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Improved agricultural practices for high value medicinal plant under mid to high altitude situation

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One of the most critical issues on the national and global agenda is the need to preserve endangered high value medicinal plant for future generations while trying to understand and document the indigenous knowledge of resource management practices (Chakraborty, 2009). Traditional medicines, particularly herbal medicines, have been increasingly used worldwide during the last two decades. Man through his keen observation and experimentation in the past identified plants having healing properties and thus developed traditional knowledge base contributing to our rich heritage (Mukherjee, 2008). As the collection of most of the medicinal plants is from the wild, in 70% of the cases the collection or harvesting is destructive in nature as either the whole plant (*Swertia chirayita*) or parts such as root (eg. Safed musli), bark (*Taxus baccata*) yields the active principle, which amounts to killing of the plant. Similarly perennial Himalayan herbs *Nardostachys grandiflora* (jatamansi) and *Picrorhiza kurrooa* (kutki) are declining in their populations in the wild due to over-harvesting (IUCN, 2008). These are valued for their aromatic and medicinal properties. A good agricultural practice in the context of medicinal plants is a cultivation programme designed to ensure optimal yield in terms of both quality and quantity of any crop intended for health purposes. There is a need to create awareness regarding the importance of medicinal plants as an important resource, which contributes both to our primary health care needs and to our exports as well. The need of the hour is to come up with a policy framework that ensures in-situ and ex-situ conservation of medicinal plants, development of agro-techniques, and most of all sustainable use and harvesting of medicinal plants through good cultivation practices (Mukherjee *et al*., 2009). The problem of the medicinal plant as a depleting resource can be a blessing in disguise as the danger of their extinction may provide an impetus to their formal harvesting and this could, in turn, lead to enhance rural well being and local economy (Mukherjee and Chakraborty, 2008). A substantial percentage of rural population is directly or indirectly associated with the medicinal plant based industry. It is a difficult task to train farmers and other relevant persons as producers, handlers and processors of medicinal plant materials. While pharmaceutical and other companies are striving to meet the requirements for the quality control of herbal medicines, they cannot force farmers, producers, handlers and processors to follow good agricultural and collection practices for medicinal plants. The training of farmers and other relevant persons is therefore one of many important measures to be taken to ensure that good agricultural and collection practices are adopted in order that medicinal plant materials of high quality are obtained. Quality control directly impacts the safety and efficacy of herbal medicinal products. Keeping the above aspect in mind the present investigation was conducted to know the diminishing population of endangered plant species along with good agricultural practices to conserve them as natural resources as well as in farmer's field.

Present experiment was conducted during the year of 2009-11 at Regional Research Station (Hill Zone) under the aegis of Uttar Banga Krishi Viswavidyalay, Kalimpong to know the population of endangered plant species at high altitude and good management practices of conservation of these medicinal plants in Darjeeling- Sikkim Himalaya. For study purposes vigorously surveyed various part of north eastern Himalaya and try to know what the farmers were practicing and how this ultimately depletes valuable resources. Further, owing to the difficult terrain and sporadic distribution of some targeted species in Darjeeling hill, an alternative sampling method considering the size of the habitats was adopted to know about the population of threatened species in high altitude range. A belt transect of 100 m × 20 m with three 20 m × 20 m plots at equidistance within the transect have been adopted to sufficiently cover the habitat. Fifteen 1 m × 1 m quadrates in each plot, (eight quadrates in the periphery and seven within in a random fashion) have been adopted for studying density of few medicinal plants. Depending upon the size of the habitat the number of transects to be laid in each site will be decided in the field.

Short Communication
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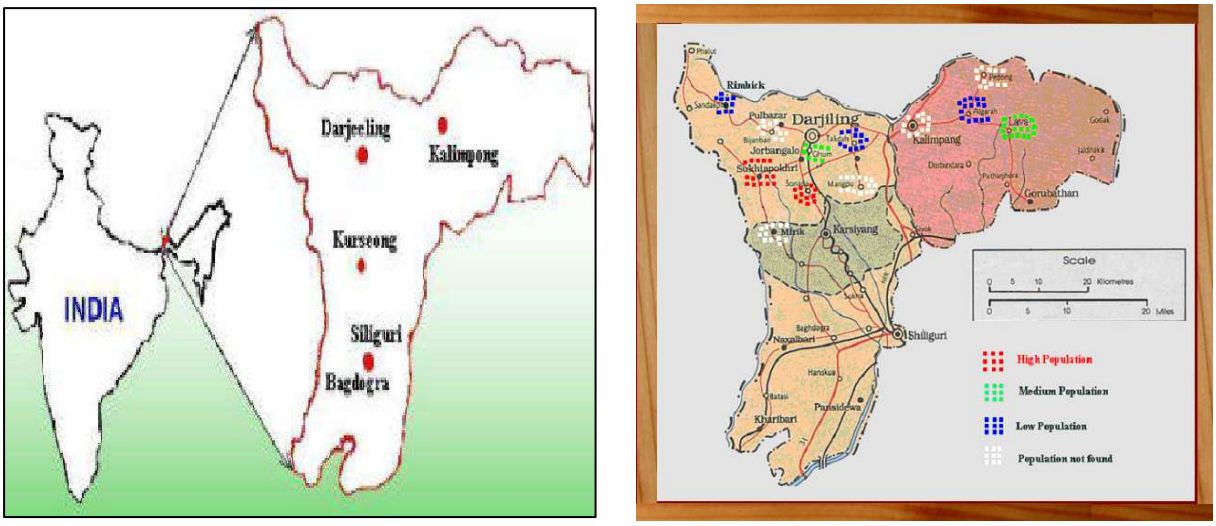

Fig. 1: Map of the study area

For documentation of GAP (Good agricultural practice) for high value medicinal plants, interviews were conducted with the local inhabitants, selected information, the herbalist hakims (local vaidyas and physician of eastern system of medicine), medicinal plant seller in the local markets. Further we adopted questioning method during the survey in order to get qualitative and participatory approach about the plant resources and their medicinal utilization by the local people and also study the soil status of the region (Table 1). During a series of plant explorations (2007–2011) in Dajeeling Himalaya (Fig. I), the high value targeted taxa were *Aconitum heterophyllum, Angelica glauca, Dioscorea deltoidea, Dactylorhiza hatagirea, Hedychium spicatum, Heracleum candicans, Picrorhiza kurrooa, Podophyllum hexandrum, Saussurea costus, Swertia chirayita* and *Valeriana jatamansi*.

Table 1: Physico-chemical status of soil sample of high altitude range of Darjeelig hill

Location	pH	ECE (inch cm^{-1})	Available (kg ha^{-1})			Total N (%)	Organic C (%)	Organic matter (%)	C/N ratio
			N	P_2O_5	K_2O				
Lava (2000 m msl)	5.2	0.11	278	23.8	239	12.46	0.87	5.64	16.98
Phalut (2450 m msl)	5.1	0.21	379	26.7	319	14.28	0.51	5.40	14.35

Scientific assessment on species adaptability to agro-climatic zones, growth potential, agronomic yield, and economics of cultivation, specially, suggested *Aconitum heterophyllum, Picrorhiza kurrooa,Coptis teeta, Saussurea costus, Swertia chirayita* and *Valiraina jatamansi* as highly promising taxa both in terms of providing economic benefits to farmers as well as substantial quality raw material. Mass seed production of *Aconitum, Swertia, Saussurea* and *Valeiana* offers high hopes for expansion of their conservation program. During the series of observation and day to day visit various part of Darjeeling district and North Sikkim region, I found that farmer mostly don't know how to handle the valuable plant resources. Further, experiment done by ourselves in our research field at Kalimpong we developed certain good agricultural practices for high altitude medicinal plant particularly in respect of *Swertia chirayita*, *Valiraina jatamansi* etc.

Table 2: Status of endangered medicinal plant at Phalut region of Darjeelng (2300 m msl)

Sl. No.	Medicinal plant	Population density (Individual / sq.m)
1	*Nardostachys grandiflora*	1.64
2	*Gentiana kurro*	1.33
3	*Podophylum hexandrum*	0.46
4	*Picrorhiza kurrooa*	1.02
5	*Swertia chirayita*	14.03
6	*Gloriosa superba*	1.19
7	*Abution indicum*	0.86

Our study revealed (Table 2) that population of endangered medicinal plant was only few and this is less than 2 % with respect of *Nardostachys*

grandiflora, Podophylum hexandrum, Gentiana kurro, Picrorhiza kurrooa, Gloriosa superb and *Abution indicum.* However, population of *Swertia chirayita* is just 14.03 % of the sampling zone. Our work at Kalimpong, revealed that if one can follow improved agricultural practices they can easily conserve high value medicinal plant (Table 2). These are as follows:

Prevention of contamination: During cultivation there are many different risks that can cause the plants to become contaminated. For example, if the soil or irrigation water is contaminated with pesticides and industrial waste this can easily be absorbed by the plant, or if the harvested plants are placed in dirty containers there are high chances that they will become contaminated. Many buyers now insist on testing the medicinal plant material and if traces of pesticide residue, heavy metals, or excessive levels of bacteria or fungi are found then the produce may be rejected.

Optimisation of active ingredients: Maximising the medicinal properties of the relevant plant parts should always be a priority during cultivation. The location of the cultivation site, the variety of the species used, the irrigation cycles, the harvest time are some of the factors that may influence the potency of the active ingredients. These should all be researched and planned to ensure that the medicinal plant material contains the highest level of active ingredients possible. To maximise the potency of medicinal plants collected from the wild there are three main factors to take into consideration: the collection site, the collection time and the maturity of the plant. Factors such as altitude, soil type, and climate can have a significant effect on the active ingredients of the plants.

Best yield and income: Good Agricultural Practices also explore how to optimise the yield of the crop, and therefore the income for the farmer. For example, the quality of the seed, the spacing between the plants and the rows, plant nutrition, weed management, insect pest and disease management, irrigation methods and the harvest stage and time all have a significant impact on the yield, as well as the quality of the crop. The roots and rhizomes of *P. kurrooa* contain 26-27% Picrorhizin in addition to other active constituents such as kutkoside (Airi, 2000). Picrorhizin is a major constituent of many important liver and stomach medicines. Besides, it is also used in drugs prescribed for treatment of respiratory diseases and allergic manifestations. Traditionally the plant was collected during August – September, however, in order to maximize economic gains, now the collection starts in month of July itself. The entire plant is uprooted and material is cleared of adhering rootlets and dried in sun for a week. It is largely collected from Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Sikkim.

Documentation and traceability: Keep records at each stage of production. Record keeping is a major issue so that one can know about the history of the plant origin and its proper management, which will be help for future conservation of endangered plant along with full value of active ingredient. Use 'harvest tags' to record details of each harvest and the plant materials subsequent processing activities. Documentation should begin with the name of the species, details of where the seeds or planting material came from and the date of collection. Seed packets should always be well labelled the sowing date should be recorded in the farmer's diary. At this stage it is good to allocate the crop with a unique 'crop number', which can be referred to throughout the documentation process. All activities on the farm, including application of compost and any other inputs, weeding and irrigation should be recorded in the farmer's diary.

Table 3: GAP is needed for following endangered plant species of different state

State	Species being promoted for GAP
Arunachal Pradesh	*Aconitum heterophyllum, Coptis teeta, Picrorhiza kurrooa, Rauvolfia serpentine, Taxus wallichiana*
Himachal Pradesh	*Aconitum heterophyllum, Acorus calamus, Angelica glauca, Berberis aristata, Nardostrachys jatamansi, Picorhiza kurroor*
Meghalaya	*Cinchona ledgeriana, Rauvolfia serpentine, Solanum khasianum, Swertia chirata, Taxus wallichiana*
Uttaranchal	*Aconitum heterophyllum, Coptis teeta, Dactylorhiza hatagirea, Nardostrachys jatamansi, Picrorhiza kurrooa, Podophyllum hexandrum, Raulfia serpentia, Saussurea costus, Swartia chirata,Taxus wallichiana*
West Bengal	*Valeriana jatamansi, Piper longum, Gloriosa Superba, Podophyllum hexandrium, Swartia chirayita, Taxus wallichiana*

Experiment result revealed that before start of conservation of high value medicinal plant in high altitude range following aspect should always kept in mind to the grower as well as conservators:

Site selection

Grow only those medicinal plants which are recommended for cultivation in that area. Choose land that has access to a clean and reliable source of irrigation water. Make sure there is sufficient space between your fields and other fields where pesticides are used to prevent any sprays from contaminating your crops. Do not grow medicinal plants near potential sources of contamination such as industrial sites or busy roads.

Land preparation

Nourish the soil with plenty of organic matter. Prepare the land according to the specific needs of the medicinal plant species, If possible, send a soil sample to a nearby laboratory for testing and plan any addition of plant nutrients accordingly. Do not use compost made from city waste or from human excreta or any fresh manure for plant nutrition.

Sowing / Planting

Use seeds that were harvested during the previous season and free of pests. Procure seeds or planting material from reliable sources. Sow seeds or transplant seedlings at the correct time. Our observation revealed that in Darjeeeling Himalaya sowing of *Swertia chirayita* seed in the month of April at low altitude level (1250 m asl) and at high altitude (>1800 m asl) sowing at June month gave maximum germination percentage (Mukherjee, 2008 a). Where required, treat the seeds before sowing, preferably through organic means. In an 'intercrop', select compatible species which do not compete with main crop for inputs. In *Aconitum heterophyllum* seeds, tuber segments or young leafy stems can be used as propagules. The fruits (capsules) that turn light brown (before splitting) are collected during late October to mid-November for better germination of seeds. The seeds should preferably be collected during morning hours.

Irrigation

Apply a mulch to conserve soil moisture, If possible, test the irrigation water for any contaminants and adopt appropriate measures to prevent contamination. Irrigate medicinal plants according to the specific water requirements of the species. In *Aconitum heterophyllum*, *Swertia chirayita* and *Valeriana jatamansi*, planted beds need irrigation during early summer (Mukherjee, 2008 a). The retention of soil moisture is necessary to decrease seedling mortality. Irrigation requirement depends on the texture and porosity of the soil. In dry season, irrigation at least once in a week is necessary to retain soil moisture. However, water logging results in withering of plants at lower altitudes. Hence, well-drained beds are recommended for cultivation of the crop.

Weeding

Manage weeds before they start competing with the main crop for nutrients and light. Initial flush of weeds must be controlled effectively so as to ensure a weed free environment to young plants. The weeding and hoeing cycles should be so arranged as to keep the field free from weeds. The prescribed schedule of all inter-cultural operations such as weeding, hoeing, topping, nipping of buds, pruning, shading and earthing up etc., must be adhered to in a manner to optimize the overall productivity. Use of herbicides should be avoided as far as possible. In case of their inevitable usage, available evidence of safety to the target crop should be considered adequately. Use mulch to maintain moisture in the soil and to inhibit growth of weeds.

Insect pests and diseases

In general crop protection plans should be limited to the use of bio-control agents and bio-pesticides. Under compulsive circumstances care should be taken to use smallest effective dosage of pesticides on the basis of crop protection protocols prescribed for the target species. When chemical pesticides are used for crop protection, residue analysis should be carried out through appropriate testing agencies following standard procedures. Select medicinal plant species that are resistant to local insect pests and diseases. Maximise resistance against insect pests and diseases through adjusting sowing time, appropriate seed treatment, balanced plant nutrition and timely irrigation. Use organic practices such as use of companion crops, trap crops, light-traps, crop rotation etc. Identify and promote multiplication of predatory insects and birds. Try to solve the problem with an organic pesticide, either made from locally available resources or buy a product from a reputed manufacturer or institution. Use chemical pesticides only if there are no other options, and only if there is sufficient time between application and harvest to guarantee that the chemical cannot be detected in the medicinal plant material.

Harvest

The harvesting season should be determined and followed on the basis of qualitative parameters set for the end product of the constituents rather than the total vegetative yield. Harvest at the right stage to ensure maximum levels of active ingredients. Keep sacks of freshly harvested green leafy herbs in the shade to prevent degradation caused by build up of heat, do not harvest weeds with the medicinal plants. Care should be taken that harvested plant parts should

not touch the ground. Harvesting of *Swertia chirayita*, *Podophyllum hexandruium* should be in dry period avoid harvesting when it is raining, or early in the morning when there is due on the ground. Keep green leafy herbs in the shade to prevent them from wilting after harvest. When in doubt of regeneration, do not collect more than 70% of any plant population. *A. heterophyllum* tubers harvested in May–June contain lower quantity of atisine (0.35%) as compared to those harvested in November and December (0.43%), which also contain traces of aconitine. The tubers harvested in May, however, show higher quantity of aconitine and hypoaconitine as compared to those harvested in other seasons (Taghizadeh *et al*., 2004).

Harvesting plant parts

The extraction of some plant parts has a bigger impact than others, i.e. taking roots are typically more damaging than taking seeds or flowers. It may affect the whole life cycle of the individual plants and produce a number of ecological impacts. For instance, persistent harvesting of the root of a single stemmed, sparsely distributed plant may threaten the survival of the species. The inappropriate harvesting methods of the tubers and bulbs of *Onosma hookeri* Clarke, *Aconitum violaceum* Jacq, *Fritillaria delavayi* Franchet and *Dactylorhiza hatagirea* D.Don or the uprooting of *Meconopsis simplicifolia* (D.Don) Walpers and *Meconopsis horridula* Hook.f. & Thomson in order to collect the aerial parts, obviously removes the whole individual and has a detrimental effect on sustainability. The uprooting of deep-rooted species such as *Valeriana jatamansi*, *Citronella*, *Lemon grass* in a fragile ecosystem would result in soil impoverishment by erosion and deprive the plants from their required nutrients. This corroborate with the finding of Mukherjee (2009). Similarly, the uncontrolled harvest of seed leads to decreases in seedling establishment. The over-harvesting of flowers may result in fluctuations of species availability in the following years. The debarking of the plants may result into slow death of the whole plant. *P. kurrooa* being in steady demand has very high harvesting pressure. It is reported that a total of 286 plants as shoot part and 500 as root parts are harvested to make a kilogram weight of *P. kurrooa* (Rai *et al.*, 2000). Hence collection from wild should be done on a rotational basis which will help in the recuperation of the area and a sustainable harvest. It has also been reported that plants in the alpine areas complete their reproductive phase during the months of September and October. Hence harvesting should be done during the month of October when active constituents have the highest proportion (Nautiyal & Nautiyal 2004). This knowledge should also be spread amongst the collectors so that harvest is done after seed set.

Post harvest processing

Post harvest processing is usually the most critical stage in determining the end quality of the medicinal plant material. Once the plants have been harvested there are many potential risks; they are likely to be handled by many different people, placed on different surfaces, transported on polluted roads or stored for days or weeks in people's houses, all of which involve considerable chances of contamination, degradation and/or damage. The best way to prevent this from happening is to anticipate all the potential risks and take preventative measures before any problems occur. If problems are not prevented before they occur then it can.

Primary processing

Washing and cleaning methods for freshly harvested materials should be laid down in consideration of the target plant part. The procedure for this purpose should ensure removal of soil particles adhering to the materials. Freshly harvested materials should not be stored as such and the drying process should be initiated in a continuum. Where necessary, the length of such storage should be minimized and handled in a manner to prevent degradation or rotting. Processing yards or sites should be clean, well ventilated, and have the facilities for protection against sunlight, dust, rain, rodents, insects and livestock. The drying procedure and the temperature employed for this purpose should be in conformity with the quality needs of the farm produce. In case the agronomic package prescribes specific procedures for this phase, compliance to the same should be ensured. In high humidity conditions, it may be necessary to dry the produce appropriately.

Packaging, storage and transportation

The selection of packaging material should be based on the quality requirements and possible length of storage before consumption. Essential product description such as the product name, plant part, month and year of harvest and the name of farmer/farming agency must be legibly inscribed on every pack. If the material was tested before, an appropriate label may be used indicating quality approval. The storage area should be a dry place protected from insects and rodents and such other factors that may be detrimental to the quality of the product. Organic herbs must be stored separately from the non-organic products. When multiple commodities are handled in the same storage area, care must be taken to prevent product mix up and cross contamination. Plant materials having strong aromatic compounds should be kept at a reasonably good distance from others.

Table 4: Improved agricultural practices for high value medicinal plants

Sl. No.	Parameters	Requirements
1.	The environment of the cultivation area	The detail request for the ecological environment such as air, water, and soil conditions in the cultivation area
2.	The germplasm and breeding material	The plant or animal species should be identified correctly and the quality of the germplasm resource should be controlled.
3.	The management of cultivation	The cultivation process, such as how to use fertilizer, soil, water and how to control the insect pest and plant diseases, should be controlled by SOP (standard operating procedure) principles.
4.	The harvest and process at the harvest place	The optimal harvest time should be studied and fixed. The specific request for process, drying conditions.
5.	Package, transport and storage	It should be clearly recorded for each batch of the drug materials. The request for the transport, such as using clean container, for the storage, such as light, temperature, and humidity.
6.	Quality control	The specific request for quality control, such as the items to be checked, the request for the characteristic, foreign matter, water, and ash content, is clearly require.
7.	The equipment and operator	Trained operators, the request about the product and process place, and equipment.
8.	The document management	It should be recorded in every detail and particular for the whole process of cultivation, process, transport and storage, etc. The document should be kept properly at least five years.

It can be thus concluded that the study area having rich flora and fauna, is in urgent need of conservation with good agricultural practices. Some rare and endangered species of plants are still found abundantly in the region, but without protection, these may, in the near future, become endangered. The present study has shown that the area warrants a detail of good agricultural practices of in view of high value medicinal plant and conservation of the threatened plants. Besides these, population of endangered plant species and studies on the conservation of medicinal plants through improved agronomic manipulation has immense potential for researchers. Further, such studies not only benefit the scientific community but also the region and the tribal community as well.

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