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PLANT LIFE IN THE HIMALAYAN COLD DESERTS : SOME ADAPTIVE STRATEGIES

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INTRODUCTION

The Himalayas are the world's highest mountain ranges extending east-west from the river Indus to the river Brahmputra over 2400 km long with an estimated width varying between 160 to 400 km. They are a chain of three parallel longitudinal mountain zones, namely :

(a) The Great Himalaya or the Trans Himalaya in the north with the average elevation of 6000 m.

(b) The Lesser Himalaya or the Middle Himalaya with average elevation of 4500 m.

(c) The Outer Himalaya or the Siwalik ranges from the Gangetic plains to 1200 m high.

The northern limits of the Himalayan range reaches a latitude as far as 35°50′ N and this region receives very scanty rainfall whereas the southernmost limit lying at 27°N receives heavy rainfall. Vertically these ranges show a wide altitudinal range from tropical foot-hills of the outer Himalaya to peaks as high as 8848 meter, the Mount Everest.

Biogeographically the Himalayas can be divided into the following bioprovinces :

(i) Western Himalaya—comprising of Jammu & Kashmir, Himachal Pradesh and Garhwal and Kumaon region in Uttar Pradesh.

(ii) Eastern Himalaya—comprising of Arunachal Pradesh, Bhutan, Sikkim and Darjeeling district of West Bengal.

(iii) Central Himalaya—comprising the kingdom of Nepal.

The Himalayas have a diverse climate, resulting in a cold arid desert in the north-western region to the evergreen tropical and temperate rain forests in the east.

The western Himalayan ranges differ significantly from their eastern counterparts in greater breadth and length, higher latitude, scanty rainfall, heavy snowfall and cool, dry climate. This marked difference in the humidity and rainfall determines the nature and quality of vegetation in eastern and western Himalaya as it is evident from the fact that the tree line in the western Himalaya is *ca* 3600 m as compared to eastern Himalaya where the tree line extends to *ca* 4600 m. Beyond this tree line is alpine zone, which is a land of spectacular, colourful herbs and shrubs. The vegetation above the tree limit in the Himalaya consists of :

(a) Alpine scrub—dominated by *Juniperus-Rhododendron* scrub community in the subalpine zone.

(b) Alpine meadows—mainly in the moist regions in shallow saucer-shaped depressions and slopes regularly moistened by melting snow and glacial streams.

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(c) Cold deserts—mainly in the north-west Himalayan region with scanty or no rainfall, high aridity, heavy snowfall and with a curious flora adapted to this region.

The Cold deserts : Cold deserts are rainless, dry cold arid zones with severe snowfall during winter. The diurnal temperature fluctuation is so high that the day temperature reaches as high as 30°C and falls sharply during nights below 0°C. Besides, the nights are characterised by snow storms, blizzards and extreme frigid conditions.

The cold deserts in Himalaya are mostly confined to north-western Himalaya since this region receives very meagre or scanty rainfall and severe snowfall. Such cold deserts exist in Zanskar, Ladakh, Rupshu area of Jammu & Kashmir, Lahul and Spiti and Kinnaur area of Himachal Pradesh and in certain parts (Niti) of Garhwal bordering Tibet in the north-western Himalaya.

The cold deserts in the Himalaya are generally encircled by high mountains ranging from 5000 to 6500 meters. The main rock components are of crystalline and metamorphic nature with sedimentary deposits chiefly of gneisses, schists, shales, slates, sandstones, granite and quartzites. In certain areas of Ladakh, highly fossiliferous marine sedimentary rocks are common.

The soil is light sandy loam, generally very poor in organic matter and nitrogen content. Due to scanty vegetation the soil in this tract is inadequately protected. As a result, the steep and extensive slopes have eroded due to thawing snows, avalanches and by strong winds exposing barren and rocky landscapes.

The presence of many glaciers, glacial moraines and morainic deposits indicates that the huge glaciers in the past, by the process of gradual shrinking of their extensive snowfields have left vast areas of morainic deposits which in due course of time formed a specialized habitat for a characteristic plant and animal life.

Climate : The climate of the cold deserts is very harsh and extreme with scanty or no rainfall, high temperature and heavy snowfall during winter months. The diurnal temperature fluctuations are also very great.

The high mountains surrounding the cold deserts form an effective barrier against monsoon laden clouds resulting in almost rainless or scanty rainfall as is evident in Ladakh in Jammu & Kashmir, Lahul & Spiti and Kinnaur in Himachal Pradesh and certain parts of Niti in Garhwal bordering Tibet.

The temperature in the Himalayan cold deserts varies remarkably. June to September are the warmer months with average mean temperature varying between 13°C to 24°C. Whereas, December to February are the coldest months (average mean temperature varying between 1.5°C to 4.0°C). In some areas like Ladakh the mean winter temperature falls down to −8°C to −15°C. Drass is known to be the second coldest inhabited place in the world after Siberia with temperature as low as −75°C.

Cold desert flora and climatic impact : The vegetation of the cold arid regions in the Himalaya consists of a highly specialized group of Hypsophilous plants with metabolic and reproductive strategies suited for maximising their activity in very low temperature conditions. The cold desert vegetation is influenced by several drastic climatic conditions not favourable for normal plant life. Rainfall, temperature, humidity, snowfall, ultra-violet radiation, topography, exposure to sun, soil texture and nutrition, etc. are some of the factors, the impact of which are clearly felt in cold deserts. The low water-holding capacity of the soil in cold deserts is further inhospitable for plant growth. The plant species occurring here have magnificiently adapted and are highly specialized to the exacting requirements of their harsh and hostile climate. Most of the plants growing here hug the ground and insulate themselves in a protective cocoon of soft hairs; have evolved bright coloured flowers to lure the few insects for successful pollination in a very short span of their life; others develop a cushion forming habit.

The exact number of flowering plant species in the Himalayan cold deserts is not correctly assessed yet. The extensive collections so far made by Botanical Survey of India, Dehra Dun and the scrutiny of the available literature (Stewart, 1916-1917; Hartmann, 1966; Kachroo *et al.* 1977 and Billiet *et* Leonard, 1986) has revealed about 1040 species of flowering plants from the cold deserts of Ladakh, Lahul and Spiti. But this includes several alpine and oasitic elements. Families like Asteraceae, Brassicaceae, Fabaceae, Rosaceae, Ranunculaceae, Apiaceae, Saxifragaceae, Crassulaceae, Lamiaceae, Scrophulariaceae, Caryophyllaceae, Chenopodiaceae, Primulaceae, Polygonaceae, Boraginaceae of dicots and Poaceae and Cyperaceae of monocots have maximum number of genera and species in the cold desert flora whereas, *Astragalus, Artemisia, Androsace, Arenaria, Allium, Bromus, Carex, Corydalis, Chenopodium, Draba, Dianthus, Epilobium, Erigeron, Festuca, Geranium, Gentiana, Lactuca, Lonicera, Nepeta, Oxytropis, Poa, Polygonum, Pedicularis, Primula, Potentilla, Ranunculus, Saussurea, Senecio, Sedum, Stipa, Saxifraga, Stellaria, Tanacetum* and *Thalictrum* are some of the dominant genera. Some common species typical to cold-deserts above 5000 meters are listed in Table 1.

The number of flowering plant species decreases as one moves towards high cold regions due to the harsh climate, degree of summer warmth, length of growing season, etc. Further, the extreme cold and high intensity of ultra-violet radiation have resulted in high percentage of polyploidy and hybrids through mutations (Legris, 1963). This has also resulted in the development of several endemic species (Table 1) which are also distributed in the adjoining cold deserts of Tibetan plateau.

The vegetation is not compact. Only scattered grassy patches and sporadic areas of vegetation can be seen dominated by perennial, dwarf, ground hugging, cushion-forming plants growing amidst the natural heaps of stones and rubble, rocky walls and on the top of ridges. These plants have a very thick, long taproot, devoid of any erect conspicuous stem. In case of unbranched plants the leaves are normally in rosettes, lying flat on ground with almost sessile inflorescence nestling in the centre of the rosette. The large tap root systems with their high carbohydrate reserves enable these plants to survive year after year with little photosynthesis gain, apart from the firm anchorage against strong wind.

Table 1: Some typical cold desert species

(Endemic species are marked with Asterisks)

Name of the species	Family
* *Acantholimon lycopodioides* (Girard) Boiss.	Plumbaginaceae
Adonis chrysocyathus Hook. f. & Thoms.	Ranunculaceae
Allium semenovii Regel	Alliaceae
Alyssum canescens DC.	Brassicaceae
Androsace chamaejasma Host. and var. *coronata* Watt.	Primulaceae
* *Anemone rupicola* Camb. var. *glabriuscula* Hook. f. & Thoms.	Ranunculaceae
Arabidopsis thaliana (L.) Heynh.	Brassicaceae

Table 1 : Continued

Name of the species	Family
Arenaria bryophylla Fernald.	Caryophyllaceae
A. ciliolata Edgew.	,,
A. glanduligera Edgew.	,,
Artemisia salsoloides var. *wellbyi* (Hemsl. & Pearson) Ostenfeld	Asteraceae
Aster flaccidus Bunge	,,
A. tibeticus Hook. f.	,,
Astragalus arnoldi Hemsl. & Pearson	Papilionaceae
A. confertus Benth. ex Bunge	,,
A. falconeri Bunge	,,
* *A. gracilipes* Benth. ex Bunge	,,
A. heydei Baker	,,
* *A. melanostachya* Benth. ex Bunge	,,
* *A. oxyodon* Baker	,,
* *Atelanthera perpusilla* Hook. f. & Thoms.	Brassicaceae
* *Braya aenea* Bunge	,,
B. oxycarpa Hook. f. & Thoms.	,,
B. rosea (Turcz.) Bunge	,,
* *B. tibetica* Hook. f. & Thoms.	,,
Carex moorcroftii Falc. ex Boott	Cyperaceae
* *Chrysanthemum tibeticum* Hook. f. & Thoms.	Asteraceae
* *Corydalis adiantifolia* Hook. f. & Thoms.	Fumariaceae
Corydalis stricta Staph.	,,
* *C. tibetica* Hook. f. & Thoms.	,,
Crepis flexuosa (DC.) Benth. & Hook. f.	Asteraceae
* *C. multicaulis* ssp. *congesta* (Regel) Babc.	,,
* *Dianthus deltoides* L.	Caryophyllaceae
Draba oreades Schrank	Brassicaceae
Dracocephalum heterophyllum Benth.	Lamiaceae
Ephedra gerardiana Wall. ex Stapf	Ephedraceae
* *Ermania albiflora* (T. Anders) O. E. Schultz	Brassicaceae
E. lanuginosa (Hook. f. & Thoms.) O. E. Schultz	,,
* *Euphrasia alba* Penn.	Scrophulariaceae
* *E. kashmiriana* Pugsley	,,
* *E. laxa* Penn.	,,
* *E. paucifolia* Wettst.	,,
* *Hedinia tibetica* (Thoms.) Ostenf.	Brassicaceae
* *Inula falconeri* Hook. f.	Asteraceae
Krascheninnikovia ceratoides (L.) Guelden.	Chenopodiaceae
Lagotis decumbens Rupr.	Scrophulariaceae
* *L. kunewurensis* (Royle) Rupr.	,,
Leontopodium nanum (Hook. f. & Thoms.) Hand. Mazz.	Asteraceae
Lloydia serotina (L.) Reichenb.	Liliaceae
* *Lonicera rupicola* Hook. f. & Thoms.	Caprifoliaceae
Meconopsis horridula Hook. f. & Thoms.	Papaveraceae
* *Microgynoecium tibeticum* Hook.	Chenopodiaceae
Microula tibetica Benth.	Boraginaceae
Milula spicata Prain	Alliaceae

Table 1 : Continued

Name of the species	Family
Nepeta tibetica Benth.	Lamiaceae
* *Olgaea thomsonii* (Hook. f.) Iljin	Asteraceae
Oxyria digyna (L.) Hill	Polygonaceae
Oxytropis densa Benth. ex Bunge	Papilionaceae
O. lapponica (Vahl.) Gay	,,
O. microphylla (Pall.) DC.	,,
O. tetarica Camb.	,,
* *Pedicularis brevirostris* Penn.	Scrophulariaceae
P. oederi Vahl	,,
* *P. kashmiriana* var. *ornata* Penn.	,,
* *P. longiflora* ssp. *tubiformis* (Kl.) Penn.	,,
* *P. purpurea* Penn.	,,
* *P. pycnantha* ssp. *semenovii* (Regl) Prain	,,
* *P. rhinanthoidea* ssp. *speciosa* Penn.	,,
* *P. svenhedinii* Paulsen	,,
Pegaeophyton scapiflorum (Hook. f. & Thoms.) Marg. & Shaw	Brassicaceae
* *Physochlaina praealta* (D.Don) Hook. f.	Solanaceae
* *Pichorhiza kurrooa* Royle ex Benth.	Scrophulariaceae
Polygonum sibiricum ssp. *thomsonii* (Meissn. ex Steward) Rich. f. & Schiman-Czeika	Polygonaceae
P. tortuosum D. Don	,,
Potentilla sericea L.	Rosaceae
Puccinellia distans (L.) Parl	Poaceae
* *Pycnoplinthus uniflorus* (Hook. f. & Thoms.) O. E. Schultz	Brassicaceae
Ranunculus involucratus Maxim.	Ranunculaceae
R. lobatus Jacquem. ex Cam.	,,
R. pulchellus C. A. Mey	,,
Rheum spiciforme Royle	Polygonaceae
Saussurea aster Hemsl.	Asteraceae
* *S. bracteata* Decne.	,,
S. glanduligera Sch.-Bip.	,,
S. gnaphalodes (Royle) Sch.-Bip.	,,
* *S. subulata* Clarke	,,
* *S. thomsonii* Clarke	,,
Sexifraga flagellaris Willd..	Saxifragaceae
S. jacquemontiana Decne.	,,
S. pulvinaria H. Smith	,,
* *Scrophularia dentata* Royle ex Benth.	Scrophulariaceae
* *S. nudata* Penn.	,,
* *S. polyantha* Royle ex Benth.	,,
* *Sedum crassipes* Wall. ex Hook. f.	Crassulaceae
S. quadrifidum Pall. & Thoms.	,,
S. roseum (L.) Scop.	,,
S. tibeticum Hook f. & Thoms.	,,
* *Senecio tibeticus* Hook f.	Asteraceae
Stellaria graminea L.	Caryophyllaceae
* *Tanacetum artemisioides* Sch.-Bip.	Asteraceae
* *T. nanum* Clarke	,,
* *T. tibeticum* Hook. f. & Thoms. ex Clarke	,,
Taraxacum bicolor (Turcz.) DC.	,,

Table 1 : Continued

Name of the species	Family
Thermopsis inflata Camb.	Papilionaceae
Thylacospermum caespitosum (Camb.) Schischkin	Caryophyllaceae
Trisetum spicatum (L.) Richt.	Poaceae
* *Veronica koelzii* Penn.	Scrophulariaceae
* *V. nana* Penn.	,,
* *V. salina* Schur.	,,
* *V. secunda* Penn.	,,
* *V. uncinata* Penn.	,,
* *Waldheimia glabra* (Dcne.) Regel	Asteraceae
* *W. nivea* (Hook. f. & Thoms.) Regel	,,
* *W. vestita* (Hook. f. & Thoms.) Pamp.	,,
* *Wulfenia amherstiana* Wall. ex Benth.	Scrophulariaceae

The impact of climatic factors on cold desert plants are discussed below.

1. *Temperature* : In the cold deserts temperature plays a major role in governing the flora. The air temperature often goes below 0°C for many months together. As the temperature falls the atmospheric precipitation changes from rain into snow which enables the solar radiation to warm up the ground, causing variation in temperature of the soil itself. This variation in the ground and air temperature plays an important role in the biology of cold desert plants by influencing the opening of buds, growth of leaves, flowering and fruiting, etc. The day temperature in high altitudes may be as high as 15°C and as low as −20°C during night. But at very shallow soil depths the difference in minimum and maximum temperatures becomes almost insignificant. Thus, soil mitigates extremes of temperature, making the survival of plants possible. In areas of stoney grounds, open cliff faces, crags and rocks where soil is absent or scanty, the solar impact is more intense. Such rocks attain very high temperatures during day time becoming very cold as the night falls. In such extreme situations only a few selected and highly specialized plants such as *Corydalis crassissima, Astragalus* spp., *Saussurea bracteata, Thylacospermum caespitosum, Saxifraga* spp., *Androsace* spp. and mosses like *Grimmia, Encalypta, Racomitrium, Andreaea* and *Schistidium* are able to grow. Certain characteristic adaptations to overcome the severe cold include :

(i) Dense protective covering of hairs, which form a felt-like coating on the entire surface of the exposed plant and acts as a thermal blanket. Apart from providing thermal security, these glistening hairs help in reflecting the solar radiations thereby reducing the harsh impact of sun rays, e.g. *Saussurea* spp., *Thermopsis inflata, Waldheimia tomentosa, Tanacetum gossypinum.*

(ii) Many cold desert plants survive the thermal fluctuations and very low temperatures by growing in dense, closely packed mats, e.g. *Acantholimon lycopodioides, Thylacospermum caespitosum, Arenaria* spp., *Androsace* spp., *Saxifraga* spp. etc.

(iii) Development of a thick, woody and deep root system which help the plants that grow on exposed rocks and crevices to fight extremes of temperature e.g. *Ephedra* spp., *Taraxacum* spp.

Temperature also induces certain physiological specialization in cold desert plants. The plants of cold arid regions are able to survive in very low temperatures as they have a higher rate of metabolic activity at low temperature (Crawford & Palin, 1981). But at the same time, this ability has a great disadvantage to them because the metabolic activity increases with the rise in temperature which leads to the depletion of hardly produced carbohydrates or the stored-up energy at a very fast rate. This rapid utilization rate of carbohydrate reserves due to higher respiration rate in warm climates has been reported to be a limiting factor in the extension of the cold desert species to warmer regions (Mooney & Billings, 1965; Stewart & Bannister, 1973).

The other specialization developed by these plants is the increased concentration of cell sap due to conversion of starch into soluble sugar during nights which are normally much longer. This increased cell sap concentration lowers the freezing point by several degrees and this is how the cold desert plants survive temperatures as low as $-15°C$ to $-20°C$.

2. *Water* : Water is essential for all living beings. Rainfall in cold desert regions is almost negligible and only snow is the available source of water to the inhabiting plants.

The Himalayan cold deserts are usually covered by a thick mat of snow for a long period which not only affects the availability of water but also growth and development of plants. The crushing weight of snow layer is successfully overcome by the development of prostrate, creeping habit as in case of *Dracocephalum heterophyllum*, *Waldheimia* spp., *Inula rhizocephala*, *Astragalus* spp., *Pycoplinthopsis* sp.

In spite of the fact that the cold deserts experience heavy snowfall, very little amount of water reaches the plants, particularly during winter when the plants undergo a period of dormancy. With the rise in temperature during summer, the snow melts releasing huge amount of water and is dispersed quickly due to steep slopes and impervious substratum. Therefore, the plants could use very small amount of water and are forced to adapt themselves to extreme dry conditions. As a result, xerophytic plants are abundant in cold deserts. The noticeable xerophytic adaptations in the morphology and anatomy are :

a — Mat or carpet-like formations by aggregation to retain maximum water within them.

b — Development of long, thick tap roots capable of reaching deep in the rock crevices to draw available water.

c — Development of succulent habit for storing water in leaves and stem.

3. *Mist* : Mists are a common feature in high altitudes. They have a significant impact on the existing flora. They help in reducing the light intensity and at the same time distributing light more evenly due to refraction caused by suspended water droplets, that provide moisture to plants.

4. *Wind* : High velocity winds are most common in Himalayan cold deserts. The wind current dries the atmospheric air increasing the transpiration rate in plants and also makes water absorption difficult from soil. It also erodes the soil thereby uprooting the plants. The adaptations to check the strong wind current include the development of a strong, thick tap root and prostrate habit restricting the erect growth of plants.

5. *Light* : Sunlight is another important factor which affects the growth of plants in cold deserts. Due to lower air density in the high altitudes the solar radiation reaches the soil surface easily and in higher intensity. The hairy covering on plants and reddish colour of the branches and leaves protect against intense radiation. The strong ultraviolet radiation has also a stunting affect on the high altitude plants. It slows down the

vegetative growth of the plants thus producing dwarf forms. *Thylacospermum caespitosum* which forms hardhemispheric cushions takes as many as 150 years to attain a cushion of 30 cm diam.

SURVIVAL STRATEGIES AND DEVELOPMENT OF SPECIALIZED HABITS

(i) *Cushion-forming habit* : Cushion, clump or mat-forming habit is very common in cold desert plants. Such plants are perennial, short and sturdy with woody stem, deep root system capable of penetrating rock crevices and fissures to provide firm anchorage and nutrition to the plant. The heavily lignified stem gives out numerous short, creeping branches just above the ground level which get repeatedly branched and densely packed with leaves and flowers forming dense hemispheric cushion habit. Such a habit protects from the strong wind action, strong thermal radiations, dessicating effect of air, loss of water through transpiration, in maintaining the balance of temperature fluctuations between air and soil and from the continuous pressure of snow layer which may be several feet thick for months together.

(ii) *Diminutive or miniature habit* : Although the cold desert plants are generally dwarf and stunted, some of them are so significantly reduced, one may not even notice them in fields. Species like *Lancea tibetica, Pleurogyne brachyanthera, Gentiana thomsoni, G. aguatica* and *Taraxacum bicolor* are often barely 1-2 cm tall with a solitary flower. In contrast to the aerial portion, the underground tap root may be as long as 30 cm. *Ranunculus tricuspis, R. similis, R. involucratus, Anemone imbricata, Corydalis boweri, Arenaria littledalei, Lancea tibetica, Saxifraga parva, Sedum przewalskii* are some other small sided species. The genus *Saussurea* may be cited as an example of diminutive plants of cold desert. Several species of the genus range from hardly 2 cm to 10 cm in height. In case of *Astragalus heydei, Corydalis crassissima, Hedinia tibetica, Cochlearia scapiflora, Brya sinensis, Thermopsis inflata, Microula tibetica* and *Dracocephalum heterophyllum* the plants develop deep penetrating perennial rootstocks from which annual branches are produced down among the rocks or stones and they bear leaves and flowers in clusters just above the stones or rocks.

In higher reaches of cold deserts where vascular plants disappear only mosses and lichens predominate. Even these mosses show certain characteristic xerophytic adaptations to suit the cold desertic conditions. These adaptations include the formation of dense and compact cushion habit, the development of long hyaline arista-like projections from the leaf tips and attaining dark brown or reddish-brown coloration as in case of *Grimmia* spp., *Encalypta* spp. etc. Some mosses like *Racomitrium* sp. develop tortuous cell walls which is said to be an adaptation to conserve the scanty moisture.

(iii) *Bushy habit* : The number of woody plants in cold arid region is exceedingly low. *Ceragana pygmaea, Ephedra gerardiana, Hippophae rhamnoides, Myricaria prostrata* and *Lonicera hispida* form dense bushy habit with woody branches barely attaining 30-50 cm.

REPRODUCTIVE STRATEGIES OF COLD DESERT PLANTS

The ecological conditions to which the plants of cold deserts are exposed would have threatened their existence but for the very effective reproductive mechanism. During the very short favourable period the cold desert plants have to complete the entire reproductive cycle right from the opening of buds to sprouting of leaves and flowers, fruiting and even dispersal of seeds. Thus reproduction and dispersal among the plants inhabiting the cold deserts is an important aspect which maintains the population of this scanty vegetation under the existing adverse conditions. The reproduction is accomplished both by seed formation and by the vegetative propagation. It has been reported by Chaplin *et al.* (1980) that the amount of energy spent in producing a new shoot through sexual reproduction is more or less 10000 times more than that of vegetative multiplication. Obviously in a region where carbohydrates, the basic source of energy is a limiting factor, vegetative reproduction is very common. It is reported that those species which reproduce by seeds take several years longer to reach the seed producing stage than the same species growing in hotter climate. Some of the cold desert plants are annual or monocarpic i.e. producing the fruits and seeds only once. *Hypericum leptocarpus, Pleurogyna brachyanthera, Gentiana tenella, G. aquatica, G. humilis, G. rockhillii, Salsola collina, S. kali, Halogeton glomeratus*, etc. belong to this category. Some perennial species are also monocarpic but survive only for 2-3 seasons. They have large tap roots full of stored food material collected in the first season for flowering and fruiting in the next year. Cold climates are not favourable for sexual reproduction due to very low temperatures, short growing season and poor nutrient availability. In order to make sexual reproduction process easy and effective these plants therefore have evolved certain physiological adaptations which help them during the various stages of reproduction like development and formation of ovule, pollen, attracting the pollinating agents etc. for successful pollination and seed formation.

Use of solar energy for the development and formation of ovules and pollengrains has been studied rather very critically by Knutson, 1981 ; Crawford, 1982.

The green leaves of plants make use of sunlight for producing carbohydrates etc. through the process of photosynthesis, at the same time the flowers use this energy for heating purposes which accelerates the growth of pollen and seeds. Some of the flowers also have ultra-violet patterns which attract the pollinators. The bowl or saucer-shaped flowers of *Anemone, Ranunculus, Saxifraga* and many others are usually heliotropic and have highly reflective inner surface of petals ; in the central region of these flowers lies carpels and many stamens. This shape acts as small dish antenna focussing the reflected light and heat on the centre of the flower where stamens and carpels effectively retain the heat gained through such radiations. This energy accumulation by flowers helps in pollination. It has also been reported that the visiting insects on a flower for nectar feeding also absorb and accumulate heat from flowers and through this process these insects develop temperature as high as 30-32 degrees in excess of the atmospheric temperature. Thus, the heat so acquired enhances their metabolic activities including reproduction and obviously insects seek out the warm flowers in cold desert areas. On the other hand, plants could conserve energy by accomplishing pollination at the same time providing loss food in the form of nectar. In this way a sort of symbiotic relationship is formed between the insect and plants in cold desert areas.

Flower colour also plays an important role in the process of sexual reproduction as brilliantly coloured flowers can attract insects for pollination. Most of the cold desert plants like *Delphinium, Aconitum, Meconopsis, Corydalis, Geranium, Astragalus, Oxytropis, Potentilla, Saxifraga, Primula, Gentiana* etc. produce bright, sparkling flowers of red, yellow, blue, violet or purple. These plants spend much of their energy to produce large, attractive flowers, no matter how big the plant is. Gentians, saxifragas, campanulas, anemones, primulas, etc. have large flowers as compared to the size of the plant.

Seed production is also quite enormous in cold desert species to overcome the perennial drought, heavy snowfall, eroding slopes with shifting sands and stones, and over grazing. Only a few seeds ultimately succeed in establishing. Therefore, most of the species have switched over to vegetative reproduction through bulbs, bulbils, runners, stolons, offsets, and through production of new branches from rootstocks.

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Plate 1: Tufts of *Corydalis flabellata* and *Nepeta floccosa* on slopes near Kivari on way to Chumathang (Ladakh).

Plate 2 *Lonicera semenovii* Regel

Plate 3: *Indigofera dosua* Buch.-Ham.

Plate 4: *Arnebia euchroma* (Royle) Johnston

Plate 5: *Astragalus candolleanus* Royle ex Benth

Plate 6: *Acantholimon lycopodioides* (Girard) Boiss.

Plate 7. *Arenaria bryophylla* Fernald

Plate 8: *Gentiana algida* Pall. var. *nubigena* (Edgew.) Kusn.