CHAPTER 14

Conservation Plan for Swertia chirayita

14.1 Introduction

There has been global concern about the decreasing populations, loss of genetic diversity, local extinction of the important medicinal plants, etc (Badola and Aitken, 2003, 2010; Canter *et al.*, 2005). There are several reasons associated with the problems viz., unsustainable harvesting, habitat degradation, overgrazing, pathogens, herbivores, etc. In order to conserve the threatened medicinal plants, there is a need for both *in-situ* and *ex-situ* actions, such as, habitat conservation, community participation in framing policies and programmes, information on trade, development of sustainable harvesting techniques, trainings to the harvesters, development and standardization of propagation and cultivation technologies, etc, addressing targeted taxa.

The importance of *Swertia chirayita* is globally acknowledged; however, no efforts have been undertaken to replenish its source due to which the species has become critically endangered (IUCN), endangered (Indian Red Data Book), critically rare and virtually endemic to Himalaya (Samant *et al.*, 1998), and vulnerable to Sikkim (Ved *et al.*, 2003a). At this juncture, if no serious conservation initiatives are taken, the species would become extinct from many parts of Himalayan region. Therefore, on the basis of the present study, following conservation plans have been framed out for *Swertia chirayita*, which should be applicable not only in Sikkim but in the wider areas in Himalaya.

14.2 Habitat Conservation

Habitat destruction, degradation and fragmentation are the driving forces behind decline in species and biodiversity. Several anthropogenic activities can have significant negative impacts on the habitats such as clearing of forests for agriculture or township or industries, construction of roads, etc. Apart from these, the natural disturbances such as landslides, forest fires, etc., also cause habitat degradation or fragmentation. Similar problem of habitat destruction or modification have been observed threatening the existence of *Swertia chirayita* in Sikkim. Therefore, the first step in the species conservation is the conservation management of its habitat, taking micro-habitat niches as important clues. The availability of *S. chirayita* near to the human habitation or in areas where human interference existed or in open areas created due to other reasons indicates adaptability of species to minor disturbances and its habitat preferences. It was further noticed that due to the absence of human intervention in the forest areas in Sikkim, several shrub species have taken over the forest gaps and open spaces or abandoned areas resulting habitat modifications and the fragmentary distribution of the species. Therefore, the modification in government policy is required thus allowing minor and controlled human intervention under constant monitoring in the forest areas. This will help check the encroaching shrub and other unpalatable and or invasive species causing threat to the existence of *S. chirayita*. Local communities can be mobilized and imparted with responsibility to conserve the habitats of *S. chirayita* in their surroundings. They are directly associated with the nature, so their traditional knowledge and skills can be used for the preservation of the habitats.

14.3 Conservation through legalization of the wild harvesting

S. chirayita has three year life cycle. After dispersal of the seeds in the nature in third year, the plant material can be collected instead of wasting the resources, which can be an important source of income for the rural people of the mountains. Therefore, collection of *S. chirayita* can be legalized through licensing to specific number of people under defined rules and constant monitoring by the area guards of the related department, which will also help in preserving its habitats through human movement at the same time; however, only the mature plants after seed shedding should be allowed to collect which can commence from December end. Depending upon the projection of seed setting, the area managers of the government should declare the starting dates for collection and ensure that the plant materials are not collected before the seed dispersal. Further, the late collection after January should not be allowed in order to avoid damage to the new seedlings.

Strict regulations should be framed out where it should be clearly mentioned regarding the punishment such as seizure of the license, fines, etc., if the harvester goes out of their way. Additionally, the guidelines prohibiting the direct sale or purchase of the plant material should be framed. To avoid such actions, there have to be a dumping centre for the collected material from where the companies can directly purchase the material under the guidance of concern land department. This will keep check on the collection of the immature plants as well as the middle man. The harvesters should provide information on volume of plant material they collected. This will help in designing proper management plans if the harvesting records reveal decline in volume of collected plant material. Further, the sustainable and careful harvesting method should be standardized as well as the harvesters should be trained, to prevent damage to the immature plants and change to the microclimate of the area. Conservation agencies should undertake occasional surveys in the areas where the plants are being planned for harvested or during harvesting. Local communities should be involved in designing and planning of the harvesting techniques under scientific guidance from local research organizations. In each of the village or communities, stakeholder such as village panchayat or NGO should be involved in training the harvesters; their involvement enhances people's participation.

14.4 Conservation through re-introduction

Several factors, such as, washing away of seeds or percolation of seeds to deep under ground due to heavy rain, decay of seeds due to fungal attack, seed predation, etc., affects seedling emergence resulting in low availability of *S. chirayita* in its natural habitats. In addition, untimely harvesting also leads to low availability of *S. chirayita* in its natural habitats. In any of the situation, the seedlings can be developed in the nursery, near to the population site, from the seeds collected from the nature (from the similar populations), which can be transplanted back to the nature in areas experiencing diminishing populations; however, population has to be considered while transplanting, for preservation of its genetic diversity and genetic erosion. Only trained personal and qualified staffs should be permitted to collect seeds for propagation purpose; the scientific guidance and advisories of related organizations/individuals would be beneficial.

14.5 Conservation through *ex-situ* cultivation

Ex-situ cultivation of targeted high value medicinal plants is the only means by which the increasing demand of the pharmaceuticals can be meet out and the motives of *in-situ* conservation of the species can be achieved. Further, the local entrepreneurs can generate substantial income and empowerment through *ex-situ* cultivation of *S. chirayita*. Local entrepreneurs can gain 10-15 times more profit from cultivation compared to collection from the wild if proper scientific and technical guidelines are followed, as developed in the present study. There are many other advantages of cultivation over wild harvesting. Nevertheless, economic feasibility is one of the main issues for deciding to undertake cultivation of the medicinal plants (Badola and Pal, 2002; Schippmann *et al.*, 2002, Badola and Butola, 2005; Badola, 2009). In this context, it is essential to generate awareness amongst the stakeholders, basically farmers, or the entrepreneurs from time to time regarding the market potential and market related issues of *S. chirayita* to increase their involvement in its cultivation. In addition, the government should assure market and better price for their quality material, and assistance in technical and infrastructural development, provision for the purchase of their materials, etc.

14.6 *Circa-situ* conservation

Circa-situ (Hawkes *et al.*, 2001) conservation falls between *in-situ* and *ex-situ* conservation mechanisms. This includes the deliberate encouragement and the retention of *S. chirayita* in and around the agricultural field or the home gardens during the land clearing or weed removal process for agricultural purpose or the gardening purposes. Such type of conservation practices can also be encouraged along or near to the road side, where *S. chirayita* was found to be growing well in the present study, during road cleaning or clearing process.

14.7 Conservation through seed bank development

Seed banks are the best form of *ex-situ* conservation of plants. However, at present, it is considered only for the agricultural crops. The important medicinal plants like *S. chirayita* can be stored in seed banks for re-introducing the species back to the natural habitats in future when the species faces extinction risk or becomes endangered. Conventional storage of *S. chirayita* at 4^0C has been proved beneficial at least for over 24 months under present study; this should be taken as a clue to strengthen big gene bank programmes in the state. However, the preservation of the species in the seed bank and re-introduction of the species to its natural habitat is of very limited use unless the factors that cause the threat of endangerment or extinction are eliminated largely.

14.8 Conservation through communication and co-operation

Public support is vital in the conservation of the threatened medicinal plants. Prior to the initiation or implementation of the conservation efforts, confidence building between the government agencies and local stakeholders is a must, which can be done by establishing a communication strategy and through information and education programmes. Also, the community participation is an important ingredient in *in-situ* conservation of the threatened medicinal plants because it is not easier for the government officials or the associated agencies alone to keep track on the compliance of the rules and regulations by the harvesters.

The present study in totality offers essential clues and guidelines, both scientific and practical to ground level, for effective and feasible scientific based conservation and management efforts of the targeted species, *Swertia chirayita*, in particular and broadly to other threatened plant species in Himalaya and other mountainous regions of the world.

Summary

1. *Swertia chirayita* (Roxb. ex Fleming) H. Karst (family Gentianaceae) is a high value critically endangered and internationally prioritized medicinal herb for immediate conservation in Himalaya. Presnet study explored and assessed different populations of *S. chirayita* to identify potential gene stock for their variability amongst them and for habitats, and community associations, and to strengthen both *in-situ* and *ex-situ* conservation mechanisms in Sikkim using conventional approaches. Further, the study sets up a strong ground offering practically feasible recommendations and provides possible guidelines for an effective conservation and management plan for the species.

2. Quantum availability, community association and threat status of *S. chirayita* were investigated by exploring 22 natural populations in Sikkim Himalaya, India. Eleven major communities for *S. chirayita* were identified; however in 5 populations, *S. chirayita* formed pure community with smaller share of other associates. *S. chirayita* density ranged between 1.63 $\pm$ 0.69 ind/m^2 and 21.67 $\pm$ 8.62 ind/m^2, whereas, the relative density emerged high (8.27% to 78.38%) compared to overall population density in majority of the cases.

3. Of total, 13 populations showed 100% frequency of occurrence. On the basis of abundance to frequency ratio, *S. chirayita* exhibited contagious/clustered distribution in majority of the populations except two, which had random distribution. Study identified 14 microhabitats for *S. chirayita*, suggesting greater species pliability towards different microhabitat niches. The open grassy slope appeared as the most favourable microhabitat for *S. chirayita*, and marshy grassy slope as least suitable.

4. One way multivariate analysis of variance (MANOVA) revealed a significant ($p<0.0001$) variation in the recorded morphological characters including total plant dry biomass amongst populations in both rosette and reproductive forms in *S. chirayita*. In rosette form, of the six morphological character recorded, most

variations were observed in the root length with coefficient of variation ranging from 14.23% to 69.58% followed by root diameter (4.66% to 48.06%). In reproductive form, of the nine morphological characters identified, the number of branches recorded the highest coefficient of variation value ranging from 0% to 84.16% followed by number of leaves (8.59% to 83.65%) and root diameter (4.78% to 55.79%).

5. The result of canonical discriminant analysis (CDA) indicated leaf length; root length and collar diameter as the main discriminating characters and responsible for the total variation amongst the populations in rosette form of *S. chirayita*; whereas the plant height, number of leaves, leaf width and stem basal diameter were mainly responsible for the total variations amongst the populations in reproductive form, cumulatively accounting to 83.6% variation.

6. The germinability in seeds of *S. chirayita* collected from six microhabitats was determined at constant temperatures of 20^0C, 25^0C and 30^0C under both 14/10 hours light/dark photoperiod and continuous darkness. Germination was negligible in continuous darkness under all the three temperature regimes. Two way ANOVA indicated significant effects of microhabitats and temperatures on percent seed germination, germination rate, germination recovery percent and germination recovery rate.

7. In general, seed sourced from under canopy micro-habitats showed significantly ($p<0.05$) higher germination over open habitats when directly incubated in 14/10 hours light/dark photoperiod at 20^0C, 25^0C and 30^0C. When transferred after incubating for 45 days in completely dark to 14/10 hrs light/dark photoperiod, seeds from under canopy recorded significantly ($p<0.05$) highest seed germination recovery at 20^0C and 25^0C than other microhabitats (tree base, stump base, shrubberies, grassy slope) except boulder where the value was non-significant in both the temperatures. Seed germination percent, seed germination recovery percent, mean germination rate and germination recovery rate was significantly

($p<0.05$) greater at 25^{0}C than 20^{0}C and 30^{0}C comparatively. Amongst microhabitats, the variation in germination recovery rate was significant ($p<0.05$).

8. Multivariate ANOVA revealed significant variation in mean germination percentage and mean germination time in *S. chirayita* amongst populations, increasing storage period and their interaction. During initial testing, 100% seed germination was recorded in majority of the populations. The duration of storage had significant effect on seed germination; nevertheless, there was not much variation in seed germination percentage between initial and the 6 months storage in populations. The highest mean germination time (MGT) was recorded during initial test ($p<0.0001$) which ranged from 15.17 days (Sc3) to 59 days (Sc10) and six month storage recorded significantly ($p<0.0001$) lowest mean germination time.

9. The effect of two substrate combination (substrate 1: garden soil, sand, forest humus; substrate 2: garden soil, sand, farm yard manure; 1:1:1) and control (sand and garden soil; 3:1) on seedling emergence, growth, biomass and vigour were tested with the seeds from 13 wild populations in Sikkim. Seedling emergence was significantly higher in substrate 2 ($p<0.05$) over others. Substrate 2 significantly ($p<0.05$) improved all the seedling growth parameters except number of leaves. Of 13 populations, seven (Sc1, 2, 3, 8, 9, 11, and 13) exhibited higher seedling biomass and SVI using substrate 2.

10. Effect of different storage conditions (room temperature, 4^{0}C, and -15^{0}C) and different storage periods over 24 months on seed germination in *Swertia chirayita* collected from different altitudes was determined. Multivariate ANOVA revealed significant ($p<0.0001$) effect of storage condition and storage period on seed germination and mean germination time. Seed germination percentage significantly ($p<0.01$) varied between 87.78% (Sc5) to 100% (Sc2) during initial testing. Comparatively, high seed germination, low mean germination time and low rate of fall in seed germination percentage in seeds stored at 4^{0}C over different storage period were recorded.

11. Periodical phenology, growth and development in *Swertia chirayita*, an endangered high value medicinal Himalayan herb, were observed for 22 months under six growing conditions, viz., four natural (shrubberies, forest slope, open slope, tree canopy) and two nursery (temperature controlled green house and open net-shade), following the transplantation of green house produced eight month old seedlings. The green house helped in early commencement of floral bud initiation, bud sprouting, and flowering, whereas, the senescence begun quite late, comparatively. Robust plants were produced under green house and open net-shade. Study recorded the single shoot development in plants grown under all natural habitats. However, in open net-shade and green house, plants produced multiple shoots, resulting in significantly ($p<0.001$) higher total plant biomass. Under open net-shade the plant height significantly correlated with the temperature ($r = 0.703$; $p<0.05$).

12. The seeds procured from 6 *ex-situ* set ups, shrubberies, forest-slope, open-slope, tree-canopy; and green-house and net-shade, showing poor germination at initial testing (12% to 31%) were subjected to 11 pre-sowing chemical treatments. Among the pre-sowing treatments, gibberellic acid (50 to 350 μM) most effectively stimulated seed germination (96.7%, maximum; $p<0.001$) and reduced mean germination time ($p<0.05$), followed by potassium nitrate (100mM) and sodium hypochlorite (5 minutes) ($p<0.001$). Study confirms *ex-situ* produced seeds attained physiological dormancy, which was broken by pre-sowing treatments, as a tool to *ex-situ* species conservation.

13. The effects of identified pre-sowing chemical treatments on seedling emergence and vigour using seeds from *ex-situ* raised plants under natural conditions (4 sources) and nursery conditions (2 sources) were tested. Seedling emergence was promoted from 6% (control) to 69% (GA_3 250μM). Seedling emergence rate was faster in GA_3 (250μM) followed by $NaHClO_3$ (5minutes) in all the seed sources. MANOVA indicated significant effect ($p<0.0001$) of treatments on all seedling emergence variables; seed sources and treatments had significant ($p<0.0001$) effect on different seedling growth parameters. Collar diameter appeared as the

strongest morphological trait, which can be used to identify vigorous seedlings for plantation.

14. Seedlings, raised under green house, were transplanted under three growing conditions, viz. temperature controlled green house, poly house and open beds, using soil, sand and farm yard manure (1:1:1). Highest plant survival (92%; $p<0.05$) was recorded for the green house. Maximum plant biomass per plant (42.60 gm/plant) was recorded in open bed, over green house (37.79 gm/plant) and poly house (31.52 gm/plant; $p<0.05$). Overall, the high productivity (seeds and plant biomass) and greater profit (economic) was gained in open beds for the projected 100%, 75% and 50% survival; but on the basis of actual survival (green house: 92%; poly house: 77%; open beds: 63%), net economic benefit was higher under green house. Compare to expensive infrastructure requirement for green house and poly house, the study suggests that open beds, with due care maintaining better survival, are much feasible and profitable condition for large scale cultivation of *S. chirayita*, which may offer good economic returns to the cultivators, especially poor farmers.

15. The conservation requires both, *in-situ* and *ex-situ* actions, such as habitat conservation, community participation in framing policies and programmes, information on trade, development of sustainable harvesting techniques, trainings to the harvesters, development and standardization of propagation and cultivation technologies. The present study in totality offers essential clues and guidelines, both scientific and practical to ground level, for effective and feasible scientific based conservation and management efforts of the targeted species, *Swertia chirayita*, in particular and broadly to other threatened plant species in Himalaya and other mountainous regions of the world.