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Current Status of the Systematics of *Astragalus* L. (Fabaceae) with Special Reference to the Himalayan Species in India

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ABSTRACT: *Astragalus* is considered one of the most diverse genera in the family Leguminosae (*nom. alt*. Fabaceae). Although a large number of works have been carried out on the genus, no monograph is available except some regional accounts and revisions chiefly at sectional level. It may be due to the sheer size of the genus (ca. 3000 spp.) and diverse nature, the genus is quite variable in habit and habitats, size of the plants, nature of indumentums, stipules, leaf rachis, types of inflorescence, relative length of petals, pods etc. Usually, genus is divided into eight to ten subgenera and more than 245 sections. In recently conducted molecular phylogenetic studies it has been shown that none of the subgenera and large sections are monophyletic. However, it has been clearly demonstrated that *Astragalus* is monophyletic except some outlier species. The chromosome numbers are also quite interesting and significant in *Astragalus* for its phylogenetic studies. There is a strong correlation between its geographic distribution and chromosome numbers. Currently about 80 species have been recorded from India chiefly from the Himalayas. Except some of our recent publications, not much studies have been carried out on the genus in India after 'The Flora of British India'. *Astragalus* is not of much economic importance, however, some of its species are well known for commercial gum tragacanth production especially in Iran and China. In India, *A. candolleanus* is a well known drug as 'Rudanti' or 'Rudravanti' used for tuberculosis, skin diseases, coughs and blood purifier. The aim of this article is to review the entire work carried out on *Astragalus* and to bring out scattered information at one place for better understanding of the subject and to find out the future prospective of the research in India on the genus.

KEY WORDS: Taxonomy, Phylogeny, *Astragalus*, India, Leguminosae.

INTRODUCTION

Astragalus L., the largest genus in Angiosperms with about 2500-3000 species in the world, is considered a remarkable example of adaptive radiation. It occurs primarily in cold to warm arid and semiarid mountainous regions of the Northern Hemisphere and South America (Fig. 1). The genus is most diverse in the Irano-Turkish region of South-Western Asia (1000-1500 spp.), the Sino-Himalayan Plateau of South Central Asia (ca. 550 spp.) and the Great Basin and Colorado Plateau of Western North America (ca. 450 spp.). However, the centre of origin and diversity of *Astragalus* is Eurasia, specially the drier mountainous parts of South-Western and South-Central Asia and the Himalaya (Gillett, 1963; Podlech, 1986, 1998, 1999a; Lock and Simpson, 1991; Mabberley, 1997; Maassoumi, 1998; Lock and Schrire, 2005; Wojciechowski, 2005).

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The critical evaluation of all species available at various herbaria and extensive field survey reveal that ca. 80 species of *Astragalus* are found in India. The genus is mainly distributed in the temperate and alpine regions of the Himalayas at an altitudes ranging from (2000-) 3000-6000 m (Fig. 2). Only a few annual species of *Astragalus*, like *A. vogelii* ssp. *fatimensis* Maire (now in genus *Podlechiella*), *A. ophiocarpus* Benth. ex Bunge (now in genus *Ophiocarpus*) and *A. tribuloides* Delile extend their distribution in tropical and subtropical regions of Punjab and Haryana provinces. The maximum diversity of the species (ca. 65 spp.) lies in the dry cold deserts of Leh & Ladakh (Jammu & Kashmir) and Lahul-Spiti (Himachal Pradesh) in the North-West Himalaya. On the other hands, the more moist and humid East Himalaya harbors only ca. 16 species of *Astragalus* (Chaudhary et al., 2007a).

It has been observed that out of 80 species occurring in India (Table 1), about 12 species (Table 2) are not found in Indian herbaria and they have also not been collected during the recent investigations (Chaudhary and Srivastava, 2007) while they have been recorded in previous publications (Ali, 1958,

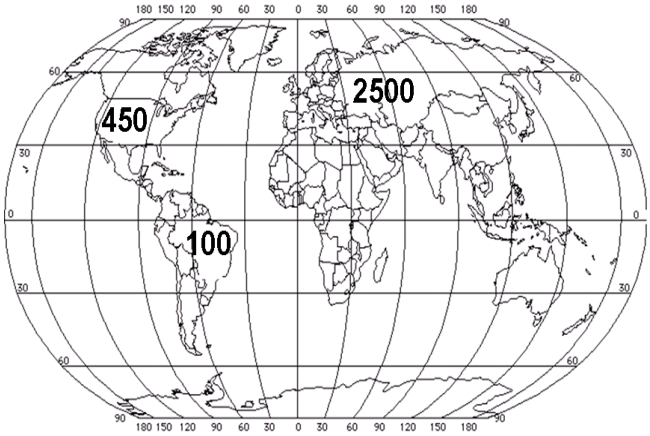

Fig. 1. Major centers of distribution of *Astragalus* in the world.

Fig. 2. Distribution sites of *Astragalus* species in India (•).

Table 1. The current sectional assignment of the 78 *Astragalus* species in India.

Sections	Species
Aegacantha	*A. grahamianus, A. langtangensis, A. multiceps, A. oplites, A. polycanthus, A. psilocentros, A. webbianus, A. zanskarensis*
Ankylotus	*A. commixtus, A. gracilipes*
Brachycarpus	*A. densiflorus, A. melanostachys, A. thomsonii, A. sherriffii*
Caprini	*A. charguschanus, A. rhizanthus* (*A. ladakhense*), *A. pindreensis* (*A. badrinathensis*), *A. candolleanus, A. drasianus, A. malacophyllus, A. gilgitensis*
Caraganella	*A. trichocarpus*
Cenantrum	*A. floridulus, A. tecti-mundi, A. lessertiodes, A. pseudochlorostachys*
Chaetodon	*A. breviscapus*
Chlorostachys	*A. chlorostachys, A. concretus, A. emodi, , A. isabellae, A. khasianus, A. maxwellii, A. stewartii, A. xiphocarpus, A. uttaranchalensis, A. stipulatus*
Chomutoviana	*A. arnoldii*
Coluteocarpus	*A. coluteocarpus, A. coluteocarpus* ssp. *chitralensis*
Diplotheca	*A. graveolens*
Dissitiflori	*A. imitensis, A. anfractuosus*
Hemiphaca	*A. macropterus*
Hemiphragmium	*A. confertus, A. srictus, A. tenuicaulis, A. sikkimensis, A. sanjappae, A. himalayanus* (*A. maddenianus*), *A. himachalensis, A. oxyodon*
Hispiduli	*A. bakaliensis, A. scorpiurus*
Hookeriana	*A. acaulis*
Hypoglottidei	*A. tibetanus, A. gooraiensis*
Hypsophilus	*A. nivalis*
Irinaea	*A. amherstianus*
Komaroviella	*A. alpinus*
Lithophilus	*A. munroi, A. kashmirensis* (*A. turgidus*)
Malacothrix	*A. pseudo-beckii*
Phyllolobium	*A. donianus, A. heydei, A. tribulifolius, A. lachungensis*
Poliothrix	*A. leucocephalus, A. rigidulus*
Rhacophorus	*A. verus*
Sesamei	*A. tribuloides*
Sesbanella	*A. falconeri, A. falconeri* var. *pilosus, A. hoffmeisteri*
Skythropos	*A. kongrensis, A. fenzelianus, A. yunnanensis*
Synochreati	*A. peduncularis*

1961, 1977; Dhar and Kachroo, 1983; Wenninger, 1991; Sanjappa, 1992; Podlech, 1999b, 2001; Kumar and Sane, 2003). In order to know the correct distribution pattern and conservation status of these species, further studies are needed to relocate them in the nature. Based on our critical study 13 species (Table 2) have been excluded as they do not occur in the present political boundaries of India or they have been transferred to some other genera (Chaudhary, 2006c; Chaudhary and Srivastava, 2007). Six new species (*A. sanjappae* Chaudhary & Khan, *A. uttaranchalensis* Chaudhary & Khan, *A. lachungensis* Chaudhary, *A. himachalensis* Chaudhary & Rana, *A. gooraiensis* Chaudhary, *A. nainitalensis* Chaudhary) have already been described and a few more are expected from India

Table 2. List of excluded as well as those species which are not represented in Indian herbaria.

Species not available in Indian herbaria	*A. arnoldii* Hemsl. & H. Pearson, *A. breviscapus* B. Fedtsch., *A. coluteocarpus* Boiss. ssp. *coluteocarpus*, *A. fenzelianus* E. Peter, *A. gilgitensis* Ali, *A. imitensis* Ali, *A. langtangensis* Podlech, *A. polycanthus* Royle ex Benth., *A. sherriffii* Podlech, *A. tecti-mundi* Freyn ssp. *orientalis* Podlech, *A. thomsonii* Podlech, *A. yunnanensis* Franch.
Excluded species	
Species do not occur in India	*A. alistschuri* B. Fedtsch., *A. charguschanus* Freyn, *A. contortuplicatus* L., *A. flemingii* Ali, *A. iodotropis* Boiss. & Hohen, *A. pyrrhotrichus* Boiss., *A. subumbellatus* Klotz., *A. stocksii* Bunge, *A. zacharensis* Bunge
Species transferred to other genera	*A. aegacanthoides* Parker (= Caragana aegacanthoides (Parker) Chaudhary & Srivastava), *A. hosackioides* (Royle ex Benth.) Benth. (= Podolotus hosackioides Royle ex Benth.), *A. ophiocarpus* Benth. ex Bunge (= Ophiocarpus aitchisonii (Baker) Podelch), *A. vogelii* ssp. *fatimensis* (Chiov.) Maire (= Podlechiella vogelii (Webb) Maassoumi & Kaz. Osaloo ssp. fatimensis (Chiov.) Maassoumi & Kaz. Osaloo

(Chaudhary and Khan, 2005d, 2006; Chaudhary, 2006, 2007d; Chaudhary et al., 2007a, b). Apart from the new species, *A. bakaliensis* Bunge, *A. pseudobeckii* Sirj. & Rech. f. have been reported from India for the first time (Chaudhary and Khan, 2005c). For many species (i.e. *A. alpinus* L., *A. arnoldii* Hemsl. & Pearson (= *A. orotrephes* Smith), *A. donianus* DC., *A. drasianus* Chowdhery et al., *A. emodi* Steud., *A. khasianus* Benth. ex Bunge, *A. kongrensis* Benth. ex Baker, *A. lessertioides* Benth. ex Bunge, *A. leucocephalus* Grahm. ex Benth., *A. tribulifolius* Benth. ex Bunge and *A. xiphocarpus* Benth. ex Bunge) new distributional sites have also been discovered within and outside the country (Chaudhary and Khan, 2003, 2004, 2005a; Chaudhary, 2005, 2006b). During the investigation, 14 species have been found endemic to India and 11 species as threatend in Indian region as they are very poorly represented in Indian herbaria by only a few very old collections as well as they have also not been collected during the present investigation (Table 3). Recently, Chaudhary et al. (2007a) have provided a very elaborate taxonomic account of endemic species found in India. The majority of these endemic species except *A. himachalensis* Chuadhary & Rana, *A. kashmirensis* Bunge and *A. uttaranchalensis* Chaudhary & Khan are rare in the nature. *A. emodi* Steud., *A. teniucaulis* Benth. ex Bunge and *A. xiphocarpus* Benth. ex Bunge have been reinstated as correct species (Chaudhary and Khan, 2004, 2005b, c) while in some previous works they have been treated as synonyms under *A. maxwellii* Royle ex Benth., *A. sikkimensis* Benth. ex Bunge and *A. concretus* Benth. respectively (Wenninger, 1991; Kumar and Sane, 2003). Similarly, A. *hoffmeisteri* var. *pilosus* Ali has been merged under *A. falconeri* Bunge (Wenninger, 1991), while the same has been maintained at varietal rank (*A. falconeri* var. *pilosus* (Ali) Chaudhary) in Chaudhary et al. (2007a). Further, the critical study of type specimens of three newly described species *A. turgidus* Rao & Balodi, *A. ladakhense* Rao & Balodi and *A. badrinathensis* Sharma et al. reveals that they come within the range of variation of quite variable species *A. kashmirensis* Bunge, *A. rhizanthus* Royle ex Benth. and *A. pindreensis* (Benth. ex Baker) Ali respectively and treated as synonyms in this work.

Although the entire genus is quite polymorphic, however, a few species exhibit tremendous amount of morphological variations within species. *A. himalayanus* Klotz. is one of such species in which at least two to three types of populations/plants have been observed in the nature. Usually, the calyx lobes are shorter than tube in this species, while in some populations the lobes are equal to or slightly longer than tube and identified as *A. maddenianus* Benth. ex Baker. Wenninger (1991) has merged this species under *A. himalayanus* klotz. due to availability of intermediate forms. Further, the hairs also vary from appressed to spreading in different populations. Apart from these, the size of the plants varies exceptionally in the species. Sometimes these variations are so pronounced that they look quite different from typical species. The molecular studies of these populations will be quite useful to understand the variation pattern within species. Recently, *A. himachalensis* Chaudhary & Rana has been segregated from *A. himalayanus* Klotz. based on morphological and molecular markers (Chaudhary et al., 2007b).

Similarly, *Astragalus rhizanthus* Royle ex Benth. is an another incredibly variable species in the genus. Podlech (1988) has treated *A. pindreensis* (Benth. ex Baker) Ali and *A. candolleanus* Royle ex Benth. as infraspecific categories and *A. malacophyllus* Benth. ex Bunge as a synonym under *A. rhizanthus* Royle ex Benth. However, based on our field and herbarium studies we have found that *A. malacophyllus* Benth. ex Bunge is distinctly differs from *A. rhizanthus* Royle ex Benth in stem length, density of hairs, number of flowers in each inflorescence and peduncle length. Ali (1961, 1977) has also treated these species as correct species. We are also conducting molecular studies on these species/taxa to

Table 3. Endemic and Threatened species of *Astragalus* L. in India.

Name	Distribution	Endemic to India	Abundance scale
A. acaulis Baker ex Hook. f.	Sikkim, Darjeeling	No	EN
A. alpinus L.	Jammu & Kashmir	No	CR
A. arnoldii Hemsl. & H. Pearson	Jammu & Kashmir	No	CR
A. breviscapus B. Fedtsch.	Jammu & Kashmir	No	CR
A. drasianus Chowdhery et al.	Himachal Pradesh, Jammu & Kashmir	Yes	Rare
A. falconeri var. *pilosus* (Ali) Chaudhary	Jammu & Kashmir	Yes	Rare
A. floridulus Podlech	Sikkim	No	CR
A. gooraiensis Chaudhary	Jammu & Kashmir	Yes	Rare
A. heydei Baker	Jammu & Kashmir	No	CR
A. himachalensis Chaudhary & Rana	Himachal Pradesh	Yes	Frequent
A. isabellae Dunn	Jammu & Kashmir	Yes	Rare
A. kashmirensis Bunge	Jammu & Kashmir	Yes	Frequent
A. khasianus Benth. ex Bunge	Meghalaya	No	EN
A. kongrensis Benth. ex Baker	Sikkim	No	VU
A. lachungensis Chaudhary	Sikkim	Yes	Rare
A. maxwellii Royle ex Benth.	Jammu & Kashmir	Yes	Rare
A. nainitalensis Chaudhary	Uttarakhand	Yes	Rare
A. oxyodon Baker	Jammu & Kashmir, Himachal Pradesh,	Yes	Rare
A. pseudo-chlorostachys Ali	Jammu & Kashmir	No	CR
A. psilocentros Fisch.	Jammu & Kashmir	No	CR
A. sherriffii Podlech	Jammu & Kashmir	Yes	Rare
A. stewartii Baker	Jammu & Kashmir	No	CR
A. tenuicaulis Benth. ex Bunge	Sikkim, Uttarakhand	Yes	Rare
A. trichocarpus Grah. ex Benth.	Himachal Pradesh, Uttarakhand	Yes	Rare
A. uttaranchalensis Chaudhary & Khan	Uttarakhand	Yes	Frequent

resolve the taxonomic problems pertaining to the correct identity of the species and their relationships.

This paper briefly reviews the research progress made in *Astragalus* from the time of its establishment to date both at morphological and molecular levels, with special reference to India. It has been realized that more collection of plant materials especially from remote areas and study of taxonomically difficult complexes and allied groups by using molecular tools will certainly throw new light on the understanding of the genus.

METHODOLOGY

The senior author is studying the taxonomy and diversity of the genus *Astragalus* in India since 2001. To carry out such studies nine tours have been conducted during 2001 to 2006 to different parts of the Himalayas in Jammu and Kashmir (Leh and Ladakh), Himachal Pradesh (Lahul-Spiti, Manikaran), Uttarakhand (Mussoorie, Deoban, Kanasar, Gangotri, Bhojwasa, Gaumukh etc.) and Sikkim (Lachen, Thangu, Giagaon, Lachung, Yungthang etc.) to collect the plants as well as to know their conservation status and record the ecological information. All collected specimens have been deposited to the herbarium of National Botanical Research Institute, Lucknow (LWG) for future reference after processing following Jain and Rao (1977). The type specimens of newly described species by authors have also been deposited at BSD and CAL. Along with plant specimens, the fresh leaf tissues have also been collected in silica gel for DNA isolation (Chase and Hills, 1991). Till date about 122 accessions belonging to 32 species of *Astragalus* have been gathered and DNAs have been extracted for further molecular studies. All extracted DNA have been kept in -20℃ deep freezer in Molecular Taxonomy Laboratory at National Botanical Research Institute, Lucknow.

In addition to the study of specimens collected during the present study, all available specimens at BSD, BSHC, CAL, CDRI, DD, K (partially), LBG, LWG, were also thoroughly examined to find out the correct species diversity of *Astragalus* within India and to note the range of variations within and between the species. Also, a large number of herbarium specimens, type specimens and Cibachromes (photographs of Type specimens) were procured on loan from BM, BSD, CAL, K, P for the study. All species were thoroughly studied and variations were recorded after examining several specimens under each species to know the limit of the species. In addition to preparing elaborate description, the data were also gathered on phenology, distribution, conservation status etc.

MORPHOLOGICAL DIVERSITY AND SURVIVAL STRATEGIES

The genus exhibits great morphological variability, particularly in its habit and habitats, size of the plants, nature of indumentums, stipules, leaf rachis, types of inflorescence, relative length of petals, pods etc. Due to changes in the habitats and ecological factors diversity within species are also enormous. Among Indian species *Astragalus rhizanthus* Royle ex Benth., *A. zanskarensis* Benth. ex Bunge, *A. tecti-mundi* Freyn, *A. himalayanus* Klotz., *A. kashmirensis* Bunge, *A. leucocephalus* Grah. ex Benth. etc. have been found morphologically quite variable. The species of *Astragalus* prefer to grow on the open mountain slopes, flat grounds, river sides, agriculture fields in very dry, hard, stony or sandy soils among grasses, boulders and in barren lands. The genus is quite sensitive to their local and microclimates. The slight changes in edaphic and climatic factors bring out drastic modifications in the general appearance and texture of the plants, which pose lot of problems in characterization and circumscription of the species. The plants of same species such as *Astragalus kashmirensis* Bunge, *A. leucocephalus* Grah. ex Benth., *A. rhizanthus* Royle ex Benth., and *A. gracilepes* Benth. ex Bunge etc., growing in different populations look quite different due to these changes. The species of *Astragalus* are herbs or shrubs with underground perennial woody rootstock and herbaceous or woody annual aerial portion. The majority of the species are perennial except a few annuals *A. vogelii* ssp. *fatimensis* Maire, *A. ophiocarpus* Benth. ex Bunge., *A. tribuloides* Delile. The habit of the plants varies from prostrate to erect. As the habitats of *Astragalus* are quite hostile due to very cold-dry climate, hard and rocky soils and high velocity of wind, most of the species have developed tufted or cushion-forming habit with deep root system and profuse prostrate or erect branches (Fig. 3) which cover the landscape and not only protect the soil from degradation and erosion, but also provides ability to retain some moisture among themselves to counter the high wind velocity (Chowdhery and Rao, 1992).

Since the species grow in very hard and dry soils, the underground portion of the plants become perennial, woody and deep rooted in search of moisture and nutrition. These rootstocks which are usually longer than upper portion of the plants and may reach more than 30 cm long, are capable of penetrating rock crevices and fissures to provide firm anchorage to the plants against the high wind velocity. The prostrate nature also enables the plants to overcome the heavy weight of snow layer and to retain the moisture. The upper herbaceous portion of the plants disintegrate every year due to cold weather after completing life cycle before the onset of snowfall. After the melting of snow, the woody rootstocks hidden under the ground again sprout into new plants. Therefore, the plants complete their life cycle (flowering and fruiting) within short span of time between July and September.

Usually, the plants are covered with dense hairs (e.g. *Astragalus kashmirensis* Bunge, *A. leucocephalus* Grah. ex Benth., *A. malacophyllus* Benth. ex Bunge , *A. munroi* Benth. ex Bunge, etc.). The dense cover of hairs acts as a thermal blanket and help in reflecting the solar radiation that reduces the harsh impact of sunrays on the plants. There are two types of hairs in *Astragalus.* In majority of the species the hairs are basally attached while in some species like *A. anfractuosus* Bunge, *A. peduncularis* Royle ex Benth., *A. nivalis* Kar. & Kir., *A. vogelii* ssp. *fatimensis* Maire they are medifixed. In a recent subgeneric classification Podlech (1982) has used this feature to divide entire Old World *Astragalus* into only two subgenera (*Cercidothrix* with medifixed hairs and *Astragalus* with basifixied hairs). The colour of hairs (black and white) is also considered important in several cases. Zarre (2003) has suggested that many micromorphological characters of hairs can be used in phylogenetic studies. The stems are generally reduced or sometimes completely absent as found in *A. arnoldii* Hemsl. & Pearson and *A. rhizanthus* Royle ex Benth. (Fig. 4).

The stipules are quite variable among different species and considered good taxonomic character for identification. They may be lateral or opposite and free or adnate to the petiole or connate. The length of adnation and connation also vary among species. The texture and venation are also important in some species in addition to the shape of the stipules. Generally, the stipules are hairy except a few species like *A. graveolens* Benth. and *A. webbianus* Benth. The leaves are paripinnately or imparipinnately compound in *Astragalus*. Usually, the leaves are imparipinnately compound with a terminal leaflet at tip. Sometimes the terminal leaflet falls early and therefore the leaves appear paripinnately compound. Ali (1977) has used this character to categorize the different groups in the genus and placed two very closely related species *A. oplites* Parker and *A. zanskarensis* Bunge in two different groups based on leaf character. However, in the present study we have observed similar leaves (imparipinnate) in both the species. The species in which the leaf rachis are hard and spiny, the leaves are paripinnately compound or they look so due to quite early fall of

Fig. 3. *Astragalus multiceps* Wall. ex Benth. (regeneration of tufted plants from the woody rootstock after the snow melts).

Fig. 4. *Astragalus rhizanthus* Royle ex Benth. (stemless and caespitose habit of the plant).

terminal leaflet. Generally, the leaf rachis is filiform and herbaceous with a longitudinal groove on upper side, however, in spiny species the rachis become hard, almost terete and persistent with spiny tip. Sometimes the terminal leaflet becomes quite reduced in the form of a linear structure or thread. The spiny rachis and minute leaflets are considered xeric characters that reduce the rate of transpiration in the plants.

The inflorescence is usually raceme, capitate raceme or head. The number of flowers in each raceme and length of peduncle are important taxonomic characters in different species of *Astragalus*. This character has been applied by Baker (1876) to distinguish subgenera of the genus. The length of bracts in proportion to pedicel length is also useful in many species. The flowers are usually purple-pink or yellow or occasionally white. The calyces are very significant trait in the genus. They are campanulate or tubular with 5 teeth. They may be hairy or glabrous, faintly veined to prominently veined, memebranous to herbaceous. The length of teeth in proportion to the tube is very distinctive character among species. In some species the fruiting calyx becomes inflated as found in *A. nivalis* Kar. & Kir. The comparative length of the petals plays vital role in the identification of the taxa at sectional and species level. The stamens are usually diadelphous (9+1) with vexillary stamen free from staminal sheath. However, very interestingly in some species like *A. himalayanus* Klotz., *A. oxyodon* Baker, *A. donianus* DC., the stamens are closed monadelphous. The apical portion of the staminal sheath is obtuse or sometimes more or less truncate while in *A. nivalis* Kar. & Kir it is emarginate like apex of its wing petals. The pods are also quite diverse in shape and

size, stipe length, unilocular and bilocular nature, indumentum, number of seeds per pod etc. The shape of the seeds in the genus is oblong, ovoid, orbicular or square reniform. The surface is smooth in low magnification, however, in the SEM study it shows different ornamentations like reticulate, double reticulate, depressed pitted or regulate (Karamian and Ranjbar, 2005). In the present study the seeds of 13 species have been investigated under SEM (unpublished), which adds some more type of ornamentations on the seed surface.

BRIEF HISTORY OF THE GENUS

Since the time of establishment of the genus a large number of taxonomic works have been done globally. Here it is not relevant to provide details of all such studies, however, some important works carried out worldwide as well as in India have been summarized briefly to provide the clear understanding of the genus.

Astragalus was first described by Linnaeus (1753) in his '*Species Plantarum*', including 33 species. He treated *Phaca* L. (very close to *Astragalus*) as a separate genus with 3 species. He identified *Astragalus* with bilocular pods due to presence of a longitudinal septum and *Phaca* with unilocular pods. Later on *Phaca* was merged with *Astragalus* due to availability of intermediate forms of the pod septum. Before the description by Linnaeus (1753), the plants were well known for European botanist Tournefort (1700), who also identified genera *Tragacantha* (corresponds present day *Astracantha* of Podlech, 1982) and *Astragaloides* (correspondes to *Phaca* of Linnaeus, 1753). Linnaeus (1753) included *Tragacantha* into *Astragalus* and the status remains so till Podlech (1982) (Fig. 5).

After Linnaeus (1753) the first monographic work was carried out by Pallas (1800) in his *'Species Astragalorum'* followed by the publication of '*Astragalogia*' of De Candolle (1802) who recognized three genera by splitting Linnaean *Astragalus* into *Astragalus* and *Oxytropis* (Fig. 5). He characterized *Astragalus* with obtuse keel and bilocular pods due to septum arising from ventral suture, *Phaca* with obtuse keel and unilocular pods and *Oxytropis* with mucronate keel at apex and bilocular pods due to septum arising from dorsal suture. Subsequently, a large number of studies have been carried out on both the New World *Astragalus* (Torrey and Gray, 1838; Gray, 1864; Jones, 1923; Rydberg, 1929; Johnston, 1938, 1947; Barneby, 1964; Gomez-Sosa, 1979, 1981, 1982) and the Old World *Astragalus* (Bunge, 1868, 1869; Boissier, 1872; Gontscharov, 1946; Podlech, 1982, 1983; Zarre and Podlech, 1997). Among these the work of Rydberg (1929) differs from others as he has divided *Astragalus* into 28 genera and many sections. However, this work was not accepted by later workers. Barneby's (1964) work considered one of the best taxonomic work so far published on the genus has provided exhaustive taxonomic account of the North American *Astragalus* in his monumental work *'Atlas of North American Astragalus'*. In addition to above quoted work, recently several revision work chiefly at sectional level have been accomplished by D. Podlech and others on the Old World *Astragalus* (Deml, 1972; Agerer-Kirchoff, 1976; Podlech 1984, 1988, 1990, 1991, 1999b, c, 2001; Wenninger, 1991; Tietz and Zarre, 1994; Zarre, 2000; Podlech and Xu, 2004, 2007). Podlech (1983) for the first time after Tournefort (1700) excluded a large number of spiny *Astragalus* from *Astragalus* and placed them into a separate genus *Astracantha* Podlech. Hoewver, Zarre and Podlech (1997) again after critical assessment of morphology and anatomy resurrected *Astracantha* to *Astragalus* (Fig. 5).

The first systematic account of Indian *Astragalus* was presented by Baker (1876) in '*Hooker's Flora of British India*.' He included 70 species from the then British India of which only 50 species were known to occur in the present India. Ali (1961) revised *Astragalus* of W. Pakistan and N. W. Himalaya. After Baker (1876), no serious attempt was made to revise the Indian *Astragalus*, except some scattered work (Parker, 1921; Rao and Balodi, 1989; Sharma et al., 1990; Chowdhery et al., 1997), while, the examination of herbarium specimens at different herbaria and plants in natural habitats revealed that there are considerable taxonomic and identification problems exist in the genus. Further, the addition of recent collections adds several new information to the genus. Sanjappa (1992) and Kumar and Sane (2003) in their check-lists have enumerated 71 and 78 species of *Astragalus* respectively based on earlier reports. In view of this, a taxonomic revision was initiated by senior author to provide the current taxonomic account of the Indian *Astragalus* that has resulted into the publication of a dozen of papers.

CLASSIFICATION

Astragalus L. belongs to the subfamily Papilionoideae in the family Leguminosae (*nom alt.* Fabaceae) under the subtribe *Astragalinae* of the tribe *Galegeae* (Polhill, 1981; Lock and Schrire, 2005). The other genera which fall under *Astragalinae* are *Halomodendron, Caragana,*

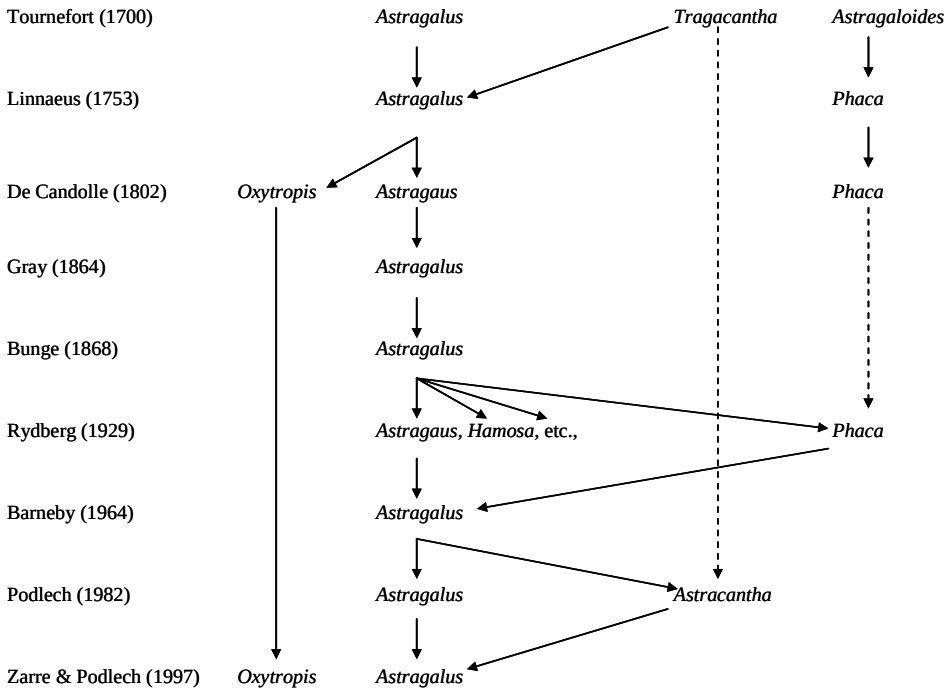

Fig. 5. Taxonomic history of *Astragalus* (after Wojciechowski et al., 1999 with some modifications).

Calophaca, Chesneya, Alhagi, Glueldenstaedtia, Biserrula and *Oxytropis*. Among them, *Oxytropis* DC. is generally considered the most closely related genus to *Astragalus* in their gross morphology and chiefly differentiated only with the apex of keel petal (obtuse in *Astragalus* and apiculate in *Oxytropis*). In Linnaeus's (1753) work, *Oxytropis* was included in *Astragalus*. Both of these genera co-exist in the same environment and habitats. Based on cytological (Ledingham, 1957, 1960) and morphological evidences it has been suggested that *Oxytropis* was evolved in Eurasia and nested within the Old World *Astragalus*.

Usually the genus has been divided into eight to ten subgenera in the Old World. Bunge (1868, 1869) segregated entire Old World *Astragalus* into 10 subgenera whereas Boissier (1872) and Gontscharov et al. (1946) accepted eight and nine subgenera respectively (Table 4). Gontscharov et al. (1946) distributed the members of subgenus *Pogonophace* among subgenera *Phaca* and *Trimeniaeus*. Baker (1876) divided Indian *Astragalus* into 10 subgenera (Table 5) chiefly based on morphological characters like: plants annual or perennial, herbs or shrubs, stemmed or stemless, hairs basifixed or medifixed, stipules adnate to the petiole, free or connate, leaf rachis herbaceous, spiny, indurate, persistent or deciduous, inflorescence head or raceme, calyx gibbous or simple, the proportion of petal length, stigma glabrous or hairy, pods unilocular or bilocular etc. He created a new subgenus *Trichostylus* and treated subgenus *Podolotus* (now in the genus *Lotus*) in *Astragalus*. Baker (1876) placed the members of subgenus *Calycocystis* under *Cercidothrix*. Ali (1961) recognized only eight subgenera. He merged subgenera *Trichostylus* in *Pogonophace* and *Trimeniaeus*, *Hypoglottis* and *Phaca* in *Astragalus (= Phaca).* However, in Flora of West Pakistan, Ali (1977) has divided the genus into eight groups without giving any formal names to these groups. Suddenly, Podlech (1982) combined these subgenera only into two subgenera of perennial species of Old World *Astragalus* on the basis of types of hairs, namely subgenus *Astragalus* with basifixed hairs (*Trimeniaeus, Calycophysa, Caprinus, Hypoglottis*, and *Phaca*) and *Cercidothrix* with medifixed hairs (*Calycocystis, Epiglottis* and *Cercidothrix*). He (Podlech, 1983) also excluded 214 thorny species from *Astragalus* and placed them into a new genus *Astracantha* Podlech which corresponds closely to subgenus *Tragacantha* Bunge (Table 4). Recently, Zarre and Podlech (1997) reunited *Astracantha* to *Astragalus* under the subgenus *Astragalus* (sensu Podlech, 1982). Later on, he (Podlech, 1994) recognized a third subgenus *Trimeniaeus* to accommodate annual species except *A. vogelii* (Webb) Bornm. which has medifixed hairs. Recently, Maassoumi (1998) has recognized only eight subgenera by placing species of *Caprinus* and *Pogonophace* to *Phaca, Trimeniaeus* and

Table 4. Subgeneric classification of the Old World *Astragalus.*

Bunge (1868)	Boissier (1872)	Baker (1876)	Ali (1961)	Gontscharov (1946)	Podlech (1982, 1983, 1994)	Maassoumi (1988)
Phaca	*Phaca*	*Phaca*		*Phaca*		*Phaca*
			Caprinus	*Caprinus*		
Hypoglottis	*Hypoglottis*	*Hypoglottis*		*Hypoglottis*		*Hypoglottis*
Trimeniaeus	*Trimeniaeus*	*Trimeniaeus*		*Trimeniaeus*	*Trimeniaeus*	*Trimeniaeus*
Tragacantha	*Tragacantha*	*Tragacantha*	*Tragacantha*	*Tragacantha*	*Astracantha* (as genus)	*Tragacantha*
Cercidothrix	*Cercidothrix*	*Cercidothrix*	*Cercidothrix*	*Cercidothrix*	*Cercidothrix*	*Cercidothrix*
Calycophysa	*Calycophysa*	*Calycophysa*	*Calycophysa*	*Calycophysa*		*Calycophysa*
Calycocystis	*Calycocystis*	*Calycocystis*	*Calycocystis*	*Calycocystis*		*Calycocystis*
	Epiglotis			*Epiglotis*		*Epiglotis*
Pogonophace		*Pogonophace*	*Pogonophace*			
Myobroma	*Myobroma*		*Astragalus*		*Astragalus*	
Aegacantha	*Aegacantha*	*Podolotus*	*Podolotus*			
		Trichostylus				

Table 5. Distribution of *Astragalus* species among subgenera (after Baker, 1876).

Subgenera	Species
Trichostylus Baker	*A. heydei* (*A. hendesoni*)
Pogonophace Bunge	*A. amherstianus, A. subumbellatus, A. scorpiurus, A. donianus* (*A. pycnorhizus*), *A. kongrensis, A. tribulifolius, A. falconeri, A. hoffmeisteri* (*A. adesmiaefolius*), *A. trichocarpus*
Trimeniaeus Bunge	*A vogelii* (*A. fatimensis, A. prolixux*), *A. tribuloides, A. gracilipes.*
Podolotus Royle (*now in genus Lotus*)	*A. hosackiodes*
Hypoglottis Boiss.	*A. confertus, A. rigidulus, A. alpinus, A. tibetanus, A. lessertiodes, A. strictus, A. oxyodon, A. densiflorus, A. melanostachys, A. tenuicaulis, A. sikkimensis, A. himalayanus, A. maddenianus, A. kashmirensis, A. floridus, A. leucocephalus, A. munroi*
Phaca Bunge	*A. macropterus, A. chlorostachys, A. stewartii* (*A. bakeri, A. longicaulis*), *A. maxwellii* (*A. ciliolatus*), *A. xiphocarpus, A. emodi, A. khasianus, A. coluteocarpus, A. tecti-mundi* (*A. frigidus*), *A. concretus, A. isabellae, A. graveolens, A. stipulatus*
Myobroma Bunge	*A. rhizanthus* (*A. anomalus, A. badrinathensis*), *A. rhizanthus var. pidreensis, A. rhizanthus ssp. candolleanus, A. drasianus, A. acaulis, A. webbianus, A. flemingii* (*A. bakuensis*), *A. pyrrhotrichus, A. malacophyllus,*
Aegacantha Bunge	*A. psilocentros, A. grahamianus, A. oplites, A. multiceps* (*A. bicuspis*), *A. zanskarensis*
Tragacantha Bunge	*A. verus* (*A. strobiliferus*)
Cercidothrix Bunge	*A. peduncularis, A. navalis, A. anfractuosus* (*A. subuliformis, A. subulatus*)

Cercidothrix (Table 4). Barneby (1964) has distributed North American *Astragalus* into seven 'Phalanxes' (informal rank equivalent to subgenus). However, subgeneric classifaction for South American species is not available till date.

Although, it is not possible to comment on any of these classifications after examining only a few numbers of species in the genus, however, the sectional division of the genus seems more natural than subgeneric classification. The characters used for separating subgenera sometimes bring closely allied species into different subgenera. Baker (1876) has placed *A. malacophyllus* Benth. ex Bunge and *A. kashmirensis* Bunge in two different subgenera while morphologically they are very close to each other. On the other hands, *A. coluteocarpus* Boiss. is much closed to *A. chlorostachys* Lindl. in gross morphology and hence both have been placed in the same subgenus *Phaca* (sensu Baker, 1876). While, former differs from later in hairy stigma a characteristic of subgenus *Pogonophace* (*sensu* Baker, 1876). However, Wenningr (1991) has remarked that hairy stigma has evolved at many times in the genus. The molecular studies have also proved that not a single subgenus in *Astragalus* is monophyletic (also see phylogeny).

Furthermore, the subgenera have been divided into sections. According to some recent treatments there are over 150 sections have been recognized in the Old World and ca. 93 sections in the New World (Barneby, 1964; Podlech, 1986) in which many are poorly delimited and untenable. Based on our critical taxonomic study, the Indian species have been distributed among 29 sections (Table 1) in which the majority of the species fall under the sections *Aegacantha, Caprini* and *Chlorostachys*. The placement of the species among different section varies from worker to worker. Among all sections available in India, section *Chlorostachys* (*sensu* Wenninger, 1991) seems more heterogenous group. The placement of *A. falconeri* Bunge and *A. hoffmeisteri* (Klotz.) Ali in the section *Chlorostachys* needs further study to ascertain their position. Ali (1961, 1977) has placed them in the section

Sesbanella. *A. coluteocarpus* also differs from other members of section *Chlorostachys* in keel petal and stigma and hence, Ali (1961, 1977) has placed it in a separate section *Coluteocarpus*. *A. graveolens* Buch.-Ham. ex Benth. has also been placed in section *Diplotheca* similarly, *A. stipulatus* D. Don ex Sims also appear unsuitable in this section due to its foliaceous connate stipules. *A. trichocarpus* Grah. ex Benth. should also be placed in some other section. Ali (1961, 1977) has treated it under section *Caraganella* while Baker (1876) has placed in different subgenus *Pogonophace* based on hairy stigma. Chaudhary and Khan (2005b) have recognized only *A. chlorostachys* Lindl., *A. concretus* Benth., *A. emodi* Steud., *A. isabellae* Dunn, *A. khasianus* Benth. ex Bunge, *A. maxwelli* Royle ex Benth. and *A. xiphocarpus* in the section *Chlorostachys* in India. The recent molecular study (Kazempour Osaloo et al., 2005) has also not supported the monophyletic nature of section *Chlorostachys* (sensu Wenninger, 1991).

Podlech (1999a) has perhaps mistakenly attributed *A. heydie* and *A. himalayanus* to the section *Chlorostachys*. Wenninger (1991) has placed them into section *Phyllolobium* along with *A. tribulifolius* Benth. ex Bunge and *A. donianus* DC. The section *Phyllolobium* is charactersied by non-interconnecting keel and wing petals and ciliate style at apex. In these morphological characters this section is very close to subtribe *Coluteinae*. In the molecular study the section *Phyllolobium* (sensu Wenninger, 1991) has been demonstrated as monophyletic which nested with *Coluteinae* (Kazempour Osaloo et al., 2005). Our study reveals that in *A. himalayanus* Klotz. the style distinctly lacks hairs and spur (interconnecting device) is absent only in wing petals. Ali (1977) has placed *A. himalayanus* Klotz. in the section *Hemiphragium* along with *A. oxyodon* Baker, *A. strictus* Grah. ex Benth. and *A. confertus* Benth. ex Bunge. The further molecular study of the section *Phyllolobium* including *A. himalayanus* Klotz. and its allied *A. oxyodon* Baker will certainly reveal some different picture of the section. Wenninger (1991) has not included *A. oxyodon* Baker under section *Chlorostachys*.

Podlech (1988) has placed *A. webbianus* Grah. ex Benth. under section *Caprini* , however, it looks more close to section *Aegacantha* in the spiny nature of leaf rachis. This needs to be investigated further by molecular study. Kazempour Osaloo et al. (2003) on the basis of molecular study have shown that the large section *Caprini* is also not monophyletic.

MOLECULAR PHYLOGENY

Astragalus is not only the largest in numbers rather it is also considered one of the most diverse and taxonomically difficult genera in legumes. The delimitation of taxa at various taxonomic ranks poses considerable taxonomic problems in the genus worldwide. It has been widely realized that at many places morphological characters alone are not sufficient to explain the systematic relationships among *Astragalus* species. In view of this, it has become now necessary to utilize molecular marker other than morphology to solve the taxonomic ambiguities prevailing in the genus. The development of recent techniques in the fields of molecular biology and gene technology have been proved quite useful for rapid and accurate determination of phylogenetic relationships among plant species (Catalan, 1997; Sareela et al., 2007). Recently, a large number of molecular phylogenetic studies have been carried out in the genus *Astragalus* by using techniques like nrDNA ITS (nuclear ribosomal DNA internal transcribed spacer), EST (Expressed Sequence Tags) of the non-coding region of the nuclear genome, various regions of chloroplast genome (*trn*L intron, *mat*K, *ndh*F, *rpo*C1 & *rpo*C2), AFLP (Amplified Fragment length Polymorphism) and RAPD (Random Amplification of Polymorphic DNA). The methodologies adopted for phylogenetic studies have been systematically summarized in Hu et al. (1999) and many research papers quoted in this work. The main objectives of these studies were to address the following points*:* 1. Position of Astragalean clade in Legume classification, 2. Establishment of relationship of different genera in Astragalean clade, 3. Infrageneric classification at subgeneric levels and sectional levels, 4. Diversification rate and age in the genus, etc.

For the first time the molecular studies have been demonstrated that the entire 'Astragalean clade' (i. e. *Astragalus* and other closely related genera of tribe *Galegeae*) nested with the other temperate herbaceous papilionoid legumes (Fig. 6). The entire clade containing 6 tribes, 45 genera and ca. 4000 species is called 'Temperate Herbaceous Clade' or 'THC' which is also referred as the 'Inverted Repeat Lacking Clade' or 'IRLC'. The IRLC is characterized by loss of the 25 kb inverted repeat in the chloroplast genome. It has been shown that IRLC and Astragalean clades are well-supported monophyletic groups (Lavin et al., 1990; Liston and Wheeler, 1994; Liston, 1995; Sanderson and Liston, 1995; Sanderson and Wojciechowski, 1996; Doyle et al., 1997; Wojciechowski, 2000; Kajita, 2001). The nrDNA ITS sequence data (Fig. 6) have revealed that within

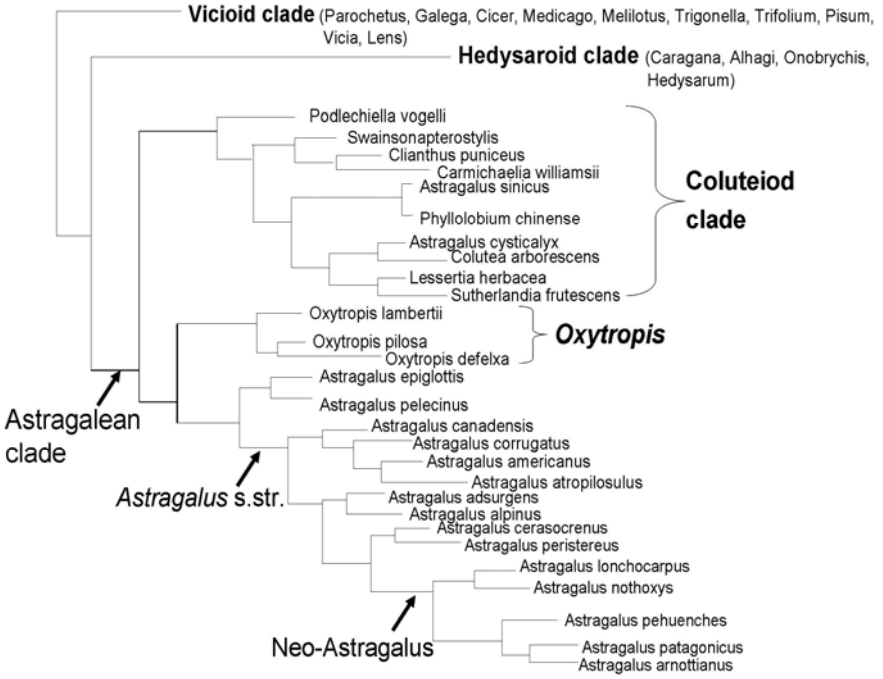

Fig. 6. Cladogram showing relationship of IR – lacking clade (after Wojciechowski, 2005).

the 'Astragalean clade,' except a few outlier species (*A. complanatus, A. sinicus, A. vogelii, A. epiglottis, A. cysticalyx*, and *A. plecinus*), all *Astragalus* species are monophyletic and form a single clade, so-called *Astragalus s. str*. (Wojciechowski et al., 1999; Kazempour Osaloo et al., 2003). It has also been demonstrated that within *Astragalus s. str*. (Fig. 6), the Old World euploid *Astragalus* (including aneuploid Old World and North American euploids) and New World aneuploids *Astragalus* (Neo *Astragalus*) distinctly form two separate groups (Liston, 1992; Sanderson and Doyle, 1993; Wojciechowski et al., 1993). North American euploid *Astragalus* species are scattered throughout the Old World group of the genus.

The recent study based on the nrDNA ITS and chloroplast gene *ndh*F sequences has revealed that monotypic segregate genera *Barnebyella* (= *A. migpo*) and *Ophiocarpus* (*A. ophiocarpus*) are nested within *Astragalus* (Kazempour Osaloo et al., 2003). However, this has not been accepted in 'Legumes of the world' (Lewis et al., 2005). Podlech (1994) has excluded them from *Astragalus* chiefly on pod characters (subglobular, laterally compressed, unilocular and one seeded in *Barnebyella* and sessile, linear, arcuately curved, unilocular and constricted between the seeds in *Ophiocarpus*). Similarly, some morphologically isolated annual species like *A. dipelta, A. schmalhausenii*, and *A. vicarius* are also come within *Astragalus* in the molecular study. More recently, Kazempour Osaloo et al. (2005) have shown that annual segregate genus *Thlaspidium* (= *A. thlaspi*) is also nested within *Astragalus s. str*.

The study of Liston and Wheeler (1994) on chloroplast *rpo*C gene revealed that *A. vogelii* is allied with *Colutea* rather than with any other *Astragalus* and finally a new genus *Podlechiella* Maassoumi and Kazempour Osaloo was erected to accommodate this species (Kazempour Osaloo et al., 2003). However, Lewis et al. (2005) have not accepted this treatment and propounded it as a premature decision. Similarly *A. complanatus, A. sinicus, A. epiglottis, A. cysticalyx, A. plecinus* also nested within coluteoid clade within Astragalean clade (Wojciechowski, 2005). However, in the study of Kazempour Osaloo, et al. (2003) *A. sinicus* has been nested within *Astragalus s. str*.

The other genus that has been segregated recently by Podlech (1983) from *Astragalus* in the Old World is *Astracantha* Podl. (= subgenus *Tragacantha* Bunge) with 214 species which is characterized by thorny cushion-forming habit, reduced inflorescence and pods and gum yielding property. These characters have also been observed in some other sections of the genus. Later on Zarre and Podlech (1997) again reunited this genus with *Astragalus* after critical study of morphological and anatomical features. The molecular study based on nrDNA ITS and chloroplast *trn*L intron sequence data has also shown that *Astracantha* is clearly nested within *Astragalus s. str*. (Wojciechowski et al., 1999).

Oxytropis is considered one of the closest relatives of *Astragalus*. Originally it was included in *Astragalus* in the Linnaean circumscription of the genus. Although it differs from *Astragalus* only in keel petal (pointed vs. obtuse) and pod septum (arising from adaxial suture vs. abaxial), but it was never considered in *Astragalus* after its separation made by De Candolle (1802). The recent molecular studies based on nrDNA ITS and chloroplast *trn*L Intron data (Wojciechowski et al., 1999; Wojciechowski, 2005) have clearly demonstrated that *Oxytropis* is monophyletic and not nested within *Astragalus s. str*., but form a separate clade within the large Astragalean clade (Fig. 6). It has also been shown that *Oxytropis* is a sister group of *Astragalus* which has Eurasian origin. On the other hand, *Caragana*, another genus of the tribe Galagae, morphologically appears very similar to *Astragalus* but forms a monophyletic group sister to Hedysaroid clade along with *Calophaca* and *Halimodendron* (Wojciechowski et al., 2000) and therefore has been placed in *Hedysareae* in the recent treatment of legumes (Lewis et al., 2005).

Linneaus (1753) segregated the genus *Phaca* based on inflated unilocular pods. Bunge (1868, 1869) retained *Phaca* as subgenus of *Astragalus*. Barneby (1964) also treated it as a *Phalanx*. The molecular data (Wojciechowski et al., 1999) do not support Linneaus's concept on genus *Phaca* and have proved that the unilocular pod has evolved many times in the genus.

The molecular phylogenetic studies (Wojciechowski et al., 1999; Kazempour Osaloo, et al., 2003) carried out to test the morphological infrageneric classification of the genus *Astragalus* have shown that none of the traditionally recognized subgenera are monophyletic. Similarly, these studies also do not support Podlech's (1982, 1983, 1991, 1994) new classification of Old World *Astragalus* based on hairs characters into only three subgenera *Trimeniaeus* (annual spp.), *Astragalus* (basifixed hairs) and *Cercidothrix* (medifixed hairs). The more recent studies (Kazempour Osaloo, et al., 2003, 2005) have revealed that some of the species rich sections like sect. *Caprini*, sect. *Chlorostachys* are also not monophyletic. Kang et al. (2003) and Kazempour Osaloo, et al. (2005) have pointed out that sect. *Phyllobium* is not nested within *Astragalus s. str*. and is a distinct monophyletic group near section *Coluteinae*. They have advocated treating sect. *Phyllolobium* (*sensu* Wenninger, 1991) as a distinct genus *Phyllolobium* Fisch. like Kang and Zhang (2004). *A. himalayanus* has been placed in section *Phyllolobium* by Wenninger (1991). Howerver, in morphological characters is differs from other member of section *Phyllolobium*. Kazempoor Osaloo et al. (2005) have not included *A. himalayanus* in their experiment which is very much needed to verify the monophyly of the sect. *Phyllolobium*.

The age and rate of diversification of species in *Astragalus* have also been studied at molecular level (Sanderson and Wojciechowski, 1996; Wojciechowski et al., 1999; Wojciechowski, 2005). These studies have shown that the rate of species diversification in *Astragalus* is higher than other angiospermic genera. More recently, Scherson et al. (2005) have observed that plasmid genes are usually not useful for phylogentic analysis in plants for closely related taxa because of low level of genetic variation. Non-coding region of the nuclear genome generally are more variable than chloroplast or mitochondrial DNA. They have developed a methodology to understand the pattern of evolution within these nuclear loci and to use this information gathered from genomics technology to understand evolutionary relationships in the Neo *Astragalus*.

All these studies have significant impact on our understanding of the relationship and diversification of the genus *Astragalus*. However, the number of samples (212 spp.) so far undertaken in these studies (Kazempour Osaloo, 2005) seems quite smaller in comparison to the large size of the genus. These molecular studies are in preliminary stage and more sampling may reveal some new findings as far as the phylogeny of the genus is concerned (Wojciechowski, 2005). The non availability of world monograph on entire genus and fossil records are another bottlenecks in the way of molecular phylogenetic studies.

Apart from these major phylogenetic investigations, recently many genetic studies have also been carried out in *Astragalus* by using RAPD and AFLP and isoenzyme study to establish the correct identity and relationship of some closely related taxa belonging to different taxonomic complexes (Luo et al., 2000; Knaus et al., 2005; Mehrnia et al., 2005; Adiguzel et al., 2006; Zarre et al., 2007; Chaudhary et al., 2007b).

In India no molecular taxonomic studies have been carried out till date. Recently, we have strated genetic study of four species of *Astragalus* (*A. rhizanthus, A. pindreensis, A. candolleanus* and *A. malacophyllus*) belonging to *Astragalus rhizanthus* complex in India. The taxonomic problems exist in the complex have already been discussed above.

CYTOLOGY

There are two main centre of distribution of *Astragalus* in the world, America (New World) and

Eurasia (Old World). There is a strong correlation between its geographic distribution and chromosome numbers. The chromosome numbers are quite interesting and significant in the genus for phylogenetic studies as they differ between Old World and New World *Astragalus* (Neo *Astragalus*). In the Old World *Astragalus* about 500 species have been examined, out of which 95% have euploid numbers (n = 8, 16, 32) and only 22 species have been so far reported as aneuploid. On the other hands, the New World *Astragalus* possesses aneuploid numbers in about 94% species (n = 11-15). Out of 250 species studied till date, only 11 species have euploid chromosome number and they all belong to North American *Astragalus* (Spellenberg, 1976). The euploids are completely absent in South American species. It is considered that New World euploid species might have migrated recently to North America from eastern Eurasia via a Behring land bridge (Wojciechowski et al., 1999). It is also interesting that the most common aneuploid numbers n = 11 in the New World is absent in the Old World *Astragalus* and similarly, the most common aneuploid numbers n = 14 in the Old World is rare in the New World.

In addition to cytology, the recent molecular data as mentioned earlier have also confirmed the monophyly of the aneuploid species of the New World, which form a well supported clade within Old World *Astragalus*. The molecular studies have shown that the North American euploid *Astragalus* species (n = 8) are scattered throughout the Old World groups of *Astragalus s. str.*, while Old World aneuploid species have restricted distribution in the genus (Wojciechowski et al., 1993, 1999; Kazempour Osaloo et al., 2003). Wojciechowski et al. (1999) have observed that the Old World aneuploid species are not closely related to the aneuploid of the New World. Based on the cytological study Ledingham (1960) suggested the New World *Astragalus* as a separate genus. However, inspite of differences in chromosome numbers and at molecular level, no morphological characters have been observed so far in the New World *Astragalus* to differentiate them from Old World *Astragalus*.

ECONOMIC IMPORTANCE

From the economic point of view the genus is of little importance. However, some species of *Astragalus* are the source of the commercial gum tragacanth. This water soluble gum is obtained by taping the stems and roots of *A. gummifer* Labill., *A. microcephalus* Willd. and many other Asiatic species of *Astragalus*. *A. verus* Oliver (= *A. strobiliferus* Royle ex Benth.) is also considered gum tragacanth yielding species in India, however, there is no evidence in recent time showing commercial utilization of this species in the country. The maximum gum tragacanth production has been reported from Iran. The gum tragacanth is widely used in the pharmaceutical industry as well as in the production of various food items like ice-cream, lotions, liquors, bakery, chewy sweets etc (Gentry, 1957). The different aspects of gum tragacanth have been elaborately discussed by Verbeken et al. (2003). *A. malacophyllus* Benth. ex Bunge is a well known drug as 'Rudanti' or 'Rudravanti' used for tuberculosis, skin diseases, coughs and blood purifier. This drug is used in India since ancient time. The survey of Gangotri–Gaumukh Himalaya conducted in 2006 revealed that the local people and saints of this areas take the leaves after making them paste and dissolving in water for 30 or 60 days during the season of the plants for purifying the blood. In another ethnobotanical uses, the leaves paste is also used by diabetic patients to reduce the sugar level in the blood. In recent time no pharmaceutical and chemical investigations have been carried out on this species which seems to be quite potential and needs to be investigated for its anti diabetic activities.

Usually *A. candolleanus* Royle ex Benth. is known as 'Rudanti' or 'Rudravanti' in Indian literature. However, during field survey it was noticed that in Gangotri-Gaumukh area *A. malacophyllus* is called 'Rudanti' or 'Rudravanti' locally. From the herbarium specimens study it was also revealed that actually *A. malacophyllus* Benth. ex Bunge has been attributed/annotated as 'Rudanti' or 'Rudravanti' on the herbarium specimens and not *A. candolleanus* Royle ex Benth. Due to misidentification *A. candolleanus* Royle ex Benth. has been designated as Rudanti or Rudravanti. *A. malacophyllus* Benth. ex Bunge and *A. candolleanus* Royle ex Benth. are very closely allied species.

Some of the species like *A. multiceps* Wall. ex Benth., *A. tribuloides* Delile, *A. chlorostachys* Lindl., *A. himalayanus* Klotz. etc.) are also used medicinally for various purposes in ethnobotanical uses (Anonnymous, 1985). However, no authentic data are available presently.

Since the species of *Astragalus* grow with very deep root system and profuse prostrate branches, they cover the landscape and protect the soil from degradation and erosion and also act as ground cover. Some of the species are also used as forage.

Astragalus root is a well known drug in traditional Chinese medicine since quite a long time. It is ethnobotanically used as a tonic and for treatment of

diabetes and nephritis. Roots are used in treating tumors of eyes, liver, throat, chest and back pain. They are also used for tissues regeneration and wound healing. The Indian women chewed the root to stimulate lactation. *Astragalus* root is also used in herbal medicines in the US to enhance the immune system of the body after cancer therapy treatment. The roots are also used for HIV infection. These reports are based on laboratory research and need to be verified through clinical trials and further studies. The powered root in the quantity of 2 to 6 g is recommended for patient for daily use. The roasted seeds are used as the substitute of coffee in China.

Apart from its medicinal values, a large number of *Astragalus* species have been reported poisonous for both livestock (cattle and sheep) and wildlife in the North America. Based on toxicity, the poisonous species of *Astragalus* have been categorized in three groups, 1. Nitrotoxin producing species: Majority of the species produce 3-nitro propanol (miserotoxin) which disrupt normal function of central nervous system which lead paralysis and death, 2. Swainsonine producing species: Some species produce a alkaloid swainsonine or locoism which inhibits cellular enzyme production that ultimately lead to weight loss and 3. Selenium accumulating species: Certain species accumulate selenium (Se) from soil and act as selenium indicator. It may be passed in the milk.

Upon grazing, the animals produce a different kind of behaviors which is described as 'crazy'. Due to this *Astragalus* is also called 'Locoweed' (loco means crazy in Spanish). The fresh leaves are more toxic than dried leaves. But selenium content is not affected by drying. It has been noticed that animals may become habituated to astragali even when other forage are available.

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豆科黃蓍屬植物系統分類現況－印度喜馬拉雅山種類概述

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摘　　要

黃蓍為豆科中最多樣複雜的屬之一。雖然過去已有不少相關研究，但至今仍未有處理全世界全部種類的該屬專論，僅有地區性的屬誌或訂正，其最大原因應為該屬種類太多(約 3000 種)，變異也很大所致。黃蓍屬在生活型、生育地、植株大小、毛被、托葉、葉軸、花序、花瓣長、果莢形態等都有相當程度的變異。傳統上黃蓍屬可被分為 8 到 10 個亞屬，約 245 個節。近年的分子譜系分析結果顯示，黃蓍各亞屬和其中較大的節都不是單源群；但除少數例外之外，整個屬則可視為一單源群。根據這些結果可以發現黃蓍屬植物的染色體數目與其地理分布有相當程度的關聯。目前在印度黃蓍屬植物大約有 80 種，大多集中在喜馬拉雅山區，但除了本研究群，本屬在"英屬印度植物誌"發表之後，鮮少有進行相關研究。整體而言黃蓍屬的經濟重要性沒有很高，除了在伊朗、中國有中藥黃蓍胶的買賣。在印度，*A. candolleanus* 則是被用於治療肺結核、皮膚病、咳嗽、淨血之藥-"Rudanti"和"Rudravanti"。本文為有關黃蓍屬分類研究之整理，特別提供了印度產本屬植物的資訊，以供後續相關研究者的參考。

關鍵詞：分類學、譜系關係、黃蓍屬、印度、豆科。

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