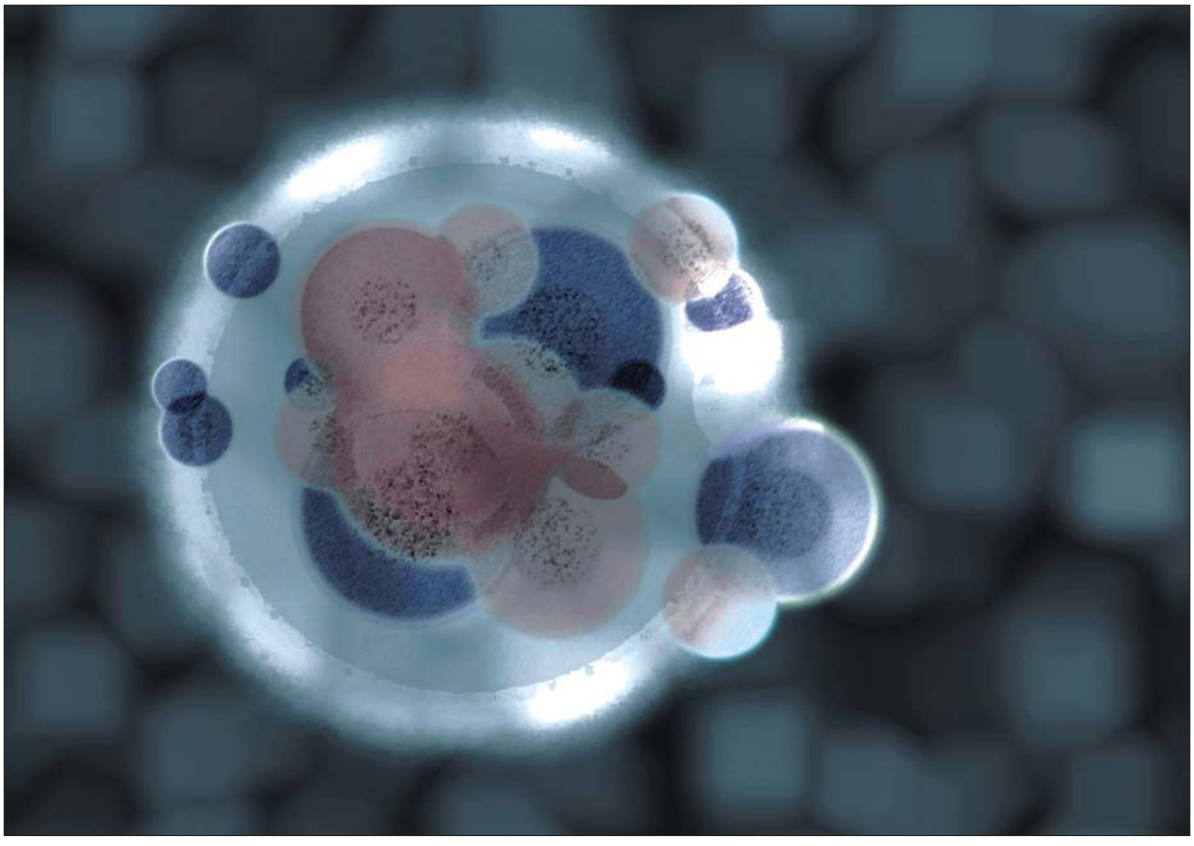

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Recovery and Restoration of Some Critically Endangered Endemic Angiosperms of the Kashmir Himalaya

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Abstract: Floristic diversity constitutes an indispensable resource-base for the human livelihood. Plants, being vital components of the biodiversity and the ecosystems they form, are essential for human progress and survival. In the recent past, however, human actions have brought a large number of plant species at the brink of extinction. One of the conservative estimates suggests that 60,000 to 100,000 plant species are threatened worldwide. These include a large number of endemic taxa, which being of considerable phytogeographic importance, need immediate attention of the botanists and conservationists. The Kashmir Himalaya harbours a rich angiosperm-flora, about 152 species of which are endemic exclusively to the Kashmir region. Many of these endemics are of great economic value, especially in food and fodder, local and commercial medicine, etc. Due to over-exploitation, habitat destruction and other anthropogenic activities, together with their innate sensitiveness, many of these endemics have become rare and threatened. This necessitates a thorough study of the threatened endemics of Kashmir so as to pave way for their conservation. The present study aims to dilate upon the taxonomy and the *ex situ* conservation aspects of five critically endangered endemic flowering-plant species of the Kashmir Himalaya, viz. *Aquilegia nivalis*, *Aconitum kashmiricum*, *Lagotis cashmeriana*, *Megacarpaea polyandra* and *Saussurea costus*.

Key words: Endemics, angiosperms, ex situ conservation, Kashmir Himalay

INTRODUCTION

The incredible array of life forms on our planet is our biological diversity, or biodiversity. It comprises plants, animals, micro-organisms, their genetic material and the ecosystem that they are ingredient of. In addition to providing valuable resources, such as food, drugs, raw material and sources of energy, biological systems provide key environmental services. The latter include the regulation of climate and biogeochemical cycles, hydrological functions, soil protection, crop pollination, pest control, recreation and ecotourism and number of miscellaneous services (Myers, 1996). Clearly environmental services are of gargantuan importance to human welfare, even though the fiscal value of these services is inadequately qualified and principally unappreciated by mainstream economists (Myers, 1996). There is, however, immense indecision as to the nature of the relationship between the provision of environmental services by biological systems and biological diversity (Ghilaroo, 1996; Myers, 1996; Benetsson *et al*., 1997).

It may be that towering levels of biodiversity are decisive in as long as ecosystem with the competence to endure disturbance over the long-term. Indeed, major contribution of biodiversity to environmental services in the provision of fail-safe system through the perceptible redundancy of species (Myers, 1996). As is appreciated by Evans (1976), who wrote that in the long run, probably the most imperative phase of the conservation of ecosystem is the preservation of biological system which may meet needs as yet unforeseen.

Humanity has evolved over millions of years in an integral nature and it continues to depend on intact nature for its future development. But humanity also depends on nature as the supplier for its needs. Maintaining the intactness of nature and exploiting her contain is contrasting, even mutually exclusive elements. Today's human societies still live to a substantial extent on the harvest of past intact nature-a nature now speedily losing its intactness and sumptuousness. Consequently a diminution of human impacts becomes a must; it can be anticipated to yield more benefits from nature and for long term human endurance than any other measure currently executed or advocated.

There is swiftly growing necessity for protecting nature from increasingly excessive impacts due to the

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activities of one of her millions of species that has relatively lately entered the scene: *Homo sapiens*). For enduring health and development of nature and for maximizing her capabilities to sustain human life, nature needs, first of all, to be relined from mounting impacts caused by ourselves (Kinne, 2004a, b). The foremost aim of conservation is to further natural products and to trim down their damage or neglect and thus to prop up human well being. Curiously, the natural harvest is usually considered possession of *Homo sapiens*-predominantly of the present generation. Each human-caused species extinction is a witness against us, an external manuscript of our failure. Our planet which is increasingly congested with the humans, the endurance of biodiversity will eventually hinge on utilitarian, particularly economic imperatives. It seems certain that political leaders will find aesthetic and ethical consideration insufficient reason to conserve the Earth's evolutionary heritage at the expense of economic growth and development. Only a carefully balanced compromise, based on scientific knowledge and on insight, can disentangle this Gordian Knot.

Centers of learning in Indian have hardly seriously attempted to school the younger generations in the basic principles and impact of conservation. In India very little information was available on threatened plants till a 5 year project on the study, Survey and Conservation of Endangered Flora (POSSCEF) was initiated in 1980 by the Botanical Survey of India (BSI). An upshot of this has been that some of the most gorgeous animals and plant species have befall endangered and their survival is considered implausible if conservation measures are not initiated instantaneously. Extinction threats in the wild are alarming and populations of organisms has been reduced to such a perilously low level and the extent of their habitat has been so severely reduced, that their survival demands premier precedence (Oza, 1977, 1987).

A century ago, Kashmir would have been a naturalist's paradise. Its flora attracted the attention of even non-botanists, nature-lowers, poets, *sofis* and *reshis*. There are reports indicating that in Kashmir dense forests descended up to the interior of the present day city and towns. Though the natural phenomenon like glaciations, soil erosion, landslides and avalanches, protracted periods of rain or droughts, burning of forests etc. may have taken a toll on our flora, most of the modern threats to species are anthropogenic in nature and includes habitat loss or modification, over exploitation, over grazing, tourist influx, unplanned development, introduction of exotic species etc., undue political interference, population expression and general public apathy coupled with lack of administration has led to this mess.

In Kashmir Himalaya, studies on rarity or conservation of plants have received little attention in the past (Saharia, 1982; Dhar and Kachroo, 1983a, b; Hajara, 1983; Kapur, 1983; Dar and Naqshi, 1984; Maunder, 1988; Vir Jee *et al*., 1990; Kaul, 1997; Dar and Naqshi, 2001; Dar and Dar, 2006). The Kashmir Himalaya flora includes a large number of endemic taxa. Dhar and Kachroo (1983a) reported 15.94% of endemics in monocots (Poaceae excluded) and an overall mean of 31.38% in dicots. However, as per the latest information (Dar and Aman, 2003), 152 (ca. 8%) taxa are endemic to this region, which forms just about 3% of the total Indian angiosperm endemics. Nonetheless, the extent of endemism in Kashmir can be appreciated by considering the fact that this region constitutes only 0.48% of the total landmass of India, is geologically younger and, among adjoining regions, has the least area per endemic taxon. Dhar and Kachroo (1983b) further report that about 40% of the endemic species in the Kashmir Himalaya are threatened.

The present endeavor is to conserve and propagate five economically important, critically endangered endemic angiosperms of Kashmir by maintaining their populations *ex situ* in Kashmir University Botanical Garden (KUBG) so as to support their recovery and restoration and provide long - term backup collections for sustained use by the local populace.

MATERIALS AND METHODS

Study area: Kashmir Valley The Valley of Kashmir, often referred to as the paradise on earth for its diverse rationale, is situated in the northern fringe of Indian subcontinent between 33°.20′and 34°.50′ N latitudes and 73°.55′ and 75°.35′ E longitudes, covering an area of about 16,000 sq. km. The Valley is formed by a girdling chain of Himalayan mountains, namely the Pir Panjal Range of the Lesser Himalaya in the south and Zanskar Range of the Greater Himalaya in southeast to northeast and the west. It is believed that the Kashmir Valley was once a large lake called Satisar.

The entire territories of the Valley form two distinct topographic divisions, the mountain ranges and the Valley proper. The mountains vary in their height, rising up to an altitude of about 4,200 m and are beset with sub-alpine and alpine meadows and at the top with permanent glaciers. The Valley proper is an oval, alluvium-filled river basin with an altitude of about 1,600 m at its capital city - Srinagar and a variety of rich fresh-water bodies, such as springs, lakes, etc.

The climate of the Valley is predominantly temperate, changing to subalpine and alpine higher up in the mountains. A unique feature of the climate is four distinct

seasons a year, namely spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). The annual average precipitation is about 75 cm, with sufficient rains during the months of March and April and also during July and August; during winter precipitation is mostly in the form of snow. July is the warmest month of the year, with temperature rising to an average of 29.5°C; January is the coldest month, with temperature coming down to -5°C. The maximum relative humidity (80%) occurs during the months of November-December and the lowest (71%) during May.

Preparation of land: A portion of land in the Kashmir University Botanical Garden (KUBG) was selected for the purposes of present study. In this experimental plot, many beds (approx. 8×4ft) were prepared for growing the target endemic plant species.

Field survey: Detailed scanning of all the relevant literature, guidance of experienced persons and knowledge from the local tribals were exploited to obtain relevant information regarding the distribution, appropriate sites, local names, etc. of the target species. Legal permission was requested from the concerned Govt. and military authorities with respect to the prevailing security scenario in the State.

Collection of plant material: Ten plant species specified were searched for in the herbarium of University of Kashmir (KASH). Some of these species are not at all represented in KASH, while 1 or 2 specimens of others have been collected prior to 1970, reflecting their rarity. The field survey trips undertaken in far off areas in the Kashmir Himalaya during the year 2004-2005 to locate these species. The extreme rareness of these taxa became evident during these trips.

Specimen processing and taxonomic description: The target species collected so far were identified and taxonomically described using the available literature and the specimens of these species collected by previous authors (if any), besides examining the specimens collected during the course of present study. Usually a few specimens from each locality from where these species were collected, were processed for herbarium purposes. These specimens were subjected to usual standard herbarium methodology (such as pressing, drying, preservation, etc.) in order to prepare their voucher specimens. They were assigned specific numbers, depending upon the locality from where they have been collected.

RESULTS

Survey and collection: Many localities in the Kashmir Himalaya were extensively surveyed for the location and collection of the target endemic plant species, stress was laid on those places from where these species have been reported previously. In all, nine field survey trips were conducted during the period of present study. In the course of these field trips, it became evident that these species are indeed extremely rare and difficult to collect. These species fall in to 5 genera and 4 families (Table 1).

Threat status and its field assessment: A total of 257 accessions of the five target plant species have been collected. All these species occupied fragile habitats with harsh edapho-climatic conditions and were represented by small and fragmented populations (Table 2). The data pertaining to their threat status assessment are given in Table 3.

Sowing of the collected plant material: The target plant species collected were planted in different beds in the experimental plot at KUBG. Watering, deweeding and protection from disease and rodents was being paid utmost attention. For watering of the project plants, a fifty-foot deep tube well was dug in the experimental plot itself. This greatly eased out the problem of watering the planted material in the said plot and aided in their survival.

Standardization of propagation through vegetative propagules: The afore-said project plant species were collected in the form of whole plants, rhizomes, or seeds. The propagules sown in the project plot were pursued from sowing till their sprouting afresh. It was found that all these species yielded best results in terms of the rhizomes. Contrarily, seeds did not show such encouraging results in terms of their germination both in the field and *in vitro*. Thus, rhizome was ascertained to be the best vegetative propagule for the survival, healthy sprouting and sustenance of all the target species maintained.

Propagation: The collected plant specimens (rhizomes) planted in field beds and trial pots flourished successfully. These target species were put to multiplication trials by their vegetative parts. Species wise *Aquilegia nivalis* has hard, robust, branched and less spreading rhizome. The acclimatized accession of this species was found to produce many (4-6) off-shoots from a single rhizome collected during the filed survey. This trait of the species to propagate vegetatively has great promise, especially when in natural habitat rare specimens

Table 1: Details of five target species

Species name	Family name	Life form	Common/Local name	Habitat	Specimens examined	Uses (if any)
*Aquilegia nivalis*Falc. ex Jackson	Ranunculaceae	Perennial herb	Columbine	Occurs in moist shady or open places, in slightly hard or pebbled soil at an altitude of 3,000-3,800 m	Gulmarg, 3800m, 11.06.2004, *G.H. Dar* and *A.R. Dar* 02 (KASH); Thajwas, 3150 m, 19.08.2004, *G.H. Dar* and *A.R .Dar* 08 (KASH)	Not knomn
Lagotis cashmeriana (Royle) Rupr.	Scrophulariaceae	Perennial herb	Kashmiri-Hare's Ear	Occurs in wet places (glacier-fed) in open or shady areas, rock crevices, loose-soiled and less-pebbled patches at an altitude of 3,000-4,000 m	Gulmarg, 3800 m, 11.06.2004, *G.H. Dar* and *A.R. Dar* 02 (KASH); Thajwas, 3150 m, 19.08.2004, *G.H. Dar* and *A.R .Dar* 08 (KASH); Naranag,, 3600 m, 18.07.05, *G.H. Dar* and *A.R. Dar* 13 (KASH)	Whole plant considered medicinal. The paste of leaves applied for wound healing in cattle. Rhizome used as adulterant in place of *Picrorhiza kurrooa*
Saussurea costus (Falc). Lipschitz	Asteraceae	Perennial herb	Kuth	Occurs on moist, shady slopes among jnniper shrubs or in open places at an altitude of 2,800-3,800 m	Gulmarg, 3100 m, 15.06.2004, *G.H. Dar* and *A.R. Dar* 05 (KASH); Naranag,, 3100 m, 18.07.05, *G.H. Dar* and *A R. Dar* 14 (KASH)	Rhizome used as spasmodic in asthma, cough and cholera, in skin disease and rheumatism, also as insect repellent
Megacarpaea polyandra benth.	Brassicaceae	Perennial herb	Chatter	Occurs in open, moderately moist, loose soils at an altitude of 3,400-4,000 m	Gagargalli (Uri), 3600 m, 8.08.2004, *G.H. Dar* and *A.R. Dar* 09 (KASH)	Fleshy roots are relished as pot herb or eaten raw. Leaves are prized as spinach
Aconitum kashmiricum Stapf ex Coventry	Ranunculaceae	Perennial herb	Pevak, Kashmir Mankshood.	Loose-soiled, less-pebbled, moist and open alpine slopes at 3,000-3,800 m	Gulmarg 3500 m, 11.09.05, *G.H. Dar* and *A.R. Dar* 19 (KASH)	Not known

Table 2: Details of field survey trips to collect the target species during 2004-2005

Locality	Date	Species collected	No. of accessions collected	Part collected
Gulmarg (Apharwat to Sarsoon Post)	10-13th June 2004	*Aquilegia nivalis*	25	Whole plant
Gulmarg (Apharwat)	10-14th July 2004	*Lagotis cashmeriana*	04	Whole plant
Uri (Ban Behak)	5-11th Aug. 2004	*Saussurea costus*	15	Rhizome/fruiting heads
Uri (Gagargalli)	15-21st Sep. 2004	*Megacarpaea polyandra*	6	Rhizome/whole plant with fruits
Naranag	12th-19th June 2005	*Megacarpaea polyandra*	13	Rhizome
Gulmarg (Khillanmarg)	29th June-4th July 2005	*Aquilegia nivalis,*	7	Whole plant
		Lagotis cashmeriana,	18	Whole plant
		Aconitum kashmiricum	66	Whole plants/tubers
Naranag	13th-22nd July 2005	*Saussurea costus*	17	Rhizome
		Lagotis cashmeriana	13	Whole plant
Sonamarg (Thajwas, Zaildardub)	29th July-11th August 2005	*Lagotis cashmeriana*	55	Whole plant
		Aquilegia nivalis	09	Whole plant
Gangabal	17th-16th October 2005	*Saussurea costus*	09	Rhizomes

Table 3: Threat status and its assessment of the collected species

Name of species	Threat status	Current threats	Threat status assessment in the field
Aquilegia nivalis	CR	Fragile habitats, grazing pressure	Very small, restricted populations, growing in extreme alpine conditions
Lagotis cashmeriana	CR	Fragile habitats, grazing pressure	Small, fragmented populations, with low sexual reproductive potential
Saussurea costus	CR	Extreme exploitation for medicinal purposes, illicit trade and grazing pressure	Reduced, restricted populations, less sexual reproductive effort, only a few viable seeds per head ,over exploitation of rhizomes greatly affecting vegetative propagation
Aconitum kashmiricum	CR	Loose-soiled, less- pebbled, moist, extremely fragile, open alpine slopes	Harsh and fragile habitats, squeezed populations and restricted distribution, extensive grazing of flowering portions, exploitation of tubers for medicinal purposes
Megacarpaea polyandra	CR	Harsh alpine habitats, exploitation as a vegetable by local tribals	Extremely restricted and shrinked populations, only a few reproductive individuals seen

of this species get chance to produce may off-shoots and even then it produces 2-3 of them. *Lagotis cashmeriana* has a small, cylindrical, relatively hard runner type of rhizome. This rhizome runs not much deeply in soil and at many places produces vegetative buds, developing few five threads like roots downwards and hence producing a new individual. The same trait of the plant species was exploited in the experimental plot at KUBG and hence proved economical and successful means of multiplication of this fragile species. *Saussurea costus* has relatively less hard or more appropriately a spongy rhizome which is less branched and descends vertically. Usually only one plant can be found arising from one rhizome, but if the rhizomatous stock is relatively older (2-3 years), it produce (3-4) vegetative buds, which are quite well separated on the main rhizome from each other. These vegetative buds

on careful separation from the main rhizome, planted on moderately moist, fertile and loose soil, show survival and develop into new individual. Such means of propagation at brisk rate in this species is especially important, because most of the seeds produced by this species have been found to be non-viable. In the acclimatized individuals of *Aconitum kashmiricum*, the underground tubers where found important for vegetative propagation. The plant infact has two underground tubers, one of previous year and second of the present year. The previous year's tuber is being exploited by the plant in the following year to sprout and attain vegetative growth. Once plant started its synthesizing process a small new tuber is initiated in the close proximity of the previous year tuber and this new tuber grows with progress of the growing season and ultimately attains its critical size (subjected to favourable growth conditions) to support the plant in the next sprouting season. In the experimental plot in many trial pots, it was found that in few vigorously growing individuals instead of two underground tubers, 3 or even 4 underground tubers were developed from the same plant. Trials were conducted for the multiplication of this species by vegetative means from its underground tubers. In the subsequent experiments the stated tubers were cut vertically into 2, 3, 4, or even 5 sections depending upon the vigourness of the tuber, so that each section may get a sizeable part of the apical bud. These cuttings were then planted in the trial pots putting them at a depth of 2-3 cm below soil. It was observed in many trial pots that these vegetative sections developed into new plants. After repeated trials it was standardized that 2 sections in normal sized tubers and 3 to 4 sections in highly vigorous tuber are optimum for the establishment of all such sections and to successfully produce new plat. This observation got actually confirmed from above said trials; because once too many sections are made from the underground tuber most of these section do not get the critical section of the apical bud to produce new plant successfully. This trait of the said species is highly potentious for its rapid multiplication vegetatively.

Megacarpaea polyandra has one unbranched, much thick, very long and deep soil penetrating main rhizome. Like *Saussurea costus*, here also in relatively older individuals, the rhizome bears 4 or even 5 vegetative buds which are well separated from each other. These vegetative buds when carefully separated from the main rhizome and planted in moderately moist, loose and well drained soil, produce new individuals in most of the cases.

Apparent strategy: From the experience of extensive field survey of these target species in their natural alpine habitat and in the experimental plot, the most probable strategy of these target species was worked out. Species wise, it was quite obvious from field study that the capsules (fruits) of *Aquilegia nivalis* are being browsed by the cattle before the seed dispersal and few survived capsules disperse seeds which find limited germination microsites in alpine habitats and still most of the new recruits have to face adverse climatic conditions, hence leading to meager increase in population through reproductive effort. As a result of this the plant mostly invests major portion of its resources towards the rhizome portion and hence propagates mostly by vegetative means. In *Lagotis cashmeriana* quite a few number of reproductive individuals can be found in a population and majority of them is being browsed by cattle even before reaching the seed production stage. Even survived flowering spikes each, on an average produces 27-40 flowers with only 7-15 seeds. This very meager number of reproductive individuals coupled with low seed set in fragmented populations cannot ascertain the survival of this species and hence vegetative means which is economical and efficient has been adopted as the main survival and propagation strategy. *Aconitum kashmiricum*, populations in the beginning of the growing season can be found in full reproductive bloom in natural habitats, but when searched for seeds in later season it is almost impossible to locate few achenes; reason being, this species grows in extensively grazed regions of alpine meadows and further its fruit formation season and aggregation of different herds of cattle brought down from higher alpine elevations coincides and renders almost whole population achene less. So the sole propagations means of this species is by underground tubers. The *Saussurea costus* has over the years most probably has learnt (as a result of various constraints, such as, over exploitation, illicit trade, pollinator deficiency etc.) that it is wasteful exercise to invest resources for seed formation and that too when habitat is no more that congenial for seedling survival. So thrust in this species is again on vegetative propagation by underground perennial parts. *Magacarpaea polyandra* is very restricted plant in strict sense and appears to have learnt to use its resources in a very tricky manner. In this species very few reproductive individuals can be found in a population. Each such individual produces very large number of flower and about 60-70 seeds, protected by outer relatively hard covering. Still only few seedlings can be found in a particular population. Furthermore, during study it was found that individual which enters reproduction in present year, will not undertake such reproductive effort in at least in next two years, reason being this plant has to invest huge amount of resources

to raise a large reproductive spike bearing huge number of flowers and for this particular plant it is not possible to repeat same in year after year. Hence besides sexual reproductive effort to some extent, the survival strategy of this plant is being aided to a greater extent by vegetative means. Overall it can be said that these critically endangered perennial species are still struggling hard for their survival, adopting various means for furthering their population size and at present it ample clear that they have found vegetative means as best possible strategy for survival and multiplication.

DISCUSSION

Critical analysis of the planted material of the target species at KUBG, vis-à-vis the natural habitat conditions of these species turned a very helpful tool in devising an ideal experimental setup for the best possible survival, growth, vigour, reproduction and seed set of these target species. For this purpose same species accessions were divided into many sub sets and planted under different conditions in the field beds. The results varied in terms of survival, vigour and to some extent in the reproduction. *Aconitum kashmiricum*, a typical alpine species was collected in the form of 66 accessions as a result of various survey trips and planted in different experimental setups in the experimental plot at KUBG. Almost 45 accessions survived and acclimatized, flourished, produced flowers and a few seeds. The species found the conditions in pots (with moderate moisture, soil mixed with sand and the partial shade) as the best conditions for survival, growth, flowering and multiplication. *Saussurea costus* showed maximum survival, as almost all (56) the rhizomes planted sprouted and produced broad leaves and even a few produced flowers. *Aquilegia nivalis* collected in the form of 41 accessions showed mixed results as few individuals (4) produced flowers and seeds, while as other specimens have shown healthy vegetative growth. The 90 accessions collected for *Lagotis cachemeriana*, showed retarded vegetative growth initially, but after shifting to different experimental conditions such as, open and shaded field beds and trial pots, simple garden soil and soil mixed with sand, showed health vegetative growth although none entered into reproductive phase. The 19 collected accessions of *Megacarpaea polyandra* showed poor vegetative growth in the experimental plot, but gained momentum in the second year and few specimens even entering into reproduction. Also 7 seedlings obtained from seed germination trials are in good vegetative growth in trial pots.

Overall results are highly satisfactory in this perspective that, because of the inaccessibility of the high-elevations areas in Himalayas and restricted distribution of threatened species, a paucity of information exists on their distribution pattern, population status and indigenous use pattern, despite the interest and efforts to collect and compile information on these species CSIR, 1989; Chaurasia and Singh, 1996; Gaur, 1999; Kala, 2000, 2002a-c). The successful vegetative propagation protocol developed in present communication is potentious, easy, economical, less sophisticated, adoptive and accommodations, less time consuming, practical as compared to usual modern methods (e.g., tissue culture) of propagation of RET species.

The results achieved are of direct practical relevance in conservation and sustainable use of plant biodiversity of the Kashmir Himalaya. Location, collection and maintaining these 5 target species as *ex situ* population in the KUBG will pave the way for the recovery, restoration and conservation of these economically important and critically endangered narrow endemic angiosperms of Kashmir, thereby providing long-term backup collection for sustained use by the local populace. Maintaining these target species of critically endangered angiosperm endemics of Kashmir in accessible *ex situ* Conservation during the present study will help KUBG implement target 12 (VIII) of the Global Strategy for Plant Conservation (GSPC). Besides their endemic value, most of these species are socio-economically important, especially in medicine; these aspects are related to target 12 (V) and 12 (IX) of GPSC.

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