identification of bio-control agents, plant based pesticides, solarization, lure traps (kairomones/ pheromones/ light) *etc*. for management of the pests and diseases below threshold limits[6].

Strengthening Basic Research on Physiology and Biochemistry of Plants

Stress Physiology and Extraction Protocols: Synthesis of secondary metabolites in any plant tissue is associated with the amount of stress it has experienced[19]. Subjecting plants to the known levels of biotic and abiotic stresses and learning the subsequent response could help in understanding the plant's physiology. Alteration of crop cultivation techniques accordingly would result in maximizing active ingredient production in the economic plant parts. Further, this could be of great use in identifying species suitable for problematic areas. Development of standard operating protocols and efficient extraction methods should receive priority for improving the recovery of the bioactive molecules from the plant tissues.

In vitro Production of Pharmaceutical Macro-molecules: Pharmaceutical industries demand raw material of uniform quality that is difficult to achieve from collection as well as cultivation. In addition, the raw material collected from the wild could also contain unwanted and sometimes harmful species, thereby hampering the efficacy of the final produce. To overcome these problems, a number of attempts have been made for *in vitro* production of active ingredients in the recent past[19]. However, a rapid and reliable protocol need to be developed, which could be accepted by the industries.

Bio-prospection: Few drugs are in large demand, and are being exploited from wild at a rate faster than their natural regeneration[7]. As a result, there is always shortage of such species in the market. Also, sometimes the concentrations of active ingredients in the species are too low, requiring more materials for meeting the industrial demands. To address this, new and potential species need to be evaluated for various properties[20,21], which could help in identifying cheaper, better and purer input source over existing one. For instance colchicine, an important compound for the treatment of gout and for ploidy studies, was initially extracted from *Colchicum autumnale*. However, identification of *Gloriosa superba* as better substitute was possible only through prospection.

Conversion of Compounds into Desired Types: It is obvious that not all the chemical compounds obtained from a particular plant could be of same medicinal value. Some low value compounds produced in the plants could be converted into more useful types through transformation.

For example, conversion of artimisinic acid into artimisinin is possible through bioconversion[22]. Research is needed to develop such technologies and transfer to the industries.

Development of Rapid Detection Kits/ Methods for Adulterations and Residues: Presence of pesticide/ heavy metal residues is a prime concern in the MAP sector. Also, adulteration of the produce with cheap substitutes is a common practice. Thus, development of rapid and convenient technologies could help the growers to fetch better prices for quality produce. For example, test sticks have been developed for differentiating *Bt* cotton seeds from non *Bt* one. In the similar way, simple and handy kits could be developed for differentiating genuine drugs from adulterated one.

Post Harvest Management and Value Addition

Standardization of Crop Specific Harvesting, Grading, Packaging and Storage Conditions: Regrettably, the raw material in our country is traded on the physical weight basis rather than on active ingredient content. This practice does not safeguard the genuine farmers producing better quality raw materials from those doing malpractices. In addition, the packing and storage conditions can significantly alter the chemical composition of the produce, making undesirable changes in the product. Suitable post harvest practices need to be developed to avoid post harvest losses and help the growers in fetching better returns[23].

Adoption of Precise and High Fidelity Instruments: MAPs are characterized by the presence of bioactive molecules, which make them different from other crops in terms of input requirements. Thus, novel instruments need to be evaluated to perform the analytical procedures e.g. electronic nose for detecting aroma compounds. Further, customized high precision instruments need to be developed for quality control.

Value Addition: Product diversification is vital for obtaining better price to the produce in the markets. For example, extraction of oils and oleoresins would be more profitable for the producer rather than selling raw drugs in aromatic plants and crops like ginger. Development of value added products including nutraceuticals, galanicals/ non-prescription and over the counter drugs, functional foods etc. could help the entrepreneurs to get premium prices for their produce. For example, development of pummelo (*Citrus grandis*) beverages with use of kokum (*Garcinia indica*) as natural colourant and mango ginger (*Curcuma amada*) as bitterness suppressant was found to have a high benefit to cost ratio[24].

Rural/ Tribal Development

Documentation and Appropriate Utilization of Traditional Knowledge: Due to urbanization and changing lifestyles of tribal populations in places like Andaman and Nicobar Islands[25] and North Eastern India, the indigenous technical knowledge (ITK) is vanishing at rapid rate. Such knowledge need to be documented in proper databases and libraries for adequate protection. Further, these ITKs need to be tested and validated through multi-disciplinary studies and new knowledge could be generated. The results, either in the form of products or processes, could be commercialized and a part of the benefits might be used for the welfare of these communities. Further, multiplication of plant material for cultivation could also help in generating employment to the rural mass[11].

Value Addition at Farm Level: Postharvest operations such as sorting, grading and drying of the produce need to be standardized considering the resource availability of the farmer. Small and cottage scale enterprises need to be taken up by the rural masses for production of value added products such as pickles, chutneys, juices etc. Formation of growers' cooperatives could help in establishing suitable processing equipments for common benefits.

Developing Linkages Between Industries and Growers : To bridge the gap between what industry wants and what producer offers, linkages between these two stakeholders need to be strengthened. Contract farming of prime crops need to be adopted which could ensure assured market for the produce and instill confidence in the growers for area expansion under MAPs.

Fostering Trades

Development of Market Information System: Data regarding monthly (and gradually, weekly) arrival and trade of various MAPs in the major markets of the country need to be generated and made available to the stakeholders. Dedicated Agri Export Zones could be proposed for areas having wide diversity of MAPs such as the Himalayan region, Western Ghats etc.

Identification of Niche Areas: The trend for the herbal products especially the cosmetics and healthcare products need to be analyzed and the market preference need to be studied for creation of novel products. Existing product range and consumer demands should be studied to identify the niche areas, where commercialization is highly required but has not yet been done adequately.

Research on Public Private Partnership (PPP) Mode : Public sector expertise and private sector research funding could work hand in hand on various frontiers of MAPs research as well as commercialization. However, issues of IPRs must be dealt with utmost care in such cases. Such collaborations would also aid in synchronization of production with the demand posed by the industry.

Transfer of Technologies: A number of research projects have been funded for development of MAPs by various funding agencies of our country. The outputs and outcomes in the form of processes, products and protocols arising out of research projects need to be commercialized and the profits generated could be put in use for funding further research studies.

Inter-institutional Networking and Collaborations

Many government, private and autonomous agencies are involved in the research of MAPs in our country. Networking and collaborations could avoid the chances of duplications of researches at different institutions and strengths of each institute could be efficiently utilized for achieving the holistic solutions to the standing problems.

Apart from the discussed measures, development and implementation of national policies are required to be taken care to support the task. In a nutshell, there is vast potential for development of medicinal and aromatic plants sector in our country. However, the strategic planning and its thoughtful implementation would determine the ultimate future of the sector. ❐

References

1. M.P. Shiva, Inventory of forestry resources for sustainable management and biodiversity conservation (Indus Publishing Company, New Delhi, India), (1996).
2. S.S. Purohit and S.P. Vyas, Medicinal plants cultivation: a scientific approach (Agribios India Publishers, Jodhpur, India), (2007). pp.: 104-109.
3. K. Chandra Prakash, P.D. Pitamber and B.S. Sajwan, J. Ethnobiol. Ethnomed. DOI: 10.1186/1746-4269-2-32 (2006).
4. A.A. Waman, P. Bohra, B.N. Sathyanarayana and B.G. Hanumantharaya, In: Biotechnological approaches for sustainable development. (Ed.) Pullaiah T. (Regency Publications, New Delhi, India), (2015) pp.: 141-156.
5. K. Joshi, P. Chavan, D. Warude and B. Patwardhan, *Curr. Sci.* **87,** 159–165 (2004).
6. S. Maiti and K.A. Geetha, Country Status Report on Medicinal and Aromatic Plants in India.pp.: 101-123. In: Proc. Expert Consultation on Promotion of Medicinal and Aromatic Plants in the Asia-Pacific Regionheld at Bangkok, Thailand, 2-3 December, 2013, (Eds.) R. Paroda, S. Dasgupta, M. Bhag, S.P. Ghosh and S.K. Pareek, APAARI, Bangkok, Thailand (2014).
7. U. Schippmann, D.J. Leaman, A.B. Cunningham and S. Walter, *Acta Hortic.* **676**, 31-44 (2005).
8. K.S. Walter and H.J. Gillett, (1997) IUCN Red List of threatened plants (IUCN, Gland), (1998).
9. A. Agelet, M.A. Bonet and J. Valles, *Econ. Bot.* **54**, 295-309 (2000).
10. V. Sarasan, C. Ryan, M.R. Margaret, A. Caroline, M. Monica, P. Grace and K.R. Jennifer, *In Vitro Cell. Dev. Biol.—Plant* **42**, 206–214 (2006).
11. V. Sarasan, C.K. Geoffrey, W.S. Gudeta and P.C. Stevenson, *Plant Cell Rep.,* **30**, 1163–1172 (2011).
12. T. Dhanani, R. Singh, A. Waman, P. Patel, P. Manivel and S. Kumar, *Ind. Crops Prod*. **77**, 901-909 (2015).
13. M. Sankaran, D.R. Singh, S. Singh, V. Damodaran and L.B. Singh. High yielding varieties in horticultural crops developed by CARI (Central Agricultural Research Institute, Port Blair, India), (2012).
14. G.R. Smitha, *Res. Crops,* **14**, 274-283 (2013).
15. A.A. Waman, K. Umesha and B.N. Sathyanarayana, *Acta Hort.* **865**, 383-386 (2010).
16. A.A. Waman and P. Bohra, *Intl. J. For. Usufructs Manage.,* **14**(1), 10-17 (2013).
17. M. Mander, J. Mander and C. Breen, Domestication andcommercialization of non-timber forest products in agroforestry systems (FAO, Rome, Non-wood Forest Products 9, 1997) pp.: 104-109.
18. K. Umesha, G.R. Smitha, B.S. Sreeramu and A.A. Waman, *J. Appl. Hort.* **13**(2), 157-162 (2011).
19. T. B. Jha and B. Ghosh, Plant Tissue Culture – Basic and Applied (University Press, Hyderabad), (2005), pp. 109-124.
20. S. Das, T.E. Sheeja and A.B. Mandal, *Indian J. Trad. Know.* **5**, 207-211 (2006).
21. S.P. Ghosh, Promotion of Medicinal and Aromatic Plants in the Asia-Pacific Region. In: Proc. Expert Consultation on Promotion of Medicinal and Aromatic Plants in the Asia-Pacific Region held at Bangkok, Thailand, 2-3 December, 2013, (Eds.) R. Paroda, S. Dasgupta, M. Bhag, S.P. Ghosh and S.K. Pareek, APAARI, Bangkok, Thailand (2014). pp.: 33-60.
22. M.Z. Abdin, M. Israr, P.S. Srivastava and S.K. Jain, *J. Med. Arom. Plants Sci.* **22**, 378-384 (2000).
23. R.B. Rawal, Production, processing and utilization of medicinal and aromatic plants in Nepal. Paper presented during the First Asian Symposium on Industrial Utilization of Medicinal and Aromatic Plants held at FAO/RAP, Bangkok, 4-7 November 1996 (1996).
24. B. Pooja, K.N. Sreenivas and B.S. Sreeramu, *Fruits* **67**, 249-256 (2012).
25. S. Gupta, M.C. Porwal and P.S. Roy, *Indian J. Trad. Know.* **3**, 287-293 (2004).