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Review

Current status and potential prospects of medicinal plant sector in trans-Himalayan Ladakh

G. Phani Kumar*, Raj Kumar, O. P. Chaurasia and Shashi Bala Singh

Medicinal and Aromatic Plant Division, Defence Institute of High Altitude Research (DIHAR), DRDO, C/o 56 APO, Leh-Ladakh.

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The study reveals that Ladakh is rich in vegetation, medicinal flora and endemic diversity. The traditional knowledge on native plant species highlights Amchi system of medicine and their traditional health-care system, both logistically as well as economically. The excessive extraction of medicinal plant resources for use in the pharmaceutical industry, has resulted in ruthless destruction of natural populations of medicinal plants. Present study, attempts to assess the current status of knowledge of medicinal plant resources of Ladakh and herbal products. It also focuses on the importance of documenting traditional knowledge and practices, related to conservation and sustainable utilization of medicinal plants of Ladakh. An approach for prioritizing strategies for action is proposed, which is a three step process, namely technology development, technology dissemination, technology assessment and refinement. Besides, the approach highlights the importance of involving indigenous communities, traditional institutions and NGOs to complement efforts of academics, scientists and government departments to ensure conservation and utilization of this resource.

Key words: Ladakh, medicinal plants, Amchi system, trans-Himalayas, conservation biology.

INTRODUCTION

Medicinal plants offer alternative remedies with tremendous opportunities to generate income, employment and foreign exchange for developing countries (Rawat and Uniyal, 2004). Many traditional healing herbs and their parts have been shown to have medicinal value and can be used to prevent, alleviate or cure several human diseases (Dhar et al., 1999). Consumption of herbal medicines is widespread and increasing in recent years and approximately 80% of the people in developing countries depend on traditional medicines for primary health care needs (Farnsworth et al., 1985). Out of the 350,000 plant species identified so far, about 35,000 (some estimate up to 70,000) are used worldwide for medicinal purposes and less than about 0.5% of these have been chemically investigated (Comer and Debus, 1996). The global market for the medicinal plants and herbal medicine is estimated to be worth US$800 billion a year and the market for Indian traditional systems of medicine is about Rs. 4000 crores per year (Rajasekharan and Ganeshan, 2002; Kempana, 1974; Chauhan, 1996). India is one of the leading countries in Asia in terms of the wealth of traditional knowledge systems related to herbal medicine and employs a large number of plant species which includes Ayurveda (2000 species), Siddha (1121 species), Unani (751 species) and Tibetan (337 species) (Kala, 2002).

The Himalayan region is a reservoir of a large number of medicinal and aromatic plants (MAPs) and designated as one of the global biodiversity hotspots, where ecological, phyto-geographical and evolutionary factors favour high species diversity. The Himalayan region occupies only 15% of the country's geographical area, it accounts for about 30% of the endemic species found in the Indian subcontinent. This region alone supports about 18,440 species of plants of which about 45% are having medicinal potential (Maikhuri et al., 2005; Nautiyal et al., 1998). The Indian trans-Himalayas span over 186,000 km^2 above natural tree line zone and is known for its sparsely distributed vegetation and relatively low species diversity. This zone sustains more than 1000 plant

*Corresponding author. E-mail: phani_bot@rediffmail.com.

species, 225 avian species and many rare and endangered mammalian fauna, including the snow leopard (Fox et al., 1994; Kala and Manjrekar, 1999). Two of the ten major bio-geographical zones of the Indian subcontinent stretch along the trans-Himalayan and main Himalayan ranges (Rodgers and Panwar, 1988). Ladakh region of Jammu and Kashmir contributes the highest geographical area in the trans-Himalayan region of India, followed by Lahaul-Spiti in Himachal Pradesh, northern part of Sikkim and Uttaranchal. High-altitude Himalayan zone is full of fragile habitats and decline in tree-species richness, however rich in representative (native) and endemic biodiversity elements (Dhar et al., 1999). Defence Institute of High Altitude Research (DIHAR), India is situated at the altitude of 10,500 ft above sea level and working for the conservation of biodiversity as one of the major aspects. The present study is mainly focused on Ladakh, it includes the following five valleys namely, Changthang, Indus, Nubra, Suru and Zanskar.

In a wider context, there is a growing demand for plant based medicines, heath products, pharamaceuticals, food supplements, cosmetics etc. in the national and international markets. Conservation and sustainable use of medicinal plants are issues on which immediate focus is required in the context of conserving biodiversity and promoting and maintaining the health of local communities, besides generating productive employment for the poor with the objective of poverty alleviation in tribal and rural areas. Keeping the above facts in view, the present article attempts to (i) identify medicinal plant resource base of Ladakh, (ii) highlight the potential and role of medicinal plants in the Tibetan system of medicine, (iii) assess the present state of knowledge on threatened medicinal plants of Ladakh, (iv) cultivation and conservation implications, (v) reveal the value added products based on trans-Himalyan flora, (vi) suggest a coordinated plan for strengthening the medicinal plants sector in Ladakh. The results of the investigation will help in developing a strategy for conservation and utilization of the medicinal plants by promoting strong linkages among different types of institutions.

SURVEY METHODS

Extensive field surveys (Jain, 1991) were undertaken since a decade, to gather data ethno-medico-botanical information on vegetation of Ladakh and the traditional uses of medicinal plant species across various localities in the Ladakh. Information was gathered using semi-structured questionnaires about the types of ailments treated by the traditional use of medicinal plants and the preparation of herbal medical formulations. The information related to traditional system of medicine given in the text was gathered from traditional healers living across the Ladakh (Changthang, Indus, Nubra, Suru and Zanskar valleys).

Several workshops were organized in different valleys of Ladakh and various groups of indigenous people were invited to participate, through helping to document their indigenous knowledge on medicinal plants, identifying the needs of medicinal plant conservation and also establishing a high altitudinal medicinal plant garden for RET spices at Leh. Specimens of each species identified were maintained at DIHAR herbarium. Samant et al. (1998) carried out Literature survey for the compilation of various traditional practices, beliefs, raw materials used for curing different ailments, cultivation and conservation practices. Rarity of species is determined by field study, visual estimation, literature and herbaria. The criterion for categorization of threatened species is based on the IUCN (Nayar and Sastry, 1987; IUCN, 2001; Ved and Tandon, 1998).

Geographical location and climate of the study area

Ladakh, ‘the land of high-rising passes’, is located in the state of Jammu and Kashmir, India (32°15'-36° N; 75°15'-80°15'E). It is bounded on the north and east by China and in the north-west by Gilgit and Skardu (Pakistan), whereas Baramula, Srinagar, Anantnag and Doda districts of the state of Jammu and Kashmir lie in the west and the states of Punjab and Himachal Pradesh touch its southern borders. Ladakh with an area of 96,701 km^2 (includes area under the illegal occupation of Pakistan, illegally handed over by Pakistan to China and under the illegal occupation of China). Siachen is the largest glacier located in the extreme northwest of Ladakh. The barren mountain landscape of Ladakh is broken by a series of rivers, notably the Indus and tributaries including Zanskar, Markha, Shyok, Nubra and Suru. The high-altitude (8000 ft to 24,000 ft), harsh natural environment of Ladakh is characterized by extreme temperature (30°C to +30°C), high radiation, strong winds, low precipitation (< 100 mm.yr–1), low humidity and desert-like extensive barren landscape, rugged topography, steep and vertical glaciated slopes, minimal forest cover and few pasture lands at high elevations (Chaurasia and Singh, 1996; Kumar et al., 2009).

Socio-economic status of Ladakh

Administratively, Ladakh is divided into two districts - Leh and Kargil. In Ladakh, where ecological constraints are high, socio-cultural factors and economic development have been found to have effect on the demographic structure. Natural environmental constrains dictate many aspects of traditional life, especially settlement site and agricultural system. Ladakh is inhabited by the following ethnic groups: 1) Buddhists: Ladakhi Bodh/Bhot/Boto/Bot, Gara, Mon Dolba, Beda, Changpa (Pastoralists of Changthang), Brokpa (Buddhist Dards); 2) Muslims: Balti,

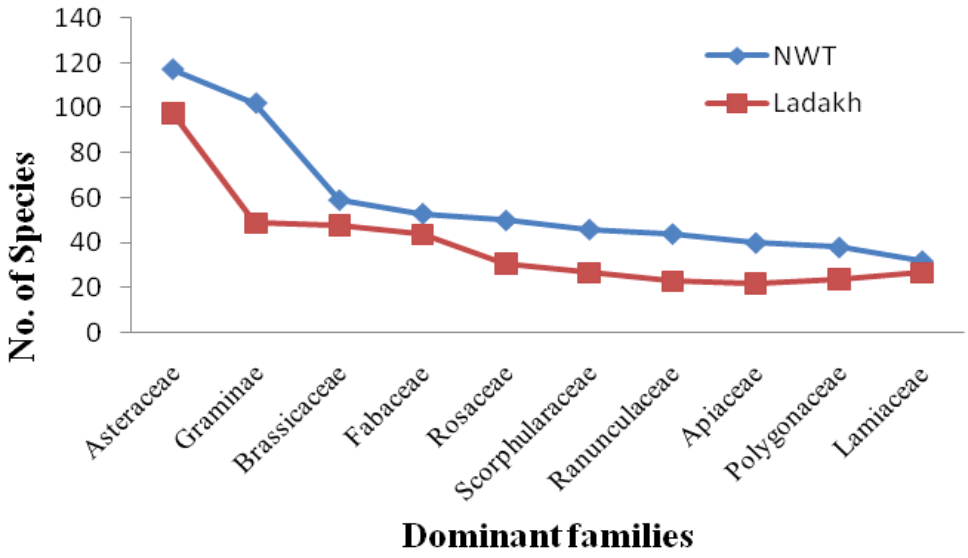

Figure 1. Comparison of dominant families of Ladakh and North-west Trans-Himalayas (NWT).

Purigpa, Argons, Drokpa (Muslim Dards) and 3) Tibetans (Recently colonized in Ladakh) (Bhasin, 2005). The inhabitants live primarily in small villages scattered over a vast region. It is inhabited by around 2 Lakh persons and has one of the lowest population densities in the world (2001 census of India). Cultivation and habitations in the Ladakh region are mostly confined to the river valleys, like Indus, Nubra-Shyok, Shingo-Sru (or Dras-Suru-Wakha) and Zanskar. Some villages are also situated on the low lying mountain slopes and around the rivers in the Chang-Chenmo. Sex ratio in Ladakh is 823 females per thousand males (Census of India, 2001). Locals depend on traditional folk-medicine practitioners deal with various herbs for preparing medicines and therapeutic use. Components of Ladakh medical pluralism are Lamaism, Shamanism and Amchi medicine (FRLHT, 2003).

Vegetation and medicinal flora of Ladakh

Flora and vegetation at the landscape level are important components in the study of the diversity of life forms and ecological patterns in spatial variability (Farina, 1998). The flora of Ladakh comes under alpine and high alpine zones, and differs significantly from the rest of the Himalayas, due to prevailing unique climatic conditions and physiography. Tree line is more or less absent in this zone, however annual and perennial herbs followed by stunted shrubs and bushes dominate the flora which counts more than 750 plant species: 540 dicots, 65 monocots and two gymnosperms (Chaurasia et al., 2007; Kachroo et al., 1977). The dominant families of the study area are Asteraceae, Brassicaceae, Fabaceae, Graminae, Ranunculaceae, Lamiaceae etc. and followed more or less the same sequence with North-west trans-Himalayan (NWH) vegetation (Aswal and Mehrotra, 1994). The graphical representation of dominant families in NWH and Ladakh are shown in Figure 1. Extensive studies by Kala and Mathur (2002), Kala and Jayapal (1999), Mani (1978), Joshi et al. (2006) on Ladakh floral diversity showed six habitat communities. These are Ephedra-Artemisia community, *Poa annua-Ranunculus hirtellus-Pedicularis oederi* community, *Caragana brevifolia*-Cotoneaster community, *Hippophae rahmnoides-Myricaria germanica* community, Artemisia-*Salsola collina-Kraschenennikovia ceratoides* community, Agropyron-Trisetum-Oryzopsis-Carex community. The distribution vegetation has adhered to particular altitude range and sometimes to particular valleys. Maximum number of plant species (429) were identified between 11000 to 12000 ft asl and then decreased number of species with increased altitude. Distribution of plant species in different altitudes of Ladakh are graphically reresented in Figure 2.

Medicinal plants are one of the most important parts of biological resources in trans-Himalaya and it is believed that over 50% of plants in the region have been recorded with medicinal value (Singh and Chaurasia, 2000; Kala, 2005). Medicinal plants of Ladakh can open avenues of economic growth in the emerging world market. Further, it has been realized that medicinal plants of the trans-Himalayan region, offer an advantage in having much greater possibilities of providing novel bio-molecules in view of the environmental stress (Mani, 1994). In the present study, medicinal plants of Ladakh are being grown under three categories, alpine mesohytes, oasitic vegetation and desert vegetation. Spatial distribution of MAP's valley-wise are shown in Figure 3.

The parts of Suru valley is characterized by high humidity, more rainfall and shows the characteristic of

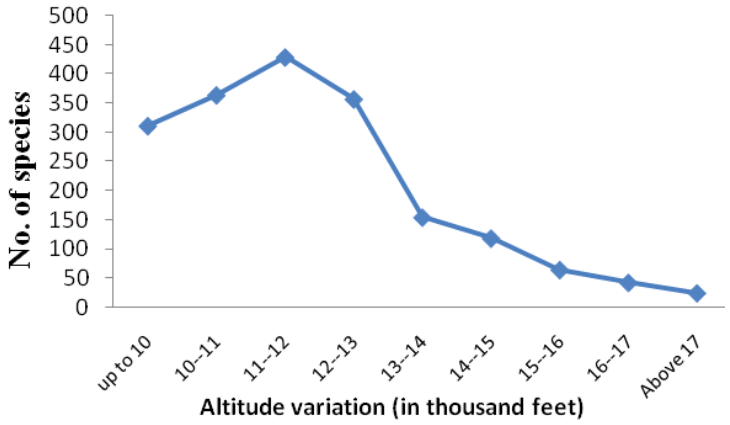

Figure 2. Distribution of plant species in different altitudes of Ladakh.

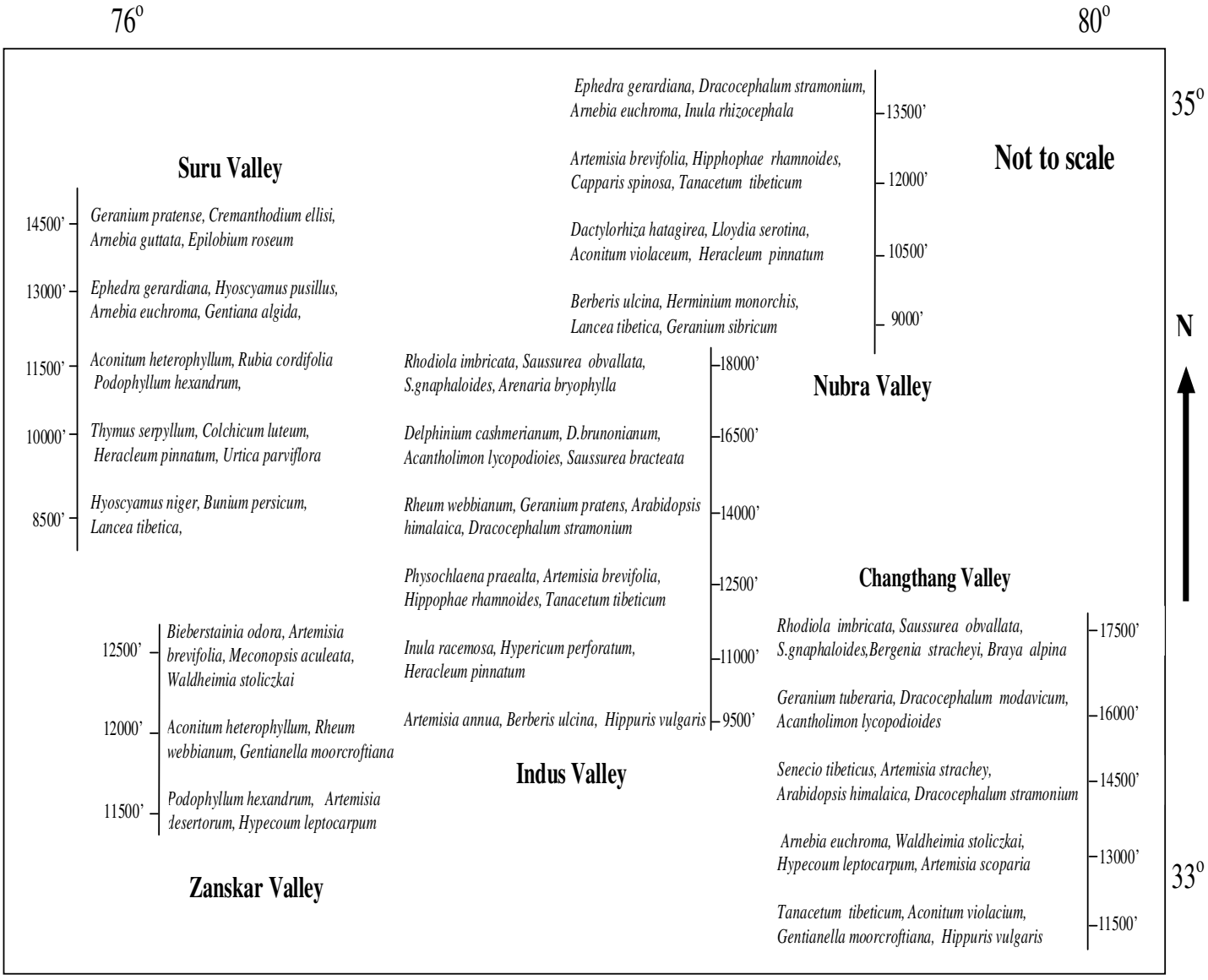

Figure 3. Spatial distribution of MAP's in different valleys of Ladakh (altitude in feet asl).

alpine mesophytes. The common mesophytic medicinal plant species are *Podophyllum hexandrum*, *Lavetera kashmiriana*, *Lotus corniculatus*, *Astragalus rhizanthus* etc. The habitation nearby river beds Zanskar, Indus, Nubra and Shyok represented by Oasitic vegetation. The medicinal plants of this zone are *Hippophae rhamnoides*, *Dactylorhiza hatagirea*, *Allium przewalskianum*, Peroveskiana, *Mentha longifolia*, *Potentilla cuneata*, *Sedum ewersii*, etc. Desertic flora found growing around high passes like Khardungla (18,380 ft), Changla (17,342 ft) and Tanglangla (17,240 ft). The same vegetation was also found in the barren lands of Indus and Changthang valleys, characterized by little rainfall, low humidity, extreme fluctuation of diurnal temperature and high velocity winds etc. The common MAP's are *Acantholimon lycopodioides*, *Meconopsis aculeata*, *Rhodiola imbricata*, *R.heterodonta*, *Saussurea obvallta*, *S.gnaphaloides* etc. Besides these, there are several medicinal plants that are being used in the Indian system of medicine and pharmaceutical industries.

Plant endemism in Ladakh

Threat is more difficult to characterize, since it may be a natural consequence of biological or geological processes or be the result of past or present human activities directly or indirectly influencing the plant populations or their environment. The populations keep changing size and density over a period of time and such changes may make plant species rare, endangered and threatened, eventually leading to their extinction (Maikhuri et al., 1998; Kala, 2000). During the study, it was observed that the frequency of some important medicinal and aromatic plant of Ladakh with which it was earlier abound, have considerably declined due to their unscientific exploitation, natural calamities, road construction, uprooting for fuel, overgrazing and other activities. This destruction has rendered many species endangered and threatened.

In recent years, it was also observed that the population size and number are decreasing in higher elevations. Many species found in Ladakh are considered 'critically endangered' and many more are 'endangered' or 'vulnerable'. The following villages and areas are famous across Ladakh for their medicinal plant wealth and diversity; Sapi, Kanji, Kardhungla, Changla, North Pullu, South Pullu, Hunder and Summur etc. Many Amchis from all over Ladakh travel to these "hot spots" to collect MAPs and they are thus sites of intense collection. Many plant species like Saussurea, Rheum, Artemisia, Thylacopsermum can be seen hanging along roadside near Khardungla 18,380 ft. and other high motorable passes. The forest department has also made extensive exercises to protect natural habitats and notified three protected areas (Hemis National Park, Karakoram Wildlife Sanctuary and Changtang Wildlife Sanctuary), five wildlife reserves (Randum, Sabu-Chakur, Rizong basgo, Gya-Miru and Kangri) and three game reserves (Boodh Karbu, Tongri and Lung lang) in the region. The field observations on rare, endangered and threatened (RET) medicinal and aromatic plants have been made and compared as tabulated in Table 1 (Nayar and Sastry, 1987; IUCN, 2001). Overall situation of medicinal plants in Ladakh is under pressure and many wild species are threatened.

Traditional system of medicine

Tibetan medicine has been the traditional health system of Ladakh for over 1000 years. The Tibetan science of healing, Sowa rigpa (gSo-ba Rig-pa), is an integrated system of health care which contains elements of Ayurveda and Chinese medicine. Since Amchis are the practitioners of this system, it is also known as Amchi medical system (Dash, 1976), 60% of the public health of Ladakh is looked after by this system (Kala, 2005). Besides India, China, Mongolia, Persia and Nepal have contributed in the evolution of the Tibetan medicine. Plant materials are the major ingredients in Tibetan medicine, besides animal products, minerals and salts. Depending on the availability, Amchis used to collect medicinal plants from the nearby areas of their villages. Some of the Tibetan medicines were made up of purely plant species and their parts. The medicine is rarely made up of a single constituent and most often it is a combination of 3 to 40 ingredients (Tsarong, 1986; Phuntsog, 2006).

Many of the plant species that are being used in the system, have been available at high altitudes of Ladakh. Each plant species may be utilized as ingredient in single to several Amchi formulations. Some important trans-Himalayan medicinal plants based on the number of formulations being used is given in Table 2. For instance, *Sassurea lappa* is an ingredient in 58 formulations; *Inula racemosa* in 31 formulations and *Oxytropis chiliophylla* in 17 formulations.

Few Amchi medicines, where Ladakh flora plays amajor role are Bya khung -5; Da trig -7 and Tig ta -8, etc. The numerical value given at the end of the medicine name denotes the number of plants used in preparing the respective medicine. Gradually, Tibetan medicine has gained considerable momentum in Western countries, due to the growing awareness about the side effects of allopathic medicines (Kala, 2002). Some important Amchi formulations where trans-Himalayan medicinal plants play major roles are given in Table 3.

Cultivation and conservation of medicinal plants

Consumption of herbal medicines is widespread and increasing day by day. India is one of the major raw material-producing nations of South Asia and within the

Table 1. List of threatened medicinal plants of Ladakh.

Name of the Taxa	Family name	Local name	Altitude (ft)	Part used	*IUCN status[19-21]	
					NWH	JK
Acantholimon lycopodioides (Girad) Boiss.	Plumbaginaceae	Longze	14500-16000	Whole	EN	EN
Aconitum heterophyllum Wall. Ex. Royle	Ranunculaceae	Bona-karpo	10500-12500	Root	CR EN	CR EN
Aconitum violaceum Jac. Ex Stapf	Ranunculaceae	Bona-nagpo	10000-12500	Root	CR EN	VU
Arnebia benthamii (Wall. Ex G. Don) John.	Boraginaceae	Balchar	9000–12000	Root	CR EN	CR EN
Arnebia euchroma (Royle ex benth.) Johnston	Boraginaceae	Demok	13000-16000	Root	EN	EN
Arnebia guttata Bunge	Boraginaceae	Demok	11000-14500	Root	VU	
Artemisia maritima L.	Asteraceae		10000-12000	Leaf	EN	VU
Bergenia stracheyi (Hk.f. and Th.) Engl.	Saxifragaceae	Gatikpa	11000-13000	Root, flower	VU	VU
Betula utilis D.Don.	Betulaceae	-	10000–13000	Root	EN	CR EN
Bunium persicum (Boiss) Fedtsch.	Apicaceae	-	9750-12000	Fruit	NL	EN
Colchicum luteum Baker.	Liliaceae	Tukapa	10500-12000	Rhizome	NL	R
Cremanthodium ellisii Hk. F. Kitam	Asteraceae	Lukumentok	14750-16000		NL	R
Dactylorhiza hatagirea (D.Don) Soo.	Orchidaceae	Ambolakpa	9500-11000	Tuber	CR EN	EN
Delphinium cashmerianum Royle.	Ranunculaceae	Lunde-kaown	14500-16500	Seed, stem, flower	R	NL
Ephedra gerardiana Wall. ex Stapf.	Ephedraceae	Chhapat	10000-11600	Stem, root	VU	EN
Ephedra intermedia Schr and Mey.	Ephedraceae	Chhapat	9300-11000	Root, leaf	NL	VU
Ferula jaeschkeana Vatke	Apiaceae		9500-11200	Root	VU	VU
Fritillaria roylei Hk.	Liliaceae	Abhisa	11200-12000	Bulb	CR EN	EN
Geranium sibricum L.	Geraniaceae	Eyamlomentok	9600-10500	Leaf	CR EN	R
Herminium monorchis (L.) R. Br.	Orchidaceae	Peo	10250-11500	Tuber	VU	NL
Hippophae rhamnoides L.	Elaegnaceae	Sastalulu	9000-13500	Whole	LR-NT	VU
Hyoscyamus niger L.	Solanaceae	Gay-lantang	8500-10000	Fruit	LR-NT	VU
Juniperus communis L.	Cpressaceae	-	9500-12000	Fruit, leaf	R	NL
Jurinea dolomiaea Boiss.	Asteraceae	-	10000-12000	Whole	NL	EN
Lancea tibetica Hk.f. and Th.	Scrophulariaceae	Chagna	9500-11000	Seed	R	R
Lloydia serotina (L.) Reichenb.	Liliaceae	Rtsa-awa	9600-10400	Tuber	NL	R
Meconopsis aculeata Royle	Papaveraceae	Achatsarmum	14000-15200	Leaf, flower, fruit	CR EN	EN
Physochlaena praealta (Decne.) Miers	Solanaceae	Langthang	10,000-16,000	Seed, flower	VU	VU
Podophyllum hexandrum Royle	Berberidaceae	Demokusu	12000-13700	Root	EN	EN
Polygonatum multiflorum (L.) All.	Liliaceae	Ra-mnye	10200-12000	Root	VU	VU
Polygonatum verticillatum (L.) All.	Liliaceae	Ra-mnye	10000-12500	Root	VU	VU
Rheum spiciforme Royle	Polygonaceae	Lachhu	10000-16000	Root	VU	VU
Rheum webbianum Royle	Polygonaceae	Chu-rtsa	11250-13400	Root	VU	VU
Rhodiola heterodonta (Hk. f. and T.) A. Boiss.	Crassulaceae	Solo-marpo	16500-18380	Root	NL	NL
Rhodiola imbricata Edgew.	Crassulaceae	Solo-carpo	16500-18380	Root	NL	EN

Table 1. Continued.

Rhododendron campanulatum D. Don	Ericaceae	-	9000–12500	Leaf, flower	VU	VU
Saussurea bracteata Decne.	Asteraceae	Jar-bag	17000-18380	Flower, leaf	R	NL
Saussurea gnaphalodes (Royle) Sch-Bip.	Asteraceae	Yuliang	17500-18380	Whole	R	NL
Saussurea gossypiphora D.Don	Asteraceae	-	15000-17000	Flower	EN	R
Saussurea lappa (Decne.) Sch-Bip.	Asteraceae	Rustha	10000-13000	Root	CR EN	CR EN
Saussurea obvallata (DC.) Edgew.	Asteraceae	Spanrtsa-Dobo	16500-17500	Root	VU	NL

*IUCN status abbreviations: CR EN- critically endangered; EN- endangered, VU- vulnerable; R- rare; LR-Nt-low risk-near threatened; NL-not listed; NWH-north west Himalayas; JK-Jammu and Kashmir.

Table 2. Some important trans-Himalayan medicinal plants based on number of Amchi formulations.

Scientific name	Amchi name	Nature	No. of formulations
Saussurea lappa	*Ru rta*	Neutral and oily	58
Inula racemosa	*Manu*	Neutral	31
Oxytropis chiliophylla	*Stag sha*	Cold	17
Picrorhiza kurrooa	*Hong Len*	Cold coarse	17
Rubia cordifolia	*Btsod*	Cold	15
Aconitum violaceum	*Bonga lophra*	cold	14
Hippophae rhamnoides	*Star bu shing*	Hoy oily	13
Hypecoum leptocarpum	*Par pa ta*	Cold coarse	11
Rheum spiciforme	*Chuma rtza*	Hot	11
Rhododendron Sp.,	*Da lis*	Hot coarse	8
Carum curvi	*Gosngd*	Hot	6
Hyoscymus niger	*Langthang tze*	Oily cold	5

country; however, Ladakh supports a large number of such species. Conservation, propagation and utilization of medicinal plants become a major thrust area of research activity throughout the country (Ayensu, 1996; Kumar et al., 2009). There is now, wide recognition of the contributions that medicinal and aromatic plants make to the global economy and human welfare. Many of the medicinal plants in developing countries are extracted from the wild, it may be the result of loss of genetic diversity and has led to rapid depletion of a number of MAPs from their natural habitats (Singh, 2002). Domestication and cultivation of MAPs is one of the viable options to meet the growing demands from the industries and to reduce the extraction pressures in the natural habitats of MAPs. In Ladakh, Defence Institute of High Altitude Research (DIHAR) has conducted several workshops and field demonstrations on conservation practices of MAP species (Figure 4). Some important medicinal plant's cultivation techniques for the region of Ladakh are presented in Table 4, which includes Germination %, type of vegetative propagation, requirement of seed and manure, and approximate production ha^{-1}. Recently, some NGO's have showed their interest on encouraging medicinal plant cultivation in Nubra, Indus and Zanskar valleys.

It is surprising that most of the local people do

Table 3. Some important Amchi formulations where trans-Himalayan medicinal plants plays major role.

Name of the formulation	Treatment	Trans-Himalayan flora (%)
Bong dkar -6	Hoarseness	60
Bya khung -5	Eczema, enterocolitis	50
Bya khyung cdud rtzi gsum sbyor	Wound healing	95
Cong zhi -21	Epigastric burning	43
Da trig -7	Diarrhoea, dysentery	66
Dkar po -6	Glaucoma and cataract	50
Phyng snon -9	Bacterial and viral fiver	51
Rdo rji rab byams	Neurotonic for depressive psychosis and neuro muscular cramps	44
Ser po -9	Antispasmodic and analgesic	57
Smug po gab pa sel bai se – 8	Chronic peptic ulcer	52
Smyug pos el bai se -8	Antacid in peptic ulcer, gastritis, oesophygitis	48
Spyi joms bde bai myugu	Gastrointestinal bleeding	41
Star byang ngis	Stimulant, antihypertensive, dyspepsia and dysnoea	90
Tig ta -8	Hepatic stimulant, all types of jaundice	75
Zh byed -11	Uterine haematoma	42

Figure 4. High altitude Rare, Endangered and Threatened (RET) species garden at Leh.

not know the economical importance (market value) of highly medicinal value plant species like Podophyllum, Hippophae, Dactylorhyza etc. Besides lack of knowledge, there is a certain lack of co-ordination among the villagers about the importance of several species in modern systems of medicine, and so, they are not willing to cultivate these herbs. Therefore these people need to be made aware of the importance and to receive information collectively, so that they can discuss themselves, accompanied by their knowledge of technology for cultivation. As compared to the traditional crops, the cultivation of medicinal crops has many advantages. These include: i) better returns than traditional crops, ii) very high domestic and export demand, iii) could be stored for a long time iv) required minimum resources, v) lower cost of cultivation and vi)

Table 4. Conservation techniques of some important MAP's for Ladakh climate.

Name of the plant	Seed germination and requirement	Vegetative propagation	Manure and irrigation	Part used and harvesting period	Total production
Aconitum heterophyllum	62-65%; 1.5 kg/ha	Root divisions/tubers; Req: 95,000 cuttings/ ha	FYM and compost (1:2) @ 7 t/ ha; irrigation in every 48 h	Root; Oct-Nov	93 kg/ha (after 2nd year)
Allium carollinianum; A. prezuwalskianum	67-75%; 7 kg/ ha	Division of bulbs; Req: 1,25,000 bulbs/ha	FYM @ 5 t/ha; irrigation in every 24 h	Bulbs, leaves; Aug-Sep	110 kg/ha/year
Podophyllum hexandrum	50-60%; 3.5 kg/ ha	Rhizomes cuttings; Req: 11,000 cutting/ha	FYM / green manure @ 5 t/ha; Irrigation in every 24 h	Rhizome; Oct-Nov	5 t/ ha (after 4th year)
Dactylorhiza hatagirea	Very less % of germination and not recommended	Tuber division; Req: 50,000 tubers /ha	FYM @ 8 t/ha, mulching is required; irrigation every 12 h	Tubers; Sep-Oct	1.5 t/ha (after 3rd year)
Arnebia euchroma A. benthami	60-70%; 5 kg/ha	Root cuttings; Req: 50,000 cuttings / ha	FYM @ 6 t/ha; Irrigation in every 48 h	Roots; Sep-Out	1.2 t/ha (after 4th year)
Rubia cordifolia	80%; 1.5–2 kg/ha	Root cuttings; Req: 22,000 cuttings /ha	FYM @ 10 t/ha; Irrigation in every 3rd day	Root; Sep-Oct	3 t/ha (after 3rd year)
Polygonatum verticillatum	70%; 2 kg/ha	Rhizome cuttings; Req: 42,000 cuttings/ha	FYM @ 15 t/ha; Irrigation in every 48 h	Rhizome; Sep-Out	1.3 t/ha (after 3rd year)
Rheum webbianum	50-60%; 600 gm/ ha	Rhizome cuttings; Req: 16000 cuttings/ha	FYM @ 4 t/ ha; Irrigation in every 24 h	Rhizome; Oct- Nov	4 t/ha (after 3rd year)
Inula racemosa	70-80%; 200 gm/ ha;	Rootstocks; Req: 40,000 cuttings/ha	FYM @ 15 t/ha at the time of land preparation; light irrigation in every 3-4 weeks	Root Oct- Nov	8 t/ha (after 2nd year)
Hippophae rhamnoides	80-90%; 50 gm/ha	Root cuttings, suckers or stem cuttings Req: 1,500 cuttings/ha	FYM @ 20 t/ ha; Plantation of male: female ratio should be 20:80; light irrigation at initial stage	Leaves, fruits and seed Aug-Oct	Fruit: 10-15 t/ha/year Leaf: 30 t/ha/year (after 4th year onwards)
Rhodiola imbricate	5-10% can be increased by cold treatment upto 60%	Rhizome cuttings; Req: 30,000 cuttings /ha	FYM @ 40 ton/ha; Irrigation is required weekly twice	Rhizomes Sea: Sep - Oct	2 t/ha (after 5th year)
Sasuurea lappa	85%; 1.25 kg /ha	Root cuttings; Req:15,000 cuttings/ha	FYM/ green manure @ 15 t/ha; Excessive watering at initial stages and later on every 4th day.	Root Sea: Oct-Mar	3 t/ha (after 2nd year)

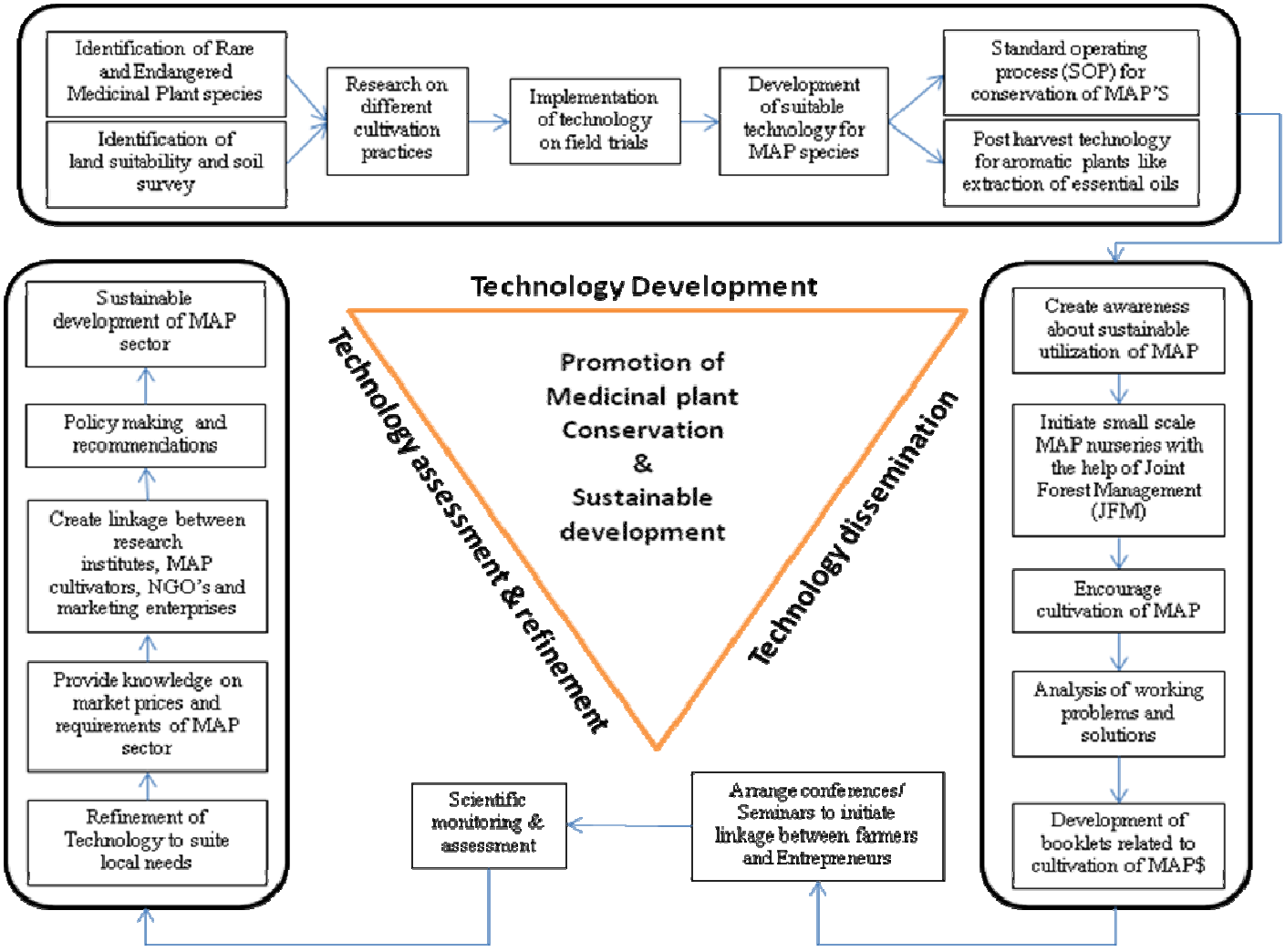

Figure 5. A model plan for Conservation and sustainable development of MAP sector.

better prices prevail in the market. Cultivation of MAPs could provide an opportunity to enhance incomes of people residing in harsh environments, such as high elevation zones of the Ladakh.

Herbal products developed from Ladakh

Herbal-based medicated products have drawn considerable attention from research institutions and industries in recent years, at the national and international level. The World Health Organization (WHO) has given emphasis on development and utilization of herbal products and medicines for the benefit of world population and to see cost effectiveness and minimum side effects of these products (Tsarong, 1986). The major products developed by DIHAR, DRDO are seabuckthorn based herbal multivitamin beverage, herbal antioxidant supplement and herbal appetizer.

It is also available in blended brands such as guava–seabuckthorn nector, pineapple–seabuckthorn nector, mango–seabuckthorn nector, orange–seabuckthorn nector, apple–seabuckthorn nector, apricot-seabuckthorn nector and apricot based UV protective oil. Ladakh Foods is building a portfolio of products from fruit juices to jams and sauces, based on the little-known seabuckthorn berry, which grows in the Ladakh region. The high medicinal and nutritional value of these plants make the products highly beneficial for local residents as well as for troops deployed at high altitude, near the line of control, e.g. Siachen glacier.

Priorities and strategies for future action

Convention on Biological Diversity (CBD) states that, the systematic approach of medicinal plant conservation plays a vital role in environment management and

development through traditional as well as scientific practices (Uniyal et al., 2006; Aase and Vetaas, 2007). For overall sustainable development of Ladakh, the medicinal plant sector could prove valuable. Medicinal plants should be cultivated to save the forests and alpine regions and at the same time, meet the rising demands of herbs to improve the livelihoods of the hill people (Kala, 2005). It is well known that, the cultivation of medicinal and aromatic herbs to be one such potential option. At this stage, a strategy for future need is to be developed. On priority, the strategy must address the conservation of wild medicinal plants, threatened with extinction. The present scenario offers a unique opportunity for government representatives, scientists and NGOs to work in coordination, to devise mechanisms to promote traditional health-care system and engage rural inhabitants in conservation, cultivation, processing and marketing of raw material.

Documentation and preservation of high altitudinal medicinal plant species of Ladakh and their traditional knowledge system are the most important aspect, for the benefit of humankind, before it is lost forever. This will require a systematic approach which contains technology development, technology dissemination, technology assessment and refinement (Figure 5). It is a three directional process interlinking each step with the other. Research and development institutions have a role in the development of suitable and sustainable technology; state government and forest agencies have the role to implement the technology into field level, and entrepreneurs have the role to make a sustainable market for the sector. However, no single institution/agency can meet all the challenges involved in this sector. The problems can only be overcome by building effective partnerships between farmers/ growers, extension agents, private sector, NGOs/GOs, researchers, policy makers and, more importantly by enhancing information exchange.

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