Modern pollen deposition in subtropical zone of Kumaon Himalaya, India*

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Pollen analysis of thirty three surface samples from subtropical belt of Kumaon Himalaya shows dominance of arboreals. *Pinus roxburghii* followed by *Quercus, Viburnum,* Rosaceae, Oleaceae and *Mallotus* are the chief constituents of the regional pollen rain and their representation in the pollen spectra shows a close coherence with their composition in the extant vegetation. Other arboreal taxa present in the area, such as, *Myrica, Rhododendron, Salix, Celtis, Populus, Bauhinia, etc.*, are either under-represented or absent in most of the samples. This is attributed to their low pollen productivity since majority of them are entomophilous. Among the non-arboreals, grasses, sedges, Cheno/Ams, Tubuliflorae, *Artemisia* and *Justicia* are better represented than Brassicaceae, Urticaceae, Ranunculaceae, *Polygonum plebeium, etc.* which fail to exhibit their actual preponderance in the vegetation of the region.

Key-words—Pollen rain, deposition pattern, subtropical zone, Kumaon Himalaya, India.

INTRODUCTION

ONE of the important aims of the Quaternary palynological researches is to reconstruct palaeovegetation so as to deduce the palaeoclimate. The pre-requisite for correct interpretation of pollen diagrams, is to have knowledge of present vegetation of a region and its ecology on one hand and to construct the modern pollen rain spectrum of the same vegtation on the other as well as to understand the pollen deposition pattern in the area.

The present study of the modern pollen rain was undertaken primarily for high resolution interpretation of six pollen diagrams for different regions of Kumaon Himalaya. For this 33 surface samples from a transect across Sat Tal, Khurpa Tal, Tarag Tal, Naukuchia Tal and Simar were investigated which covered different forest stands and plant communities, viz., Chirpine, Oak, mixed Chirpine-Oak, *Bauhinia* and scrubs in the altitudinal range between 1000-1500m, covering an area of about 1000 sq km.

CLIMATE

The montane vegetation belt under investigation is subjected to well pronounced climatic fluctuations. During January, the coldest month, the temperature ranges from 5.5°-8°C, whereas by March the progressive rise in the temperature reaches to an average summer temperature between 27°-35°C. The rainy season commences from the middle of June and average annual rainfall is 2000 mm in this belt.

MATERIAL AND METHOD

A total number of 33 surface samples, both moss-cushions and soil samples, were collected from five localities, namely, Sat Tal, Khurpa Tal, Tarag Tal, Naukuchia Tal and Simar. A distance of 100 m between two gathered samples (Table 1) from each locality was maintained and the material was processed according to the standard technique of Erdtman (1943). The slides were prepared in 50% glycerine for pollen examination.

About 300 pollen grains were counted for each sample and the pollen spectra construction is based on total terrestrial pollen and the plotted frequency of each plant taxon is arranged in a sequence, i.e., trees, shrubs, herbs and ferns. The modern pollen depositional model is, however, based on selected taxa (Text-fig. 1).

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Table 1. Provenance of surface samples collected from Kumaon Himalaya.

Sample No.	Locality	Details
1.	Sat Tal	Soil-sample from over a boulder inside Oak forest
2.	"	Moss-cushion from Chirpine forest
3.	"	Moss-cushion from Oak forest
4.	"	Moss-cushion from *Bauhinia* forest
5,6,7 & 8.	"	Moss-cushions from Chirpine forest
9.	"	Moss-cushion from *Bauhinia* forest
10.	"	Moss-cushion from mixed *Bauhinia*-Chirpine forest
11.	Khurpa Tal	Moss-cushion from over a boulder inside Chirpine forest
12 & 13.	"	Moss-cushions from the Oak trunk
14,15 & 16.	"	Moss-cushions from Chirpine forest
17 & 18.	Tarag Tal	Moss-cushions from Chirpine forest adjacent to a cultivated field
19 & 20.	"	Moss-chushions from mixed open forest
21,22 & 23.	"	Moss-cushions from Chirpine forest
24.	Naukuchia Tal	Moss-cushion from a boulder near lake site
25.	"	Moss-cushion from a hill slope c 100 m above lake
26.	"	Moss-cushion from a hill slope c 200 m above lake
27.	"	Moss-cushion from a hill slope c 300 m above lake inside the forest
28.	"	Moss-cushion from a boulder 350 m above lake
29.	Simar	Moss-cushion from Chirpine forest near cultivated field
30.	"	Moss-cushion from cultivated site
31,32 & 33.	"	Soil samples from a boulder near cultivated fields

MODERN POLLEN/VEGETATION RELATIONSHIP

Text-fig. 2

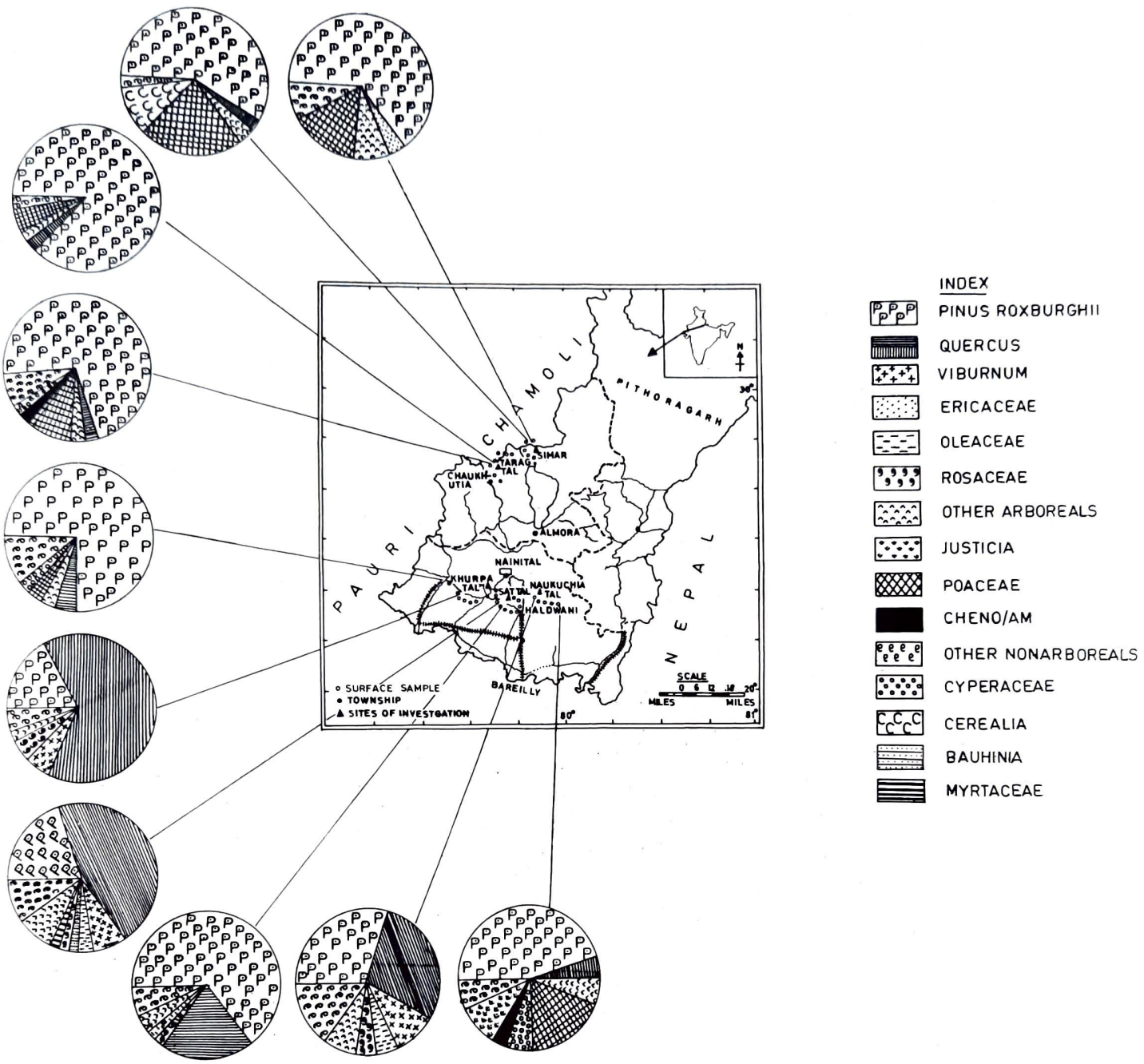
1. Sat Tal

Sat Tal Valley is situated about 16 km south-east of Naini Tal and 6 km south of Bhim Tal within the altitudinal range of 1300-1500 m a.s.l., between 79°32" N Long. and 29° 23" E Lat. The valley is surrounded by steeply rising hills of the outer range of Kumaon Himalaya.

Kenoyer (1921), who carried out exhaustive studies on the vegetation succession in the area has recognised broadly three main plant communities, i.e.,Chirpine-formation, Oak-formation and *Bauhinia*– formation. The Chirpine forests are mainly confined to higher elevations and occur in almost pure state, except a little intermixing seen on the lower elevations. Oak forests occupy lower elevation, i.e., below the Chirpine belt, particularly in the moist and shady depressions. *Myrica esculanta, Salix wallichiana, Phoebe lanceolata, Myrsine africana,* etc. alongwith shrubby elements — *Punica granatum, Colebrookea oppositifolia,* etc. are the important constituents of Oak forests. *Bauhinia* community is seen mainly in the erosion prone bouldery area with marked occurrence of *B. variegata, B. retusa* and *B. vahlii* alongwith *Dalbergia sissoo, Ougenia dalbergioides, Erythrina* sp., *Indigofera gerardiana,* etc. The herbaceous vegetation is generally very scanty in both Chipine as well as *Bauhinia* formations as compared to a thick ground cover in Oak forests. *Artemisia parviflora, Reinwardtia trigyna, Urtica* sp., *Rumex hastatus, Oxalis acetosella, Berginia ligulata, Bigonia picta, Saxifraga, Polygonum* sp., *Viola* sp., etc. are the chief constituents of the ground vegetation.

Pollen rain – Pollen spectra (2,5,6,7, & 8) from Chirpine formation reflect the dominance and high values of *Pinus roxburghii,* ranging from 35-93%. *Quercus* (1-35%) is also represented in good frequencies, excepts in spectrum 9 from the transitional zone, where it declines to 1%. Other arboreals, viz., *Celtis, Mallotus, Bauhinia, Acacia, Rhododendron, Juglans* and Rutaceae are sporadic and low. The shrubby elements are represented by *Viburnum* 1-12%, Oleaceae 1-17%, Fabaceae 1-3% and *Ilex, Oldenlandia,* Lythraceae 1% each. Among the non-arboreals, Poaceae 1-10%, Cheno/Ams 1-4% and Cyperaceae 3% are the chief constituents, whereas Ranunculaceae, Tubuliflorae, Brassicaceae and *Justicia 2% each, Xanthium, Thalictrum, Polygonum plebeium,* Polygonaceae, Malvaceae and *Nymphoides* 1% each are encountered in extremely low frequencies. Fern spores (monolete 1-15% and trilete 1-10%) are abundant, though in varying frequencies which is attributable to the luxuriant growth of ferns in shaded and damp habitats.

Pollen spectra (1 & 3) from Oak forest depict the dominance of *Quercus* 42-45% followed by *Pinus roxburghii* 10-20% which despite its comparatively much less frequent occurrence remains better represented in contrast to other taxa such as Myrtaceae 3%, *Bauhinia 2% and Mallotus, Celtis, Salix, Acacia,* Tiliaceae and Rutaceae 1% each. Among the shrubby elements, *Viburnum* 7-12%, Oleaceae 1-3% and Rosaceae 2-5% are the major constituents, whereas Fabaceae, Lythraceae and *Ilex* are poorly recorded. The non-arboreals, viz., Poaceae 1-3%, Ranunculaceae 1-2% and Cyperaceae, *Arte-*



Text-figure 1. Modern pollen deposition model in Kumaon Himalaya.

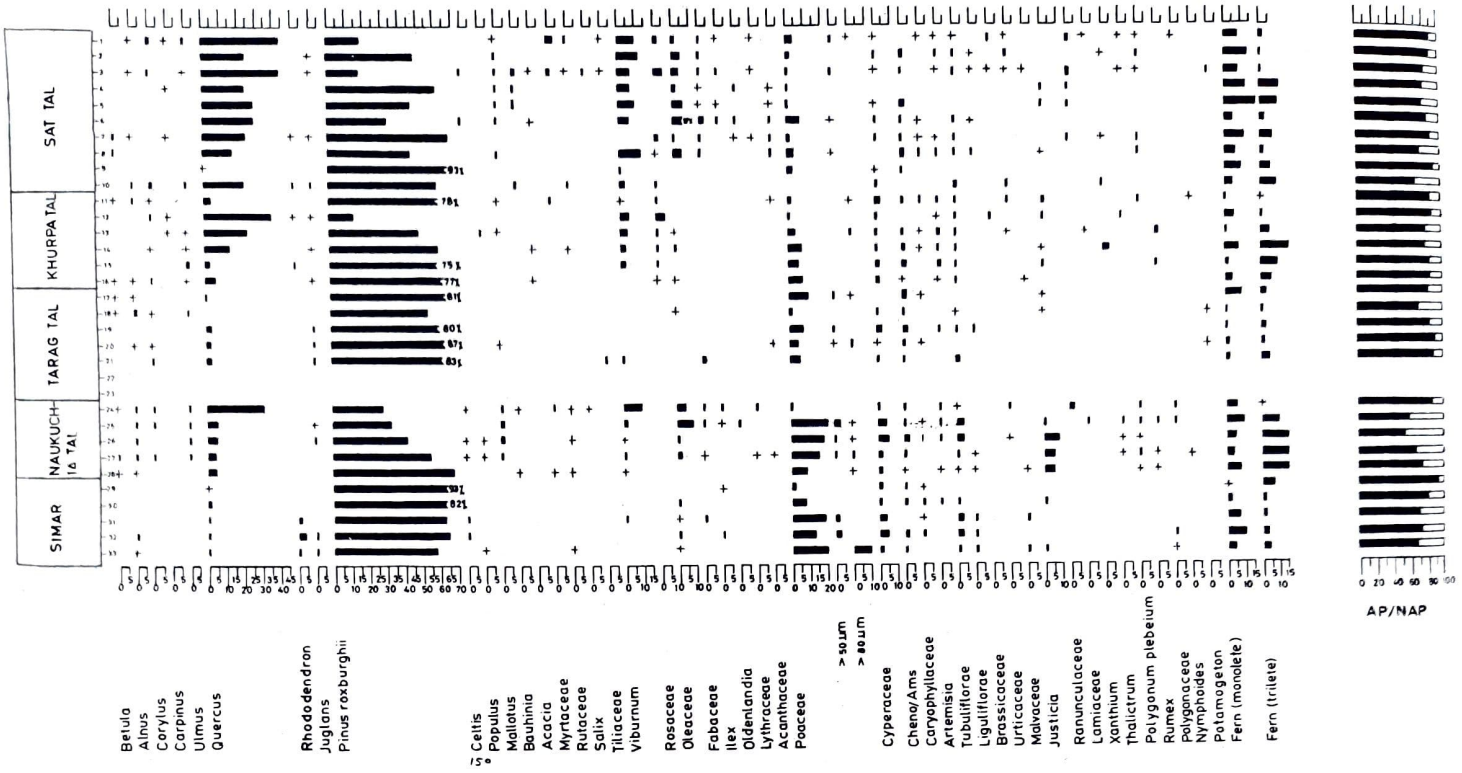
misia, Polygonum plebeium, Brassicaceae, Urticaceae 1% each are lowly represented. Fern spores (monolete 10% and trilete 1-3%) are present consistently.

Pollen spectra (4 & 9) from *Bauhinia* forest exhibit as high as 65-80% values of *Pinus roxburghii* followed by *Quercus* 25-35%.*Bauhinia,* the main component of this forest, alongwith Myrtaceae, *Mallotus* and *Ulmus* have very sporadic and low frequencies. The shrubby elements, *Viburnum* 1-5% and Oleaceae 2% are well represented, whereas Rosaceae, Fabaceae, *Oldenlandia* and Lythraceae are extremely low and sporadic. Likewise, the non-arboreals such as Poaceae, Cyperaceae, *Justicia, Xanthium,* Urticaceae and Ranunculaceae are scanty. Fern spores (monolete 5-20% and trilete 10-15%) are recorded in much higher frequencies.

2. Khurpa Tal

The valley in which the Khurpa Tal lies, is about 10 km west of Naini Tal enroute to Narayanpur, at an elevation of 1600 m a.s.l. This deep valley is surrounded by steeply rising hills with thick Oak and Chirpine forests.

Chirpine (*Pinus roxburghii)* occurs almost in pure stands, confined to higher elevations. *Cedrus deodara,* another prominent arboreal of this area, is seen only in patches just above the Chirpine forests. The Oak forests in the valley or around the lake are seen only in the southward and westward hills in highly degraded condi-



Text-figure 2. Recent pollen spectra from Kumaon Himalaya. (Percentages calculated in terms of total terrestrial pollen)

tion. As also elsewhere in this Himalayan belt, significant arboreal associates of Oak are *Rhododendron arboreum, Myrica esculanta, Castanopsis tribuloides, Symplocos crataegoides,* etc., whereas among shrubs, *Berberis asiatica, Viburnum cotonifolium, Strobilanthes dalhausianus, Woodfordia fruticosa,* etc. are the main elements.

Pollen rain — Pollen spectra from the Chirpine forest portray the preponderance of *Pinus roxburghii* 15-70%, which declines to its minimum (15%) in the pollen spectra from mixed Oak-Pine forest. Similarly, *Quercus* (5-44%) is also consistently represented as compared to many other broad-leaved elements such as *Rhododendron, Juglans, Populus, Acacia,* Myrtaceae and Rutaceae which remain 1% each. The shrubby constituents are represented by *Viburnum* and Rosaceae 1-10% each and Oleaceae and Acanthaceae 1% each. Among the non-arboreals, Poaceae 1-10%, Cyperaceae and *Xanthium* 4% each and Cheno/Ams 3% are much better represented as compared to sporadic and low frequencies of *Artemisia, Justicia, Thalictrum,* Tubuliflorae and Lamiaceae. Fern spores (monolete 1-10% and trilete 2-25%) are recorded in good numbers. The sporadic representation of temperate taxa, viz., *Betula, Alnus, Corylus, Carpinus* and *Ulmus* reveals the transport of their pollen from higher elevations where these elements grow abundantly.

3. Tarag Tal

Tarag Tal is situated 80 km north of Ranikhet and 10 km east of Chaukhutia between 75°50" N Long. and 30°E Lat. at an elevation of 1200 m a.s.l. and is surrounded by high mountain chain on its east, north and south. The mountain range towards the north attains an impressive altitude of 1800 m a.s.l. The valley in which the above lake is situated, extends westward and ultimately becomes much wider. Most of valley land is under intensive agricultural practices.

The vegetation in the valley itself is seen in much depleted state owing to over exploitation and considerable anthropogenic activities such as agricultural practices, cattle grazing, lopping, etc. However, at the higher reaches of the surrounding mountains, dense Chirpine (*Pinus roxburghii*) forests do exist. These conifer forests are almost pure in their composition except for sporadic occurrence of *Rhus parviflora, Carissa opaca, Berberis asiatica, Woodfordia fruticosa,* etc. Oak (*Quercus incana)* in seen scarcely in moist depressions alongwith its few associates, viz., *Rhododendron arboreum, Lyonia ovalifolia, Pyrus malus, Phoebe lanceolata,* etc. and common shrubby elements—*Rosa moschata, Rubus ellipticus, Zanthoxylum alatum,* etc.

Pollen rain — Pollen spectra depict the picture of the extant vegetation showing high values of *Pinus roxburghii* 55-89%, whereas *Quercus* 1-3% and *Juglans, Rhododendron, Mallotus* 1% each are metwith scantily. The shrubby elements such as *Viburnum,* Oleaceae,

Tiliaceae and Acanthaceae also show extremely low frequencies. Among the non-arboreals, Poaceae (2-15%) is dominant element, whereas Cyperaceae and Cheno/Ams 1-3% each, Tubuliflorae 2% and Caryophyllaceae, Brassicaceae, *Artemisia, Justicia, Potamogeton* are lowly represented. Fern spores are consistently recorded with varying frequencies.

4. Naukuchia Tal

Naukuchia Tal, the lake of nine contours, is situated in a valley about 23 km south-east of Naini Tal and 4 km south-east of Bhim Tal at an elevation of 1330 m a.s.l. between 79° 35" N Long. and 29° 9" E Lat. Topographically, this valley is surrounded by high mountain ranges in the east, north and south, whereas towards the west it is stretched far beyond the lake into a much wider zone.

The hill slopes surrounding the lake have dense Oak *(Quercus incana)* forests. *Phoebe lanceolata, Cinnamomum zeylanicum, Salix wallichiana, Lyonia ovalifolia, Aesculus indica, Myrica esculanta,* etc. alongwith shrubby elements, chiefly *Rosa moschata, Crataegus crenulata,* etc. are the prominent components of these Oak forests. The most common lianas in the forest are *Dioscoria bulbifera, D. kumaonensis, Bauhinia vahlii, Smilax aspera,* etc.

The hill slopes towards north, however, are almost barren, but for patchy *Pinus roxburghii* stands at higher reaches. *Euphorbia royleana* inhabits the bouldery slopes, quite gregariously. *Grewia optiva, Boehmeria platyphylla, Ficus roxburghii* and *F. palmata* are some of the common trees seen in the agricultural land around the lake or near the settlements. These trees exhibit stunted growth due to excessive lopping by the local inhabitants for fodder.

Pollen rain — Pollen spectra exhibit the high values of *Pinus roxburghii* (30-70%) followed by *Quercus* (10-40%) and *Mallotus (1-3%).* Besides, other tree taxa such as *Ulmus, Alnus, Corylus, Betula, Juglans, Celtis, Populus, Bauhinia,* Myrtaceae, Rutaceae and *Acacia,* etc. are extremely low. *Viburnum* 1-12% is well represented shrubby element, whereas *Ilex, Oldenlandia,* Acanthaceae and Lythraceae are encountered scantily. Among the non-arboreals, Poaceae 8-12%, Cyperaceae 1- 5%, Cheno/Ams 1-3%, Tubuliflorae 1-5% and *Justicia* 1-12% are the dominant constituents, whereas *Artemisia,* Caryophyllaceae, Liguliflorae, Malvaceae, Polygonaceae and *Xanthium* have a sporadic representation. *Nymphoides1%* is the only representative of the aquatic vegetation. Fern spores (monolete 5-10% and trilete 0.5-15%) are frequently encountered in variable frequencies.

5. Simar

Simar Valley, purported to be a lake in the remote past, is situated 10 km west of Bageshwar on way to Baijnath between 79° 85" N Long. ; 29°80" E Lat. at an elevation of 900 m a. s. l. It is a narrow and deep valley, surrounded by over-topping hills on the north and south with steep slopes. In the local language "Simar" means the marshy or water-logged area. The prevailing marshy conditions in the large part of this area is due to a perennial stream which flows from west to east.

In Simar Valley, the northern and southern hill slopes have Chirpine *(Pinus roxburghii)* forests, which are devoid of conspicuous undergrowth. However, Oak forests occur scarcely in the valley area. Other tree taxa viz., *Lyonia ovalifolia, Myrsine africana, Celtis australis, Prunus cerasioides, Ulmus wallichiana* and *Bauhinia variegata* are scantily distributed in these Oak forests. Along the bank of stream, mixed type of vegetation comprises *Celtis australis, Grewia optiva, Boehmeria platyphylla, Ficus roxburghii, F. palmata, Cedrela toona,* etc. together with abundant shrubby elements such as *Colebrookea oppositifolia, Rosa moschata, Vitex negundo, Adhatoda vasica,* etc.

Pollen rain — Pollen spectra depict extremely high values of *Pinus roxburghii* ranging from 50-90% followed by the low frequencies of *Quercus* 2% and *Rhododendron* 1-3%, whereas *Juglans, Celtis, Populus, Bauhinia,* Myrtaceae and Rutaceae are sporadically represented. Likewise, *Viburnum, Ilex* and Fabaceae are also recorded in low values. Among the non- arboreals, Poaceae 3-20% followed by Cyperaceae and Tubuliflorae 2-5% each, Cheno/Ams 3% and Liguliflorae 2% are the most prominent constituents. Other constituents such as *Justicia, Artemisia,* Caryophyllaceae, Malvaceae and Polygonaceae are 1% each. Fern spores (monolete 1% and trilete 2-5%) are scanty.

DISCUSSION AND CONCLUSION

The present paper is infact an attempt to evaluate pollen deposition and to correlate the recovered pollen from surface samples with the modern vegetation so as to provide the floristic spectrum of the subtropical belt of Kuman region.

Earlier Gupta (1977) and Chauhan and Sharma (1991) carried out pollen analytical investigation from Bhim Tal and Sat Tal area.

Further study on the pollen/vegetation relationship is extended to cover an important region of Kumaon Himalaya which is studded with many closely situated lakes and is subjected to marked anthropogenic activities. The lakes covered in the present study are Sat Tal, Khurpa Tal, Tarag Tal, Naukuchia Tal and Simar. More emphasis has been given to the pollen rain study of

different forest formations, such as Oak, Chirpine, *Bauhinia* and mixed Oak-Chirpine for high resolution interpretation of pollen diagrams from the aforesaid lake sites (Sharma & Chauhan, in press).

The Oak forest pollen rain studies conducted for different areas in the Kumaon Himalayan subtropical belt have brought out, in general, the dominance of arboreals over non-arboreals with *Quercus* being the most dominant element as reflected by its high frequencies in contrast to other broad-leaved taxa. The representation of *Quercus* in the pollen rain corresponds more or less with its actual composition in the modern vegetation. However, *Pinus roxburghii* pollen too are encountered in good frequencies but it does not occur in these forests which points out the proximity of Chirpine forests from where it is transported more particularly as seen in case of Sat Tal Valley pollen rain studies. *Mallotus*, a conspicuous component of these subtropical forests in Kumaon Himalaya, is some what adequately represented in the pollen spectra as compared to many other prominent broad-leaved elements, viz., *Juglans, Celtis, Populus, Salix, Bauhinia, Rhododendron,* Rutaceae, etc. which are represented by their extremely sporadic pollen. However, the presence of *Rhododendron* pollen in good numbers in only one or two samples from Simar denotes its local abundance as this taxon does not grown widely in the subtropical belt, whereas *Myrica, Engelhardtia, Aesculus, Pyrus pashia* remain totally unrepresented. Thus barring *Mallotus*, the under-representation or complete absence of some of the important arboreal taxa could be attributed either to their low pollen productivity or for their being insect-pollinated.

Similarly, the shrubby vegetation also is not represented in its totality, except for few instances, as regards to its true composition in the extant vegetation. For example, *Viburnum,* Oleaceae, Rosaceae and Fabaceae are the major constituents of shrubby vegetation and their representation compares more or less satisfactorily with the composition of these taxa in the region, whereas the meagre occurrence of certain taxa such as Lythraceae, *Strobilanthes* and Acanthaceae corresponds to their stray pollen in the spectra. However, a large number of shrubby elements, viz., *Berberis, Rhus, Jasminum, Woodfordia,* etc. which are quite common in the Oak forest or open vegetation, remain completely unrepresented as they show entomophilous mode of pollination. Also the poor preservation of their pollen in the sediments can be the cause which cannot be denied.

Likewise, pollen rain studies from Chirpine forests exhibit the dominance of *Pinus roxburghii* with excessively high values (upto 93%). It is further noticed that in Simar, Naukuchia Tal and Tarag Tal areas, this element shows a gradual improvment in its pollen frequencies with an increase in the elevation as the pure Chirpine forests are chiefly confined to the higher hill slopes. *Quercus* is totally absent in the pollen spectra from such high altitude Chirpine stands, but it is sporadically represented together with other associates in the pollen spectra from Oak-Chirpine transition zone at lower elevations. The meagre shrubby vegetation is more or less correctly portrayed by the scant pollen representation of *Viburnum,* Oleaceae and *Ilex*, since the Chirpine forests are almost devoid of any undergrowth. Thus, it is quite apparent that despite poor arboreal pollen assemblage, the spectra from pine dominated area reflect a true picture of the modern vegetation.

In the case of pollen rain studies from luxuriant *Bauhinia* forests, chiefly restricted to Sat Tal Valley, the overall picture depicts extreme paucity of *Bauhinia* pollen in the spectra irrespective of its being a dominant forest ingredient and so is true for the entire subtropical belt of Kumaon Himalaya where more than one *Bauhinia* spp. grow together with certain other legumes, though scattered in their distribution. Other legume associates of *Bauhinia* such as *Erythrina* sp., *Dalbergia sissoo, Ougenia dalbergioides, Indigofera* sp., etc. remain entirely unrepresented which can be attributed again to the entomophilous mode of pollination, differential preservation and also probably to the microbial degradation of pollen in the sediments. Another factor for their absence in the samples may be due to the fact that *Bauhinia* forests mostly occur in erosion prone bouldery hill slopes, thus washing away the settled pollen might be nullifying the chances of pollen percolation deep in the sediment. The shrubby vegetation in the *Bauhinia* forests is scanty and is represented by a few taxa, such as, *Viburnum, Ilex* and Fabaceae, though sporadic but truely represented in the spectra. The consistent and fairly good representation of *Pinus roxburghii* followed by *Quercus* in the pollen spectra from *Bauhinia* forests amply demonstrate that Chirpine, Oak and *Bauhinia* constitute the well established forest communities, particularly in Sat Tal Valley and also elsewhere in Kumaon Himalaya.

Among the non-arboreals, grasses are the most dominant constituents and attain maximum values in the pollen spectra from Chirpine forests from Simar, Tarag Tal and Naukuchia Tal, which might be owing to better ecological conditions for their growth. In Oak and *Bauhinia* forests inspite of their consistent representation grasses are recorded in reduced values. Cerealia pollen, the prominent indicator of anthropogenic activities, are sporadic throughout but show improved frequencies in the spectra from Simar, Naukuchia Tal and Tarag Tal since these areas are under intensive crop cultivation. Sedges, Chenopodiaceae and Amaranthaceae are also prominent constituents of ground vegetation and are better represented in the pollen spectra from Naukuchia Tal and Simar due to prevalence of marshy conditions

around the provenance of surface samples. However, *Artemisia* and Tubuliflorae are recorded in accordance of their contribution in the local vegetation. The enhanced frequencies of *Justicia* in one or two samples from Naukuchia Tal could be explained to its local abundance. On the contrary Brassicaceae, Ranunculaceae, *Thalictrum*, Urticaceae, Lamiaceae, etc. which though often occur in profusion, particularly in the Oak forests, fail to record their preponderance in the pollen rain.

In the pollen spectra, fern spores very well maintain high values which denote their origin from local sources as ferns often grow luxuriantly wherever damp and shaded situations or habitats exist in the subtropical belt.

Contrary to the above, some temperate taxa, viz., *Betula, Alnus, Corylus, Carpinus* and *Ulmus* do not grow in the subtropical belt. However, the occurrence of sporadic pollen of these taxa in the sediments reveals their transportation from the higher reaches.

Thus, on the basis of above studies it may be broadly concluded that the spectra do correspond to some extent with the existing vegetation, but seldom do not reflect the true composition of some of the prominent elements of the region. For example, the pollen spectra constructed from *Bauhinia* formation portray an entirely distorted picture of the surrounding vegetation, whereas there are many important arboreal elements which are though conspicuous components of the forest community or open vegetation but remain either under-represented or even totally absent due to insect-pollinated nature, low pollen production or quick microbial degradation. Infact, the long distance transport of pollen creates problems and thus, in any pollen analytical studies it is to be interpreted cautiously to reflect on the floristic composition.

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