Bioprospecting of medicinal plants in Nanda Devi Biosphere Reserve: Linking conservation with livelihood

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Six species of medicinal and aromatic plants, viz. Allium stracheyi, Allium humile, Allium rubellum, Pleurospermum angelicoides, Carum carvi and Angelica glauca having high economic value were selected for bioprospecting and brought under cultivation from wild in the high altitude villages of Nanda Devi Biosphere Reserve, Uttarakhand. The edible parts of selected species were analysed for nutritional value to evaluate their potential for promoting large scale consumption and cultivation. Among the selected species, macronutrients were found maximum for Allium stracheyi, i.e. carbohydrates (98.34 mg/g), proteins (187.11 mg/g), vitamin C (156.50 mg/g), vitamin B2 (26.12 mcg/gm), vitamin E (61.10 mg/g) and phosphorus (14.13 mg/g) followed by Allium rubellum and Allium humile. The results of nutritional value, cultivation practices and technique of value addition were demonstrated to rural inhabitants through on-site training and capacity building programmes to enhance their skill and awareness about the potential of selected species for livelihood options. The cost–benefit analysis of cultivation and collection from wild, and value addition of herbal spices were done to see if the species were feasible for developing local entrepreneurs. These efforts enhance the ability and knowledge of local inhabitants for cultivation and value addition of medicinal herbal spices in the region. The overall impacts of the work were seen as an improvement in socio-economic conditions of residing community and awareness for medicinal plant conservation in their natural habitat.

Keywords: Bioprospecting, cultivation, conservation, livelihood, indigenous knowledge, medicinal plant.

MEDICINAL plants play an important role in traditional herbal system and as a source of income in many developing countries[1–3]. The wide altitudinal variation, different habitat types and varying micro-climatic conditions in the Indian Himalayan region form perfect condition and environment for the growth of medicinal and aromatic plants (MAPs)[4–6]. However, indiscriminate and over-harvesting from their natural habitats has severely affected the availability of MAPs in the last few decades[7–9]. Many of the MAPs face the problem of habitat destruction due to various environmental perturbations and anthropogenic pressures (i.e. over-exploitation, unscientific harvesting, illegal trade, climate change) resulting in declined availability and accessibility in natural habitats[8,10–12], leading to the extinction of more than 150 plant species in the wild[4,5,13]. Most of the plant species (90%) used in traditional healthcare system and in herbal industries are brought from their natural habitats (i.e. sub-alpine and alpine meadows) in the Himalayan region[14] impacting the population density of economically potential MAPs and plant diversity in alpine ecosystem. The high demand of MAPs at local, regional and international market has attracted the attention of scientists and pharmaceutical industries for their conservation through cultivation[13,16,17]. There are a number of MAPs that find place in day-to-day uses as medicinal herbal spices locally in the high altitude villages of central Himalaya. To meet the requirement of few potential and demanding medicinal plants in the local and national markets, few farmers are engaged in their cultivation in central Himalaya[7]. Among the potential MAP species, cultivation of *Allium* species (*A. stracheyi*, *A. humile*, *A. rubellum*) has been practised by the *Bhotiya* communities of Niti and Milam valleys since the past several years while *Angelica glauca*, *Carum carvi* and *Pleurospermum angelicoides* have been brought under limited cultivation at high-altitude villages of Nanda Devi Biosphere Reserve

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(NDBR). These species are used traditionally to stimulate appetite, enhance digestion, provide distinctive taste, flavour, relieve stress and have been known for their preservative qualities. Although spices derived from the above-mentioned species may not be well known to the main-stream societies, they are in good demand by the tribal communities for the taste and associated healing properties particularly in the cold climate of high altitude regions. Further, these species have also occupied an important place in the traditional herbal system of medicinal plants for many decades in the mountain region of central Himalaya[7,18–20]. Hence, there is need to select the potential MAPs species having high economic value for large scale cultivation and domestication so that the livelihood avenue based on MAPs could be linked to conservation[21,22]. The main objective of this study was to promote bio-prospecting of selected medicinal plants for linking livelihood opportunity with their conservation in the mountain region of central Himalaya.

Study area

The present study was carried out in ten selected villages of Niti valley of Nanda Devi Biosphere Reserve in Uttarakhand (Central Himalaya). NDBR, the second biosphere reserve designated by the Government of India, represents a unique combination of mountain ecosystems having representative floral biodiversity and faunal diversity. Recognizing its uniqueness, the reserve has been included in the World Network of Biosphere Reserve. The people inhabiting the buffer zone villages of NDBR belong to 'Bhotiyas', an ethnic community of Mongoloid origin[7,21,22]. These communities are believed to be the wealth of ethnobotanical knowledge and have established symbiotic relationship between biodiversity and their cultural identity.

Methodology

In the present study, 12 representative villages involving 633 households were surveyed for documenting traditional knowledge of medicinal plants, cultivation practices, quantification of wild harvesting and other related issues. Agronomic practices for cultivation of selected medicinal plants were demonstrated to the interested rural farmers for their large scale cultivation and conservation in participatory mode[7]. Interested farmers were selected through organization of village level meeting and on the advice of the village council. Population assessment of MAPs was also carried out during July–August when majority of medicinal plants attain maximum vegetative growth[23,24]. The economic return per hectare was calculated on the basis of the yield from the entire plot[7]. For monetary (the value of US$ 1 is approximately 67 Indian rupees) output/input analysis, the cost of material and labour for various activities was worked out on the basis of market rates. The dried samples of selected species were collected and detailed analysis for carbohydrates, protein, lipid, vitamins, phosphorus, potassium, calcium and iron was carried out to see the nutritional potential of these species following standard methodology. The total carbohydrate content was determined by anthrone reagent method following Hedge and Hofreiter[25]. This resulting green colour was measured from spectrophotometer and a standard curve of glucose prepared for quantification. Total lipids were estimated using standard method[26]. Protein content was estimated by the Biuret method[27] and vitamin B2 was estimated by spectofluorimetric method as described by Watanabe[28]. Total antioxidant activity of the extracts was evaluated by the phosphor–molybdenum method according to the procedure of Prieto[29]. However, the reducing power of the extract was determined according to the method of Oyaizu[30]. The inorganic phosphorus was estimated by the method of Fiske and Subbarow[31]. Atomic absorption spectrophotometer was used for analysis of magnesium, copper, iron, zinc and manganese content. After chemical analysis of the spices prepared from selected species, training was provided to farmers/user groups on value addition/bioprospecting of cultivated/collected medicinal plant species. Farmers' capacity for building and large scale adoption of medicinal plants was considered the most distinguishing feature of demonstration of cultivation practices for biodiversity conservation and livelihood improvement. The nutritional and economic potential of the selected species after value addition (i.e. grinding, grading, packaging, levelling, etc.) was demonstrated to interested farmers to motivate them and enhance their livelihood through marketing of these products.

Results and discussion

Traditional and indigenous knowledge system

Of the 8000 species of wild edibles reported from India, 675 are found in Indian Himalayan Region (IHR) and nearly 1748 species of medicinal and therapeutic value have been identified from IHR and utilized in traditional system of healthcare and by pharmaceutical firms[30]. The traditional herbal medicinal system and trade in medicinal plants are an important source of income to inhabitant communities of NDBR[7,10]. Considering the importance of traditional and indigenous knowledge system, there is an urgent need to document the eroding knowledge base of medicinal plants, which is still maintained by the traditional and indigenous community of the region. The species (viz. *Allium humile*, *Allium stracheyi*, *Allium rubellum*, *Carum carvi*, *Angelica glauca*, *Pleurospermum angelicoides*) selected for the present study are used as medicine in traditional herbal system and as spices by traditional inhabitants of the region (Table 1). Linking

Table 1. Indigenous agronomic practices, traditional use of cultivated medicinal herbal spices in high altitude villages of NDBR

Species and part used	Traditional and medicinal use	Brief agronomic practices
Allium humile Local name: Ladum Family Liliaceae (leaves, flowers and stem)	Traditionally fried paste is added to meat and culinary purposes; leaves are used as best quality condiments. Medicinally it is used to cure jaundice, cough and cold.	This species requires dry cold climate and is raised through rootstocks during the monsoon period. High quantity of organic manure is applied and spacing between the two rootstocks is kept around 3–4 cm and requires frequent weeding, at least three to four times in a year. The crop is generally harvested thrice a year, first in the month of April, second in June and third in September–October.
Allium stracheyi Local name: Jimbu Family Liliaceae (leaves, flowers and stem)	Traditionally used as a green vegetable. The dried leaves and stem are used in the preparation of spice and condiments. Medicinally the decoction of green leaves is used to cure cold cough, lung and nasal infection.	*Allium stracheyi* bulbs (single or two pieces cut into vertical section) are transplanted in the spring season (April–July). It requires a moist and shady place and requires fortnightly weeding. The crop is generally harvested thrice in a year at lower altitude and twice in higher altitude.
Alium rubellum Local name: Doodhu Family Liliaceae (leaves and flowers)	Traditionally used as vegetable and condiments. Medicinally the regular use of leaves as condiment is reported to be good for the patients suffering from jaundice and also useful in curing cold and cough.	Cultivation is done through seeds in moist and wet soil at high altitudes. It requires high quantity of manure as compared to other species of *Allium*. It also requires frequent weeding, at least three to four times in a year and is harvested thrice a year.
Angelica glauca Local name: Choru Family Apiaceae (leaves, stem and rootstock are used)	Traditionally the root is used as a flavoring agent, spice and condiment. The powder of root is used to cure stomach ailments of children. Leaves and stem of the plant are used to cure dysentery and provide relieve from body pain caused due to extreme cold.	It requires temperate climatic conditions (2200–2800 m asl). A deep rich porous soil and heavy inputs of organic manure (sheep and goat dung) is essential for better yield. It is propagated by root cuttings or seeds in the month of October–November however, propagation through seed is more common. Seedlings raised through root cuttings are transplanted during rainy season and require frequent weeding (once in three months). It is harvested after three years. Sometimes it is harvested biennially for good yield.
Pleurospermum angelicoides Local name: Chhipi Family: Apiaceae (Rootstock is used)	Roots are used as spices and condiments. Leaves and stem of the plant are used to cure dysentery and stomach troubles. The decoction of the roots is used to cure typhoid fever, stomach pain, etc.	It is multiplied through seed as well as vegetative means in the month of November–December immediately after harvesting seeds during November. It requires temperate climatic conditions (2000–3500 m asl). A deep rich porous soil along with moist and shady conditions followed by high input of organic manure is good for its cultivation. Sheep and Goat manure is reported to be good for higher production. Transplanting is usually done on the onset of rainy season. Harvesting is preferred after 3 years but sometime it is harvested after 1 or 2 years as per the need of the farmers.
Carum Carvi Local Name: Kala Jeera Family: Apiaceae (Fruit/seeds are used)	The seeds are used as spice or condiments while the tender leaves are used in soup as an appetizer. Seeds are used to cure stomach disorders such as gastric problem.	*Carum carvi* grows best when the seeds sown in the autumn season. The land requires an occasional hoeing for better growth of the crop. Seeds can be dried either on trays in the sun or by very gentle heat over a stove, shaking occasionally.

conservation with livelihood has the benefit of safeguarding the fast eroding cultural knowledge and practice which are increasingly threatened due to globalization[31]. The promotion of domestication and cultivation of medicinal plants and further bioprospecting in the form of value added products have enormous potential of protecting traditional knowledge-based health care system practiced in the Indian Himalayan Region.

Cultivation, yield and wild collection

Many farmers in high altitude villages of NDBR have adopted cultivation of medicinal plants that have high medicinal and local market value as a result of onsite training and awareness on medicinal plant conservation, cultivation practices and planting material. The land under cultivation (6.97 ha) and percentage of total area (51.74%) was found maximum for *Allium humile* followed by *Allium stracheyi* (3.10 ha) and *Pleurospermum angelicoides* (1.60 ha) respectively, in the studied villages of NDBR (Table 2). *Allium humile* provide maximum yield (584 ± 28 kg/ha) among the six species selected for the study, in agriculture field, followed by *Pleurospermum angelicoides* (577 ± 31 kg/ha) and *Carum carvi* (362 ± 12 kg/ha) respectively. The maximum net return (Rs 331530/ha) was obtained for *Pleurospermum angelicoides*. However, monetary output/input ratio was calculated maximum (12.47) for *Carum carvi* (Table 2). Among cultivated medicinal plants *Carum carvi* showed the highest net return per unit of input. The yield of few herbal spices such as *Allium stracheyi* and *Allium rubellum* is low but their potential for producing increased yields is high and has not yet been fully exploited. The

Table 2. Land under cultivation, yield (kg/hectare) and cost benefit analysis (Rs/hectare) of selected medicinal herbal spices under cultivation at high altitude villages of NDBR

Name of species	Area under cultivation (hectare)	% of total area cultivated	Yield (kg/hectare)	Monetary input (Rs/hectare)	Monetary output (Rs/hectare)	Net return (Rs/ hectare)	Monetary output/input ratio
Allium humile	6.97	51.74	584 ± 28	26,500 ± 998	303,680 ± 9019	277,180	11.45
Allium stracheyi	3.10	18.01	296 ± 15	25,100 ± 980	153,920 ± 8290	128,828	6.13
Allium rubellum	0.50	3.71	240 ± 13	22,312 ± 793	124,800 ± 7700	102,488	5.59
Angelica glauca	1.30	8.15	350 ± 23	20,696 ± 652	217,000 ± 13810	196,304	10.42
Pleurospermum angelicoides	1.60	9.87	577 ± 31	36,210 ± 812	357,740 ± 12006	331,530	9.87
Carum carvi	1.20	8.52	362 ± 12	22,050 ± 647	275,120 ± 10953	247,070	12.47

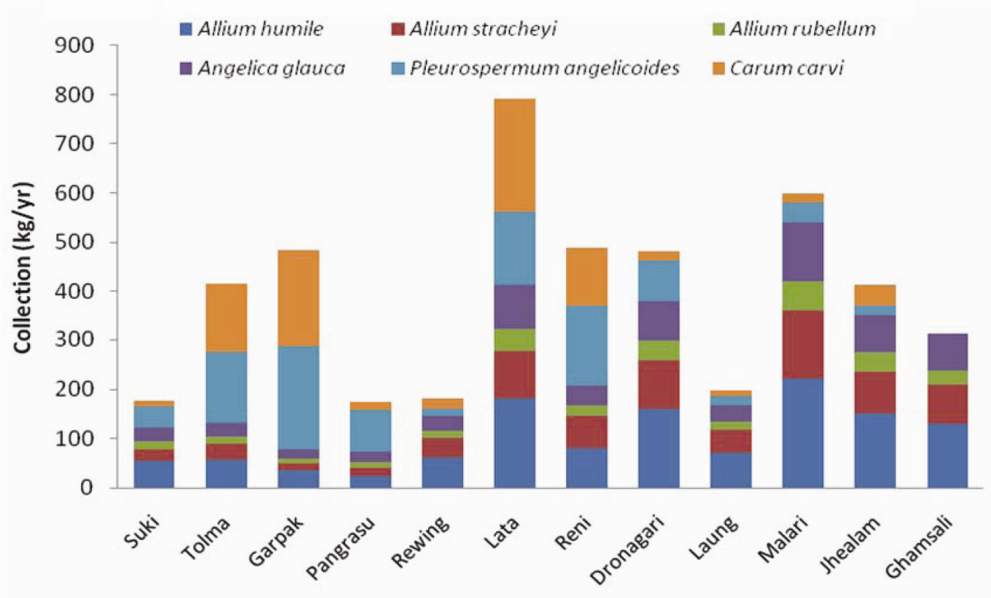

Figure 1. Wild collection (kg/year) of herbal medicinal spices by selected villages of NDBR.

medicinal plants such as *Allium humile*, *Angelica glauca* and *Pleurospermum angelicoides* are highly adapted to dry cold climatic conditions of high altitude, providing high yields from marginal lands. The monetary benefits from cultivation of these species are many-fold high as compared to traditional crops and other cash crops grown by the people of this region[7,11,16]. Medicinal plant collection from surrounding forest is common practice for forest dwellers in the region mostly by animal herders (locally called *anwals*) visiting the alpine grazing lands (Figure 1). Collection of herbal spices was calculated maximum (791 kg/year) for Lata village followed by Malari (600 kg/year), Reni (488 kg/year) and Garpak village (485 kg/year) respectively. *Allium humile* was found the most preferred herbal spice and collected in large (1220 kg/year) quantity by all families of selected villages. The total yield of *Allium humile* was found maximum (2537 ± 224 kg/ha) followed by *Pleurospermum angelicoides* (923 ± 57 kg/ha) and *Allium stracheyi* (917 ± 85 kg/ha) respectively, in studied villages. Local communities residing in the buffer zone villages of NDBR also collected herbal spices from nearby forest and estimated maximum (960 ± 63 kg/year) for *Allium humile* followed by *Pleurospermum angelicoides* (658 ± 36 kg/year) and *Allium stracheyi* (575 ± 19 kg/year) respectively (Table 3). The present monetary value of spice used and traded by rural people was estimated around Rs 11,398.62/family/year and it was estimated maximum (Rs 5,098.62/family/year) for *Allium humile* (Figure 2). Cost–benefit analysis was also carried out for value added products of selected species and found maximum (Rs 4,969,640 ± 82,904) for *Allium humile* followed by *Allium stracheyi* (Rs 1,439,780 ± 41,058) and *Carum carvi* (Rs 1,115,370 ± 26,554) respectively. Since most of the medicinal spices/condiments are consumed locally or sold in nearby rural markets, their actual contribution to the health and local nutrition to those are collecting and cultivating them is not fully accounted. Consumption and marketing of these medicinal spices in urban and semi-urban centres are comparatively low and hence the need to promote for health care and livelihood enhancement in the Himalayan regions.

Table 3. Biochemical composition of selected medicinal herbal spices under cultivation at high altitude villages of NDBR

	Allium humile	*Allium stracheyi*	*Allium rubellum*	*Angelica glauca*	*Pleurospermum angelicoides*
Carbohydrates (mg/g)	92.160	98.34	93.100	29.800	18.360
Proteins (mg/g)	151.354	187.11	167.311	106.340	102.690
Lipids (mg/g)	92.160	93.10	96.120	29.800	18.360
Vitamin C(mg/g)	141.950	156.5	153.43	66.890	65.470
Vitamin B2 (mcg/gm)	23.730	26.12	23.600	33.740	31.790
Vitamin E (mg/g)	46.210	61.10	52.190	38.730	12.450
Phosphorus (mg/g)	12.570	14.13	13.300	2.810	2.960
Potassium (meq/L)	0.324	0.34	0.336	0.272	0.312
Calcium (meq/L)	0.324	0.39	0.371	0.272	0.312
Magnesium (ppm)	0.050	0.09	0.070	0.510	0.230
Copper (ppb)	19.600	20.21	19.90	6.800	64.00
Iron (ppm)	0.170	0.25	0.220	0.880	0.640

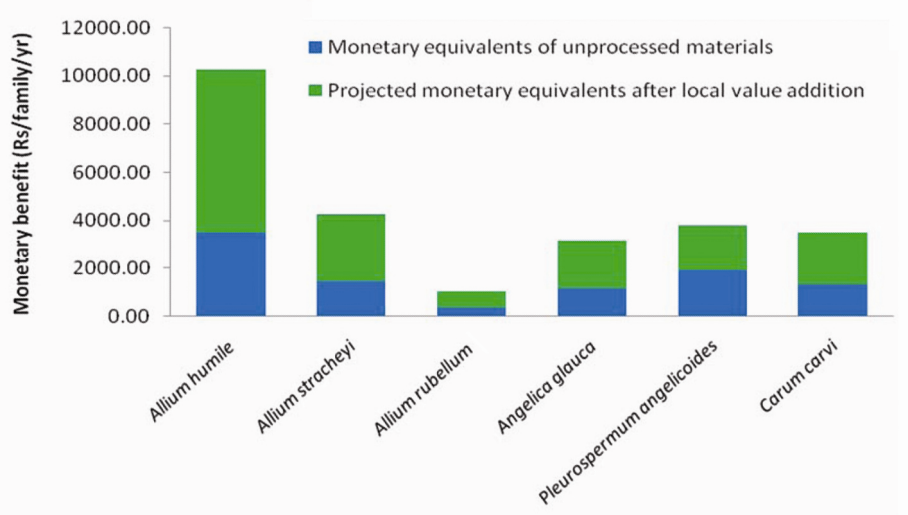

Figure 2. Comparative cost–benefit analysis per household on the basis of raw and processed herbal spices, NDBR.

Biochemical analysis and value addition

The selected species are unusual in the sense that every part of the plant can be used as a spice or cooked as a vegetable (Table 3). *Allium* species are a good source of carbohydrate, lipid, vitamins and proteins among selected species for study. With distinctive taste, flavour, odours and curative properties, these species have the potential to improve local economy if large scale cultivation, sustainable harvesting, value addition and marketing linkages are explored properly. The detailed cost–benefit analysis of MAPs used for spices/condiments in raw form and after local value addition in the form of powder is economically very high (Table 4). Value addition of medicinal herbal spices offers good income from this venture as compared to marketed spices. Once these value added products are marketed, it is hoped that the multipurpose value and exceptional flavour of traditional spices would generate higher demands in the near future necessitating farmers to cultivate them at larger scale which could lead to conservation of these species.

MAPs cultivation/conservation and local livelihood

Conservation of medicinal plants is receiving increased attention all over the globe due to their over-exploitation, population depletion, habitat loss and interest in traditional health care system[7,22,32]. The Uttarakhand government has been developing a policy to promote cultivation of some selected medicinal plant species that have high conservation value and economic potential through Herbal Research Development Institute (HRDI), Uttarakhand. And one of the important objectives of the policy is to promote the cultivation of threatened species that will reduce the pressure from the wild[33–35]. Although the implementation of the policy on MAPs cultivation and conservation has been promoted to a few people in this sector, it has not fully succeeded due to many factors such as absence of cultivation practices, post-harvest technique and proper marketing. It was observed that without having consulted the local stakeholders/farmers, a policy for the medicinal plant sector for Uttarakhand

Table 4. Total quantity (kg/year) of herbal spices and their comparative monetary equivalents (Rs/year) for selected villages of NDBR

Name of species	Quantity (kg)		Total quantity (kg)	Monetary equivalents (Rs) of unprocessed materials	Projected monetary (Rs) equivalents after local value addition
	From cultivation	From wild collection			
Allium humile	4070 ± 224	960 ± 63	5030 ± 216	2615600 ± 55560	4969640 ± 82904
Allium stracheyi	917 ± 85	575 ± 19	1492 ± 98	760920 ± 27500	1439780 ± 41058
Allium rubellum	120 ± 18	251 ± 9.3	371 ± 21	192920 ± 59418	346885 ± 13450
Angelica glauca	455 ± 40	513 ± 48	968 ± 140	600160 ± 15500	1026080 ± 18170
Pleurospermum angelicoides	923 ± 57	658 ± 36	1581 ± 109	980220 ± 29540	980220 ± 11420
Carum carvi	434 ± 24	484 ± 34	918 ± 87	697680 ± 24500	1115370 ± 26554

was framed. However, inputs and suggestions from all stakeholders actively involved in cultivation/wild collection are required for a better understanding of the problems and subsequent solutions on conservation strategies. Awareness through demonstration and capacity building training programme could enhance the skill of interested people in selecting the potential species for cultivation and conservation in the Himalayan region[7,11,36]. Over the last seventeen years (1996–2014), the G.B. Pant National Institute of Himalayan Environment and Sustainable Development, has been promoting medicinal plant cultivation/conservation and value addition in different parts of the Indian Himalayan region. In the case of Garhwal Unit of the Institute, a total of 752 farmers/stakeholders from various villages, line departments and NGOs were trained in more than 22 training programmes to promote MAP cultivation and conservation. Unemployment in the mountain region of Uttarakhand which is one of the acute problems[3,37] could be minimized to some extent through small scale entrepreneurship based on medicinal plants by involving unemployed young minds. However, the ecological status of the plants need to be assessed. Conservation of MAPs diversity can be achieved through *in situ* and *ex situ* conservation and cultivation practices that also reduce the anthropogenic pressure on wild habitat. Earlier studies[7,15,20] suggested that the cultivation of MAPs is economically more profitable compared to traditional crops which make this sector more demanding in high altitude areas with suitable environment and habitat. However, availability of planting material, agronomic practices, post-harvesting techniques and proper market channel that are important issues of MAPs cultivation need to be given attention before considering the venture for entrepreneurship development.

Conclusion

The bio-chemical analysis of wild herbal MAPs and cost–benefit analysis of their cultivation along with local value addition undoubtedly indicate a positive sign for entrepreneurship development and conservation through cultivation. Though there are some well established national brands of various spices in the country catering to the need of a sizable chunk of mainstream society, there is a fairly good scope of capitalizing on the uniqueness of the wild and traditional spices of Uttarakhand since they have huge medicinal properties, which unable them to find a place in modern kitchens in the country. And this is possible with marketing through well-established and highly growing brand/companies such as Patanjali, renowned for organic and medicinal value of their products. Local entrepreneurship could develop linkages with Patanjali for enhancing the quality of value added herbal spices and also for their proper marketing. Once marketed, it is hoped that the multipurpose value and exceptional flavour of traditional spices would generate greater demands in the near future necessitating farmers to cultivate them at larger scale and simultaneously favour their conservation.

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ACKNOWLEDGEMENTS. The authors are thankful to Dr P. P. Dhyani, G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Kosi-Katarmal, Almora for facilities and SEED-Department Science and Technology (DST), Govt. of India for partial financial support to conduct the study. We also thank Dr Kusum Payal and Dr Laxman Kandari for inputs and suggestions in the manuscript and providing baseline data on selected species. We also thank Shri Rudra Singh Butola for assisting in field based experimentation and activities.

Received 6 June 2015; revised accepted 11 April 2017

doi: 10.18520/cs/v113/i04/571-577