Mid-Holocene vegetation shifts and climate change in the temperate belt of Garhwal Himalaya

ANJALI TRIVEDI1*, B.S. KOTLIA2 AND L.M. JOSHI2

1Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.
2Geology Department, Kumaon University, Nainital, Uttarakhand, India.

Corresponding author: atrivedee@gmail.com

(Received 6 April, 2011; revised version accepted 24 May, 2011)

ABSTRACT


Pollen analysis of 3.06 m deep sediment core from the temperate lake-Nachiketa Tal, has brought out the vegetation shifts and climatic oscillations in the temperate region of Garhwal Himalaya since Mid-Holocene. The pollen sequence depicts that between 5,304 and 3,912 yr BP the mixed conifer forests dominated by Cedrus and Abies occupied most of the landscape under a regime of a cold and dry climate. The record of pollen of aquatic element, Potomogeon and freshwater alga-Botryococcus implies the existence of the lake. The broad-leaved forests mainly constituted of oak (Quercus cf. semecarpifolia) occurred sparsely in the moist and shady situations. Between 3,912 and 2,975 yr BP the mixed conifer forests got transformed into mixed oak-broad-leaved forests as evidenced from the much expansion of Quercus and improvement of its close allies Alnus, Betula, Carpinus, Juglans, Salix, etc. This change in the vegetation pattern suggests that a warm and humid climate prevailed in the region. Around 2,975 to 1,872 yr BP the abrupt decline in Quercus and its broad-leaved associates and a corresponding spurt in Pinus cf. wallichiana reflect the re-establishment of pine dominated conifer forests with reversal of cool and dry climate. Subsequent expansion of Quercus and broad-leaved taxa around 1,872 to 767 yr BP and declining trend of conifers took place with the prevalence of warm and moderately humid climate. The sporadic encounter of Cerealia pollen during this phase indicates that the area was under cereal-based agricultural practice. Since 767 yr BP onwards a warm and less humid climate prevailed than before and consequently relatively less-diversified mixed broad-leaved oak forests continued to thrive in the region, with relatively reduced frequencies of Quercus and other thermophilous broad-leaved elements.

Key-words—Palaeovegetation, Palaeoclimate, Mid-Holocene, Nachiketa Tal, Garhwal Himalaya.

© Birbal Sahni Institute of Palaeobotany, India
INTRODUCTION

Considerable data have been generated on the vegetation succession, climate change and lake level fluctuation during the Quaternary Period on a broader timescale from the subtropical and temperate belts from the different sectors of the Himalaya comprising the regions of the Kumaon (Vishnu-Mittre et al., 1967; Gupta, 1977; Chauhan & Sharma, 1996; Kotlia et al., 1997, 2010) from western Himalaya and Himachal Pradesh (Sharma & Singh, 1974a, b; Sharma & Chauhan, 1988; Chauhan, 2006; Chauhan et al., 2000; Bhattacharyya, 1988) and Jammu & Kashmir (Vishnu-Mittre & Sharma, 1966; Sharma & Singh, 1968; Singh, 1964; Gupta et al., 1984; Sharma et al., 1985; Trivedi & Chauhan, 2008, 2009) from northwest Himalaya, based on the pollen evidence from the lacustrine deposits. However, the Garhwal region with a large number of potential lakes/bogs for the Quaternary palaeoclimatic studies have hitherto not got adequate attention on this aspect, barring the sketchy proxy records retrieved from the subtropical lakes, viz. Dewar Tal (Chauhan & Sharma, 2000) and temperate belt Deori Tal (Sharma et al., 1996; Sharma & Gupta, 1997) and Sat Tal (Chauhan et al., 1997), depicting the changing vegetation scenarios, contemporaneous climatic shifts and impact of human activity during the Late Holocene. In the present paper, an attempt has been made to extend such studies in the temperate belt of this region in order to bring out more proxy signals on the vegetation shifts and climatic oscillations since the Mid-Holocene period through the pollen analytical investigation of 3.06 m thick sediment core from Nachiketa Tal, lying at an elevation of ca. 2550 m amsl.

Nachiketa Tal is located about 29 km north of Uttarkashi Town and about 4 km from Chaurangi Khal in the temperate belt of Garhwal Himalaya between 30° & 31°N and 78° and 79°E at an elevation of 2550 m amsl amidst the dense oak forest (Fig. 1). The lake is elliptical in outline, measuring about 150 m in length and 40 m in breadth with irregular margin. The lake remains covered with thick sheet of ice during the cold months of January and February.

CLIMATE

The climate of this region is temperate and typical montane type with well-defined rainy, winter and summer seasons. The maximum annual mean temperature ranges from 15°C to 25°C, but during winter it descends to 5°C and occasionally it descends below 0°C, during the cold months of January and February. Average annual rainfall is about 2,000 mm. During the months of severe cold the precipitation is in the form of snow. All the surrounding mountains remain snow clad during the winter.
VEGETATION

The hill slopes contiguous to the lake are largely covered with oak forest dominated by Quercus semecarpifolia. The other prominent broad-leaved of oak such as associated Rhododendron arboreum, Aesculus indica, Alnus nepalensis, Acer caesium, Fraxinus excelsior, Ulmus wallichiana, Myrsine africana, Salix elegans, Pyrus malus, etc. also occur frequently in the forest. Other arboreals such as Myrica esculenta, Launaea rosmarina, Quercus ovalifolia, Symplocos abaxialis, Rubus ellipticus, Lonicera obavata, Pedicularis asiatica, Rosa moschata, Rubus adnata, Geranium fulgens, Pedicularis sp., Berghnia viligula, Swertia chirita, Geranium nepalense, Agrimonia sp., Aster sp., Pedicularis sp., Sedum trifidum, Saxifraga diversifolia, Thalictrum indicum, Galium marginatum, Jasminum humile, Rubus adnata, Artemisia sp., etc.

The herbaceous vegetation on the forest floor is quite luxuriant and constituted of Anaphalis adnata, Primula sp., Potentilla fulgens, Pedicularis sp., Berghnia viligula, Swertia chirita, Geranium nepalense, Agrimonia sp., Aster sp., Pedicularis sp., Sedum trifidum, Saxifraga diversifolia, Thalictrum indicum, Galium marginatum, Jasminum humile, Rubus adnata, Artemisia sp., etc.

The higher reaches support conifer forest composed of Pinus wallichiana, Cedrus deodara and Abies spectabilis, whereas chirpine forests (Pinus roxburghii) occur gregariously on the lower adjoining hill slopes to the lake and are almost devoid of other undergrowth, besides the grasses.

MATERIAL AND METHODS

A 3.06 m sediment core was collected from the centre of the lake below 2.6 m water column using SPIZZ German core. In all, 30 samples were picked up from this core at 10 cm intervals for pollen analysis. Besides, three bulk three samples were also taken at broader intervals for radiometric dating.

The sediment composition of the core collected is uniformly black organic mud with scattered rootlets in the upper part up to the depth of 50 cm. Out of three samples for radiometric dating only one sample at the depth of 109 cm could be dated to 1,855 yr BP, whereas upper most sample at 10 cm depth proved to be modern. The available 14C date of 1,855 yr BP has been used to calculate the sedimentation rate, which is 17 years/cm. This sedimentation rate has facilitated the extrapolation of more dates, i.e. 5,304 to 3,912 yr BP. The pollen sums vary from 300 to 500, which include only the terrestrial pollen. The pollen of aquatic plants and fern spores were excluded from the pollen sum due to their origin from local provenance. However, their frequency percentages have been calculated from the pollen sums for their representation in the pollen diagram. The plant taxa recovered have been broadly grouped as trees, shrubs, herbs, fern spores and algae remains and they are arranged in the same sequence in the pollen diagram. Further, the tree taxa are put in order of their altitudinal distribution.

The AMS ages determined for this sediment core are set out in the Fig. 2.

The standard technique of pollen analysis (Erdtman, 1943) through the use of 10% aqueous KOH, 40% HF solutions and acetolysing mixture (9:1, acetic anhydride and concentrated sulphuric acid) was followed to extract the pollen and spores from the sediments. Samples for microscopic examination were prepared in 50% glycerine solution.

POLLEN ANALYSIS

All the samples analysed from this sediment core were found very productive in pollen and spores (Pl. 1). The pollen sums vary from 300 to 500, which include only the terrestrial pollen. The pollen of aquatic plants and fern spores were excluded from the pollen sum due to their origin from local provenance. However, their frequency percentages have been calculated from the pollen sums for their representation in the pollen diagram. The plant taxa recovered have been broadly grouped as trees, shrubs, herbs, fern spores and algae remains and they are arranged in the same sequence in the pollen diagram. Further, the tree taxa are put in order of their altitudinal distribution.


This pollen zone covers a time interval of 5,304 to 3,912 yr BP. The lower part of it is marked by the low pollen content, comprising few grains of Poaceae and Pinus, however, the upper half depicts the high frequency of Pinus cf. wallichiana (31.83-38%) followed by Abies (5-7.2%), Cedrus (1.56-8.8%), Quercus (1.9-9.36%) and Ulmus (3.2-4.68%) are relatively better represented in contrast to other broad-leaved taxa, viz. Betula (1.27-1.56%) and Corylus (1.9-1.56%). Among the non-arboreal taxa, Poaceae (15.88-21%) is present in high frequency followed by Thalictrum (7.2-13.9%), Chenopodiaceae/Amaranthaceae (0.8-3.9%), whereas Ranunculaceae (1.27%) is met with in low frequency. Marshy vegetation is marked by the moderate values of Cyperaceae (2.54-3.12%) and Polygonum serrulatum (0.5-1%). Potamogeton (3.2-5.46%), the sole representative of aquatic vegetation is met with
consistently in high frequencies. Freshwater algae—Botryococcus (3.2%) is recovered in one sample only. Fern spores monolete (64-130%) are abundant as compared to trilete spores (3.18-4.68%), which are in low frequency.

**Pollen Zone NKT-II (230-170 cm): Quercus-Pinus cf. wallichiana-Alnus-Cedrus-Juglans-Rosaceae-Poaceae-Cheno/Polygonum serrulatum-Fern assemblage**

This pollen zone with the time bracket of 3,912 to 2,975 yr BP exhibits the much enhanced frequencies of Quercus (24.9-37.5%). Likewise, Betula (1.02-3.12%), Alnus (1.98-2.54%) and Ulmus (1.5-3.64%) are also better represented. Juglans (2.49-4.3%), Rhododendron (1.02-2%), Salix (1.02-2.54%) and Symlocos (0.76-1.6%) turn up for the first time with increasing trend. However, Meliaceae (2%) is recorded in one sample only. Among the conifers, Pinus cf. wallichiana (1.5-18.4%) as well as Cedrus (3-1%), Abies (2.64-8.84%) and Picea (0.51-1.04%) portray a sharp decline. Shrubbery elements such as Strobilanthes (2%), Oleaceae (0.89-1.75%), Rosaceae (1.8-5.2%) and Rutaceae (2% only in a sample) appear for the first time in this zone with moderate values. Among non-arboreal taxa, Poaceae (5.81-13.55%) exhibits much reduced values with declining trend. Artemisia (1.5-5.2%), Caryophyllaceae (maximum up to 1.5-10.79%) and Ranunculaceae (3.12-4.1%) reappear with increasing trend in the upper half of this pollen zone. Polygonum serrulatum (2.56-6.49%) has relatively low frequency compared to the preceding zone together with Cyperaceae (0.5-1.66%), which becomes much sporadic with moderate values. Potamogeton (0.83-1.8%) has reduced values than in the preceding pollen zone, whereas Typha (4%) and Utricularia (0.5%) are retrieved for the first time, though sporadically. Monolete fern spores (48.12-15.8%) decline much in the upper part in this zone. On the other hand, trilete fern spores (1-3.38%) remain sporadic as seen in Pollen Zone NKT-I.

**Pollen Zone NKT-III (170-110 cm): Pinus cf. wallichiana-Quercus-Abies-Poaceae-Polygonum serrulatum-Fern assemblage**

This pollen zone encompassing the timespan of 2,875 to 1,872 yr BP demonstrates much enhancement in Pinus cf. wallichiana (3.12-60%). Similarly, the other conifers such as Picea (0.51-1.04%), Abies (2.64-8.84%) and Cedrus (5.5-8.82%) also show increasing trend with moderate values. On the other hand, Quercus (30-15%) exhibits a sharp declining trend. The other broad-leaved associates such as Alnus (4.72% only in a sample), Betula (0.694-2.56%), Ulmus (0.5-1.38%) and Juglans (0.5-1%) also are marked by their reduced frequencies than in the Pollen Zone NKT-II. Shrubbery elements such as Rutaceae (2.56%), Rosaceae (4.69%) and Cotoneaster (0.85%) are recovered very scantily. Poaceae (5-15.26%) is characterized by the slightly increased values among the non-arboreals.
The rest of the herbaceous elements, viz. Artemisia (4.69%), Ranunculaceae (1.38-5.55%) and Malvaceae (0.85%) are scarcely present. Marshy taxa Polygonum serrulatum (2.48-6.94%) is met with consistently much increased frequencies than in the preceding pollen zone, whereas Cyperaceae (1.24-1.38%) is static as before. Potamogeton (0.5% in one sample only), Typha (1%) and Utricularia (6.75%) are encountered occasionally. Fern monolete (0.58-44%) has excessively increased frequencies in contrast to the Pollen Zone NKT-III and trilete (1.28-2.48%) are recorded in low frequencies and do not show any marked change.

**Pollen Zone NKT-IV (110-45 cm): Quercus-Pinus cf. wallichiana-Abies-Betula-Poaceae-Ranunculaceae-Botryococcus-Fern assemblage**

This Pollen zone with the temporal range of 1,872 to 767 yr BP reveals the consistently much high frequency of Quercus (4.19-56.8%) with increasing trend. Similarly, Alnus (1.39-9.22%), Betula (0.7-3.96%), Ulmus (1.3-2.3%) and Corylus (0.8-1.53%) are also recorded in the improved values than to seen in the preceding pollen zone. The other broad-leaved taxa, Juglans (0.4-1.8%), Salix, Symplocos (1.5% in one sample each) and Meliaceae (0.5% in one sample only) are very scanty. On the other hand, Pinus cf. wallichiana (11.4-64.3%) portrays a sharp decreasing trend followed by Abies (8.2-1.8%) and Cedrus (0.8-4.3%), which are extremely low. The shrubby elements, Rutaceae (0.66-3.8%) and Rosaceae (0.38-0.7%), Strobilanthes (1.39%) and Cotoneaster (0.4% in one sample only) are recorded in variable frequencies. Acanthaceae shows the increased frequencies than in the preceding pollen zone. Among the non-arboreal taxa, Poaceae (5.5-13%), despite of its high frequencies, remains more or less static as before. However, Artemisia (1.5-2.9%), Ranunculaceae (1.2-4.87%), Chenopodiaceae/Amaranthaceae (0.81-1.5%) and Tubuliflorae (0.41-0.66%) has slightly increased values. Loriscera (1.21-1.33%) and Jasminum (0.5%) turn up sporadically for the first time. Marshy taxa, Polygonum serrulatum (0.4-1.8%), Polygonum puleatum (1.3% in one sample only) and Cyperaceae (0.4-2.3%) become more sporadic in this zone. Fern monolete spores (11-67.8%) decline abruptly, after a short rise in the beginning of this zone. The trilete spores (0.68-1.7%), in general, are recorded in reduced frequencies. The freshwater alga-Botryococcus (2.44-41%) reappears with increased values, after a lapse in pollen zones NKT-II & NKT III, whereas Potamogeton (0.7-1.2%) is scarcely present.

**Pollen Zone NKT-V (45-0 cm): Quercus-Pinus cf. wallichiana-Cedrus-Abies-Alnus-Poaceae-Artemisia-Ranunculaceae-Botryococcus-Fern assemblage**

This pollen zone with the temporal interval of 767 yr BP to Present also is characterized by the better representation of Quercus (10.3-32.8%), however, with slightly reduced values than Pollen Zone NKT-IV. The broad-leaved associates such as Alnus (2-3.5%), Betula (1-1.5%) and Corylus (0.98-1.5%) demonstrate slightly reduced values, whereas Juglans (0.5-1.06% each), Salix, Meliaceae (0.49-0.5% each) and Carpinus (0.49-0.35%) are sporadic. Pinus cf. wallichiana (28-41.4%), Picea (0.35-1.38%), Abies (1.5-6%) and Cedrus (1.47-3.15%) are showing increasing trend in contrast to Pollen Zone NKT-IV. The shrubby elements, Cotoneaster (1.47-1.47%), Rosaceae (0.49-0.69%) and Rutaceae (0.35-1.96%) are scarce compared to the Pollen Zone NKT-III, though scantly. Among the non-arboreal taxa, Poaceae (3.54-28.5%) dominates, exhibiting increased values in this zone together with Artemisia (1.5-5.6%) and Ranunculaceae (3-6.21%). Chenopodiaceae/Amaranthaceae (0.49-1.38%) do not show any change. Cerealia (1.5-2.5%) is met with increased values than in the preceding pollen zone. However, Thalictrum (0.69-1.06%), Rumex (0.69%) and Urticaceae (0.7%) are meagrely presented. Marshy element, Cyperaceae (0.71%) is meagrely present together with Polygonum puleatum (0.69%). Polygonum serrulatum (1.38%) is met with slightly improved frequencies, though sporadically. Among the aquatics, Potamogeton (0.35-6.21%) do not show any marked changes compared to preceding zone, whereas Utricularia (0.35%) reappears after a lapse in the Pollen Zone NKT-IV, though meagrely. However, the freshwater alga-Botryococcus (1.38-9.65%) attains somewhat increased values. Fern producing monolete spores (35.3-40.07%) are marked by an increasing trend with high frequency than before. On the other hand, trilete spores (0.35-1.96%) are infrequent.

**DISCUSSION**

The changes in Quaternary palynofloras are typically ascribed to the changing climatic patterns that affected the entire earth (Wrigth & Frey, 1965). The pollen diagram of this profile reveals a good floristic diversity. However, the diagram is mainly dominated by Quercus, Pinus, Poaceae, Cyperaceae and algal spores. As discussed earlier, the contrasting climatic requirements of Quercus and Pinus and high fluctuations in their percentages justify using the Q/P ratio as an important parameter for climate interpretation (Fig. 3). Inferred climate trends are also based on local hydrological conditions deduced from percentages of Cyperaceae pollen, fern spores, aquatic plants and algal spores.

The pollen analytical investigation of 3.06 m deep sedimentary profile from Nichikal Tal isolated in the temperate zone of Garhwal Himalaya have provided some interesting inferences concerning the vegetation shifts and climatic variability in the region since Mid-Holocene Period. The pollen sequence has deciphered that around, 5,304 to 3,912 yr BP (Pollen Zone NKT-I), the temperate belt of this region supported mixed Pine-Oak forests in which Pinus cf. wallichiana was the major component, however oak woods were confined in pockets and depressions, where moist and shady condition prevailed. The other high altitudinal conifers such as Abies

TRIVEDI et al.—MID-HOLOCENE VEGETATION SHIFTS AND CLIMATE CHANGE OF GARNHWAL HIMALAYA 295
and Cedrus also flourished well in the region, whereas the close associates of oak, viz. Ulmus and Betula occurred sparingly. The overall vegetation mosaic reflects that this region was under a cold and dry climatic condition owing to reduced monsoon precipitation. The herbaceous flora on the forest floor was largely constituted of grasses (Poaceae) along with Chenopodiaceae/Amaranthaceae. Thalichtrum and Ranunculaceae. Ferns grew in isolated patches in shady and damp situations in the proximity of the lake. The record of aquatic element-Potamogeton with moderate values together with algal-Botryococcus suggests the existence of the lake of moderate dimension during this period.

Between 3,912 to 2,875 yr BP (Pollen Zone NKT-II) the drastic improvement in Quercus and a simultaneous reduction in Pinus cf. wallichiana and other high altitudinal taxa, viz. Cedrus and Abies suggest the replacement of pine-oak broad-leaved forests by mixed oak-broad-leaved forests. This is also indicated by the increase in Q/P ratio. The mixed oak-broad-leaved forests became diversified in composition as clearly manifested by the invasion of a large number of other associated broad-leaved taxa such as Juglans, Rhododendron, Salix, Symplocos and Meliaceae for the first time together with the shrubby elements, Rosaceae and Rutaceae. This significant change in the vegetation scenario occurred in response to onset of a warm and humid climate attributable to prevalence of active monsoon precipitation. The beginning of this phase coincides with the Period of Climatic Optimum, which has been globally recorded between 9,000 to 3,000 yr BP (Bradley, 1999). This is also substantiated by the decline in grasses (Poaceae), paving the way for the proliferation of oak forests. Similarly, the low value of the local wetland members, sedges (Cyperaceae), Polygonum serralatum and Polygonum plebeium further indicates that the marshy ground was virtually submerged under high water. Fern continued to flourish well in moist and damp habitats as witnessed in the preceding phase.

Around 2,875 to 1,872 yr BP (Pollen Zone NKT-III) the expansion in Pinus cf. wallichiana together with moderate increase in other temperate conifers such as Cedrus, Abies and Picea. On the other hand, Quercus declined sharply and its broad-leaved-associates, viz. Juglans, Alnus, Betula, Ulmus, etc. turned more sporadic than before. This apparent change in the overall vegetation pattern elucidates that the Pinus cf. wallichiana dominated conifer forests succeeded the mixed oak-broad-leaved forests as a consequence of change in climate condition which became cold and dry with the commencement of this phase of reduced monsoon precipitation. This is also well corroborated by the decreased Q/P ratio. The herbaceous vegetation on the forest floor was largely constituted of grasses only since pine and conifer forests altogether are devoid of other herbaceous undergrowth. The lake got shallower as reflected by scanty presence of aquatic elements, viz. Potamogeton and Utricularia and total absence of Botryococcus as compared to witnessed in the preceding phase. However, the widening of the swampy condition along the lake margin took place owing to prevailing harsh climate as clearly indicated by the much increase in Polygonum serralatum.

Between 1,872 and 767 yr BP (Pollen Zone NKT-IV) amelioration in climate is reflected which most likely became warm and humid. This is well manifested by the sudden improvement in Quercus, Salix, Symplocos and Meliaceae as well as substantial decline in Pinus cf. wallichiana and other conifers, viz. Cedrus, Abies and Picea during this phase. Replacement of mixed pine forest by mixed oak-broad-leaved forest further supports the amelioration in climate. The improvement in shrubby elements such as Rosaceae, Rutaceae and Acanthaceae also occurred on account of amelioration in climate. The better representation of aquatic elements such as Typha and reappearance of freshwater alga-Botryococcus and reduction in sedges are indicative of the rise in lake water-level with low marshy condition along the lake margin due to increased precipitation during this period. The first encounter of cereal pollen and the improvement seen in other culture pollen taxa such as Chenopodiaceae/Amaranthaceae, Artemisia, Caryophyllaceae, Urticaceae, etc. demonstrate that during this phase the adjoining area around the lake site was under agricultural practice and the impact of intensive biotic pressure.

**PLATE 1**

<table>
<thead>
<tr>
<th>No.</th>
<th>Taxon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Abies</td>
</tr>
<tr>
<td>2.</td>
<td>Cedrus</td>
</tr>
<tr>
<td>3.</td>
<td>Pinus</td>
</tr>
<tr>
<td>4, 5.</td>
<td>Quercus</td>
</tr>
<tr>
<td>6.</td>
<td>Symlocos</td>
</tr>
<tr>
<td>7.</td>
<td>Betula</td>
</tr>
<tr>
<td>8.</td>
<td>Corylus</td>
</tr>
<tr>
<td>9.</td>
<td>Alnus</td>
</tr>
<tr>
<td>10, 16.</td>
<td>Meliaceae</td>
</tr>
<tr>
<td>11.</td>
<td>Juglans</td>
</tr>
<tr>
<td>12.</td>
<td>Ulmus</td>
</tr>
<tr>
<td>13.</td>
<td>Rhododendron</td>
</tr>
<tr>
<td>14.</td>
<td>Convulculus</td>
</tr>
<tr>
<td>15.</td>
<td>Strobilanthes</td>
</tr>
<tr>
<td>17.</td>
<td>Cannabis sativa</td>
</tr>
<tr>
<td>18.</td>
<td>Brassicaceae</td>
</tr>
<tr>
<td>19.</td>
<td>Artemisia</td>
</tr>
<tr>
<td>20.</td>
<td>Chenopod/Amaranth</td>
</tr>
<tr>
<td>21.</td>
<td>Poaceae</td>
</tr>
<tr>
<td>22.</td>
<td>Caryophyllaceae</td>
</tr>
<tr>
<td>23.</td>
<td>Tubuliferae</td>
</tr>
<tr>
<td>25, 26.</td>
<td>Polygonum serralatum</td>
</tr>
<tr>
<td>27.</td>
<td>Cyperaceae</td>
</tr>
<tr>
<td>28.</td>
<td>Utricularia</td>
</tr>
<tr>
<td>29.</td>
<td>Fern trilet</td>
</tr>
<tr>
<td>30.</td>
<td>Fern monolete</td>
</tr>
<tr>
<td>31.</td>
<td>Botryococcus</td>
</tr>
<tr>
<td>32.</td>
<td>Potamogeton</td>
</tr>
</tbody>
</table>
Since 767 yrs BP onwards (Pollen Zone NKT-V), the landscape continued to be occupied by the mixed oak-broad-leaved forests. However, the forests got less diversified than earlier as envisaged by the relatively reduced frequencies of Quercus. Similarly the other broad-leaved taxa and shrubby elements also declined with the onset of this phase. Contrary to this the moderate expansion of Pinus cf. wallichiana and other conifer also occurred by this time. The overall vegetation mosaic portrays that the region experienced a warm and less humid climate as a consequence of moderate monsoon precipitation. However, the selective felling or clearance of oak forests by the local inhabitants to meet out their various requirements cannot be ruled out. During this period, the lake probably turned smaller and shallower in dimension and the marshy margin got wider all along the lake in response to the reduction in the monsoon precipitation. This is well testified by the fact that important aquatic elements, viz. Potamogeton and freshwater alga-Braytrycoccus show decreased frequencies than witnessed in the preceding phase. Concurrently, the acceleration of the agriculture practice in the region also took place probably to cope with the food security of escalating human population in the region during the recent past. This is well documented by the frequent recovery of Cerealia and other culture pollen taxa right from the onset of this phase.

Acknowledgements—Financial assistance rendered by Department of Science and Technology, New Delhi for the Sponsored Women Scientist Project (WOS-A) (SR/WOS-A/ES-18/2009) is highly acknowledged. Authors are thankful to Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing facilities to carry out this work and to Dr M.S. Chauhan and Mrs Indra Goel for their support in various ways to accomplish this work.

REFERENCES


Erdtman G 1943. An Introduction to Pollen Analysis. Waltham Mass., USA, pp. 239.


