The Palaeobotanist 57(2008) : 453-457
0031-0174/2008 $2.00

On the evolution of Angiosperms in the Himalayan region: A summary

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(Received 10 June, 2007; revised version accepted 15 September, 2008)

ABSTRACT

Guleria JS 2008. On the evolution of Angiosperms in the Himalayan region: A summary. The Palaeobotanist 57(3): 453-457.

The paper summarises the evolution of angiosperms in different zones of Himalaya. The Himalayan Cenozoic flora has been divided age-wise as Palaeogene and Neogene flora. The Himalayan Palaeogene flora is largely a continuation of tropical peninsular flora of India. The early Miocene flora of Lesser Himalaya is also moist tropical. However, temperate plants started appearing during Miocene in the Higher Himalaya and their occurrence in Plio-Pleistocene flora of Kashmir reflect uplift of the Himalaya. The sub-Himalayan flora indicates existence of warm humid conditions in this belt which became drier by the end of Pliocene. The northern floral elements appeared to have invaded India all along the Himalayan belt. Since its birth the Himalaya has played a significant role in the immigration of plants from the adjoining regions, i.e. east, west and north, thereby enriching the Indian flora. The development of the Cenozoic flora of the Himalayan region is an expression of changing patterns of geography, topography and climate.

Key-words—Cenozoic, Angiosperms, Himalayan flora, Migration, Climate (India).

हिमालयी क्षेत्र में आवृतबीजियों के विकास के बारे में : एक सारांश

जे.एस. गुलेरिया

सारांश

यह शोध-पत्र हिमालय के विविध मंडलों में आवृतबीजियों के विकास का सार प्रस्तुत करता है। हिमालयी नूतनजीवी वनस्पति पैलियोजीन व नियोजीन काल के आधार पर विभाजित की गई है। हिमालयी पैलियोजीन की वनस्पति भारत के उष्णकटिबंधीय प्रायद्वीपीय वनस्पति के सतत् रूप में विस्तारित है। निम्न हिमालय की प्रारंभिक मध्यजीव वनस्पति भी आर्द्र उष्णकटिबंधीय है। फिर भी, उच्च हिमालय में मध्यनूतन के दौरान शीतोष्ण पेड़-पौधे दिखने शुरू हो गए थे तथा कश्मीर के प्लायो-प्लीस्टोसीन पेड़-पौधों में उनकी उपस्थिति हिमालय के उत्थान को प्रतिबिंबित करती है। उप-हिमालयी वनस्पति इस पट्टी में उष्ण-आर्द्र स्थितियों की विद्यमानता इंगित करती हैं जो कि अतिनूतन के अंत में शुष्क हो गई। ऐसा प्रतीत होता है कि उत्तरी वनस्पति तत्त्व पूर्ण हिमालयी पट्टी के सहारे भारत में घुसे। हिमालय के जन्म से ही निकटवर्ती क्षेत्रों अर्थात् पूर्व, पश्चिम एवं उत्तर से पौधों के अप्रवास में इसकी महत्वपूर्ण भूमिका रही है जिसके कारण भारतीय वनस्पति में अभिवृद्धि हो रही है। हिमालयी क्षेत्र की नूतनजीवी वनस्पति हिमालय के विकास, भूगोल, स्थलाकृति एवं जलवायु के बदलते प्ररूप की एक अभिव्यक्ति है।

मुख्य शब्द—नतूनजीवी, आवृतबीजी, हिमालयी वनस्पति, अभिगमन, जलवायु (भारत)।

Changing Scenario in Palaeobotany and Allied Subjects
Editor : J.S. Guleria

INTRODUCTION

ANGIOSPERMS or the flowering plants are the dominant plants of the world today. However, in evolutionary terms they are relatively recent, fossil evidence indicating their first appearance at around 140 million years ago in the early Cretaceous followed by rapid diversification and radiation in the mid-Cretaceous. By early Cenozoic (~65 Ma), angiosperms had attained ecological dominance in a majority of habitats over a wide geographical area.

The mighty Himalaya began to form south of the Pamir between 40-50 million years ago and covers a distance of above 2500 km from northwest to southeast terminating at both the ends with syntaxial bends. The width of Himalayan belt varies from 250-300 km and covers a latitudinal expanse of about 10^0 from 27^0-38^0 N. The collision of India and Eurasia is perhaps the most profound tectonic event to have occurred in the early Cenozoic (Tertiary) and led to the uplift of Himalaya and consequent climatic changes (Valdiya, 1998; Thakur, 1992; Rowley, 1996; Sinha & Upadhyay, 1997). Most of its development occurred during the last 10 million years. The collision and closure of Tethys resulted in the formation of continental sedimentary basins and divided the Himalayan arc into three distinct zones, from south to north these zones are:

(1) Sub-Himalaya/Outer Himalaya/Foot-Hills/Siwaliks
(2) Lesser Himalaya or Southern Himalaya
(3) Higher Himalaya or Tethyan Himalaya.

The collision resulted in the establishment of land connection between India and Southeast Asia on one hand and Arabia-Africa on the other and opened new ways for migration of plants. This was also the time when from the neighbouring areas plants started entering India resulting in increased diversity of the Indian flora. There were large scale migration and admixture to floras over India, Malaysia, Arabia, Africa, Tibet and China during the Neogene times due to establishment of land connections. The paper summarises the development of angiosperms in different zones of Himalaya and provides the latest information. The earlier information has been compiled and analysed by Awasthi (1982), Lakhanpal (1988, 1991). For the sake of convenience, the floras have been divided age-wise as Palaeogene flora and Neogene flora. By the end of the Palaeogene and after the final withdrawal of the Tethys the ground was available for the development of the Himalayan land flora. Further Himalayan orogeny created conditions favourable for immigration of temperate plants from mainland Asia during the Middle Miocene. Its major components were established during the Neogene and the final details acquired in the Quaternary Period. Himalayan vegetation can be divided into three broad zones, viz. subtropical, temperate, alpine. The subtropical vegetation is primarily an extension from the Indian side but the temperate vegetation could have come from the adjoining northeastern, northern and northwestern regions on attaining sufficient elevation by the Himalayan ranges to provide cool environment for temperate plants to grow.

Floristics changes during Cenozoic (Tertiary) in Himalaya

Palaeogene flora–Megafossils from the western Himalayan region are meagre. Palm leaves of *Livistona* have been reported from the Hemis Conglomerate horizon of Ladakh of the Late Eocene-Oligocene age (Lakhanpal *et al*., 1983). Lately two palm leaf impressions have been reported from the same horizon as *Palmacites tsokarensis* and *Amesoneuron ladakhensis* (Paul *et al.,* 2007; Mehrotra *et al.,* 2007b) which may belong to genus *Livistona*. The genus has also been reported from Tibet (Tao, 2000). *Livistona* is primarily confined today to tropical Asia (Indo-Malaya) and Australia. The occurrence of *Livistona* indicates moist tropical conditions in Eocene-Oligocene times in western Himalaya. The earliest record of megafossil from the Lesser Himalaya is represented by *Acorus*, a swampy plant which has been reported from the Subathu (Eocene) sediments of Beragua coal mines situated in the southwestern part of Jammu & Kashmir (Guleria *et al.,* 2005b). Most of the Palaeogene megafossil data have come from the northeast India (Guleria *et al.,* 2005a, b; Mehrotra, 2003; Mehrotra *et al.,* 2005b, 2007a; Prasad *et al.,* 2007). Some of the important taxa reported from the Palaeogene (Palaeocene-Eocene-Oligocene) sediments of northeast are: *Artocarpus, Atalantia, Avicennia, Barringtonia, Calophyllum, Calycopteris, Cinnamomum, Cocos, Entada, Garcinia, Grewia, Heynea, Kayea, Litsea, Mangifera, Mesua, Nelumbo, Nypa, Phoebe, Podocarpus, Schleichera, Rhizophora, Syzygium, Sonneratia, Terminalia catappa* and palms.

The presence of estuarine or littoral elements like *Avicennia, Cocos, Nypa, Terminalia catappa* and *Sonneratia* and *Rhizophora* indicate that the sea was very close to the areas, viz. Assam, Arunachal Pradesh, Meghalaya during the Palaeocene-Oligocene time. Palms were the important members of Himalayan vegetation till Oligocene as recorded from Ladakh and the eastern Himalaya.

The Palaeogene mega remains from west to east indicate the existence of moist tropical conditions in the Himalayan belt.

Neogene (Mio-Pliocene to Pleistocene flora)

No detailed exploration has so far been done for the early Cenozoic (Tertiary) plants in the Indian side of the Himalayan region for two reasons (i) inaccessibility of the area (ii) highly disturbed nature of the sediments. However, temperate plants have so far been reported from the Miocene sediments of Higher Himalaya/Trans Himalaya, representing *Populus, Trachycarpus* and *Prunus*. They have been found in the Miocene sediments of the Kargil Formation (= Liyan Formation) of Ladakh region. Obviously, during the Miocene, the Himalaya

had risen high enough to support temperate vegetation, enabling taxa such as *Populus, Prunus* and *Trachycarpus* to move into this region where earlier tropical plants like *Livistona* had grown (Guleria *et al.,* 1983; Lakhanpal, 1988, 1991, 1998; Lakhanpal *et al.,* 1984). It is interesting to note that *Populus* has also been reported from the Neogene sediments of Tibet and its occurrence with other remains has been associated with the uplift of the Himalaya (Li & Guo, 1976; Geng & Tao, 1982; Guo & Chen, 1989). Thus the history of the Himalayan temperate plants can be traced back to the Miocene epoch.

A number of megaplant fossils have been reported from the Early Miocene sediments of Kasauli/Dharamsala and Murree sediments of the Lesser Himalaya in Himachal Pradesh and Jammu & Kashmir. They are *Amoora, Bambusa, Bauhinia, Cassia, Dipterocarpus, Heynea, Semecarpus, Syzygium*, legumes and palms, etc. (Arya & Awasthi, 1994, 1995; Arya *et al.,* 2001, 2004; Guleria *et al.,* 2000a, b; Mathur *et al.,* 1996; Sahni, 1953; Srivastava & Guleria, 2004). The assemblage evidently indicates the prevalence of tropical climatic conditions in the Lesser Himalaya during the Early Miocene.

Considerable data on plant megafossils have been accumulated from the Outer Himalaya/Siwalik sediments running from west to eastern end of the Himalaya. It is the best known flora of the Himalayan region and its components are largely tropical to a few subtropical in distribution (Awasthi, 1992; Banerjee *et al.,* 2005; Guleria *et al.,* 2002; Joshi & Mehrotra, 2007; Mehrotra *et al.,* 2006; Prasad, 2006, 2007, 2008; Prasad & Pandey, 2008; for further details please refer Srivastava, 1991; Srivastava & Guleria, 2004). The recorded assemblages indicate that the area was forested by moist evergreen to semi-evergreen taxa. The flora shows steep decline in the number of taxa in the upper Siwalik as the climatic conditions changed from warm humid to dry affecting adversely the earlier vegetation of the region.

Tropical elements

Adenanthera, Afzelia, Anisoptera, Artocarpus, Bambusa, Barringtonia, Bauhinia, Bischofia, Caryota, Calophyllum, Cassia, Cratoxylon, Cynometra, Dillenia, Diospyros, Dipterocarpus, Elaeocarpus, Fissistigma, Ficus, Gluta, Hydnocarpus, Heritiera, Kingiodendron, Koompassia, Lagerstroemia, Mangifera, Mallotus, Millettia, Pongamia, Nypa, Polyalthia, Pometia, Randia, Shorea, Sterculia, Swintonia, Syzygium, Terminalia, Zizyphus, etc.

Subtropical Plants

Cinnamomum, Ficus, Litsea, Magnolia, Mallotus, Meliosma, Persea, etc.

During the Siwalik (Mio-Pliocene), the palms were very limited (Sahni, 1964; Prasad, 1987, 2006; Banerjee *et al.,* 2005; Joshi & Mehrotra, 2007; Mehrotra *et al.,* 2007c) as compared to their occurrence in the Early Tertiary. Tropical evergreen to semi-evergreen forests were present in the Himalaya during the middle to upper Miocene when the Siwalik sediments were being laid down. These forests contained several species of *Dipterocarpus, Cynometra, Elaeocarpus, Anisoptera, Gluta,* etc. The Miocene tropical forests occurred below 1000 m on the lower slopes where the precipitation was between 1500 to 3000 mm with high humidity and a short dry season. There is not a single instance of a temperate megafossil collected from the Siwalik sediments. In a general tropical monsoon type of climate prevailing in the Siwalik region, it is impossible to expect temperate plants like *Abies, Picea, Tsuga* and *Betula* unless there was an altitude of about 2000 m. There is no distinct, difference between the Lower Siwalik and Middle Siwalik flora which remained tropical and became drier towards the end of Pliocene.

Floristics composition of Karewas (Plio-Pleistocene) of Kashmir—Woods and leaves of the following taxa have been reported from the Karewa sediments of Kashmir Valley: *Acer, Aesculus, Alnus, Berberis, Berchemia, Betula, Castanopsis, Cinnamomum, Desmodium, Engelhardetia, Fraxinus, Hedera, Juglans, Litsea, Machilus, Mallotus, Nelumbo, Parrotia, Populus, Potamogeton, Prunus, Pyrus, Quercus* spp., *Rhododendron, Rosa, Salix, Trapa, Ulmus, Viburnum,* etc. In addition, woods of a number of gymnospermous taxa are known (Puri, 1957; Vishnu-Mittre, 1965; for more detail refer Lakhanpal *et al.,* 1976; Srivastava, 1991; Srivastava & Guleria, 2006). Most of the macro evidence support a cooler climate during Plio-Pliestocene in the Kashmir Valley indicating uplift of the Himalaya.

In contrast to the Sino-Japanese nature of the temperate floristics on the higher slopes, the tropical forests of the lower slopes contain Malayan/Southeast Asian and African taxa. *Cinnamomum, Dipterocarpus, Euphoria, Kingiodendron, Murraya* and *Pterospermum* are some of the Indo-Malayan elements. Similarly *Populus, Fraxinus excelsior* are West Asian/Mediterranean taxon and *Zizyphus* an African element.

It is evident from the above account that the history and development of the angiosperms in the Himalayan region is an expression of changing patterns of geography, topography and climate. Thus the extensive investigation of Cenozoic (Tertiary) flora of Higher Himalaya is recommended as it will provide more evidence on the advent of cooler Sino-Japanese/ Eurasian elements in India. Likewise work on Cenozoic flora of northwestern part of Himalaya will give an idea of the Mediterranean and Afro-Asian elements and northeast India will give idea of intermixing of southeastern elements and vice versa. The total absence of any megafossil of northern conifer in the Siwalik belt indicates that prevailing climatic conditions remained tropical in the Himalayan foot-hills up to Lower Pliocene in contrast to the cooler conditions observed in the Higher Himalaya during the Neogene and later at the end of Pliocene in Kashmir.

The occurrence of megafossils of palms and *Acrostichum* in the Lower Miocene sediments of Kasauli (Sahni, 1953;

Guleria *et al.*, 2000b; Awasthi *et al.*, 1996) and *Nypa* in the Early Miocene of Assam, Mizoram and Lower Siwalik of Darjeeling indicates existence of coastal conditions in these areas during the Early to Middle Miocene (Lakhanpal, 1952; Mehrotra *et al*., 2003; Banerjee *et al.*, 2005).

According to Venkatachala (1991, p.589) and Mehrotra *et al.* (2005a, p.85), *Nypa* was dominant during Early Palaeocene and is not known during Late Palaeogene-Early Neogene and considered its reappearance in the Quaternary as noteworthy. Further, they considered the cause of disappearance of *Nypa (Spinozonocolpites)* during the Late Palaeogene-Early Neogene due to change in edaphic conditions. Their both the assumptions are incorrect since occurrence of *Nypa* has not only been reported by its megafossils but also by pollen remains in the Upper Dharamsala of Himachal Pradesh (Mathur, 1984, p.518), and Miocene of Kerala, Meghalaya, Mizoram, Maharashtra and Tamil Nadu (Saxena, 1991; Saxena & Trivedi, 2006). The author is of the opinion that the progressive decline of *Nypa* in the younger Tertiary sediments is due to change in physical conditions around the Indian landmass i.e., recession of sea and not the edaphic conditions. The available records show that *Nypa* has continued to occur in India since Deccan Intertrappean (Late Maestrichtian) times and the assumption that it reappeared in Quaternary is untenable. Evidently its fossil remains can be found near the coastal region or in the palaeocoast sediments.

While comparing Tertiary flora of south China and north Indian flora, Mehrotra *et al*. (2005b, fig. 4) have proposed a new circuitous route for migration of Chinese elements into northeast Himalaya. According to them cooler elements moved from Yunnan in the east to Tibet (Lamling, etc.) in the west and from there they entered into Kashmir and then again moved to northeast all along the Himalaya. It is not a tenable hypothesis. Infact, the cooler taxa from Tibet and China could have entered India during the Neogene from across the Himalaya, i.e. from eastern, central and western Himalayan region instead of taking a long circuitous route to reach eastern Himalaya.

The occurrence of *Pinus merkusi* which is found in China and Myanmar is confined only to Assam or eastern Himalaya. It could not have entered Assam via Tibet or Kashmir. Similarly limited distribution of certain northern taxa to western, central or eastern Himalaya supports the above view. Taxa like *Cephalotaxus, Gnetum, Larix griffthiana, Magnolia, Michelia, Picea spinulosa, P. brachytyla, Abies delavayi*, etc. are absent in western Himalaya whereas *Pinus gerardiana* and *Cedrus deodara* are absent in the eastern Himalaya (Sahni, 1984).

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