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Leaf Impression of *Amesoneuron* (Arecaceae) from the Lower Siwalik Sediments of the Kankai Mai River Section, Eastern Nepal

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Abstract

A leaf impression of Amesoneuron (Arecaceae) is reported from the Lower Siwalik sediments of the Kankai Mai River section, eastern Nepal. The overall habit, habitat and modern distributions and climatic conditions show the existence of tropical to sub-tropical wet evergreen forests with humid swampy lowland areas during the deposition of the sediments.

Keyword Fossil, Arecaceae, Miocene, eastern Nepal

1. Introduction

The Arecaceae is a large commelinid clade of the monocotyledonous family (Chase *et al.,* 2006; Davis *et al.,* 2006) with five subfamilies namely Arecoideae, Calamoideae, Ceroxyloideae, Coryphoideae and Nypoideae and about 28 tribes (Dransfield *et al.,* 2005; 2008). This pantropical family consists of 188 genera and about 2600 species (Mabberley, 1997; Govaerts & Dransfield, 2005; Dransfield *et al.,* 2008), commonly found in the tropical rainforests of the world (Couvreur *et al.,* 2011). In the Indian sub-continent, the family comprises 20 genera and 88 species with 9 genera belonging to 24 species endemic nature (Kulkarni & Mulani, 2004). However, only 7 genera and 12 species are found in the Nepalese Himalaya (Press *et al.,* 2000).

Palmae fossils have been described from the Cretaceous–Neogene sediments of the world (Zhou *et al.,* 2013; Srivastava *et al.,* 2014; Song *et al.,* 2021 and references therein). Pollen grains have been widely reported from the Neogene sediments in the Himalaya region (Banerjee, 1968; Hoorn *et al.,* 2000; Paudayal 2012, 2013a, b; Prasad *et al.,* 2011; 2013c; Mukherjee, 2015; More *et al.,* 2016; Dhakal *et al.,* 2022), but their megafossil profiles are little known in the region (Sahni, 1931; Prasad, 1987; Awasthi & Prasad, 1990; Prasad, 2006; Singh & Patnaik, 2012; Prasad *et al.,* 2013b). This paper presents a new fossil of the Arecaceae family recovered from the Lower Siwalik of the Kankai Mai River section, eastern Nepal (Fig. 1).

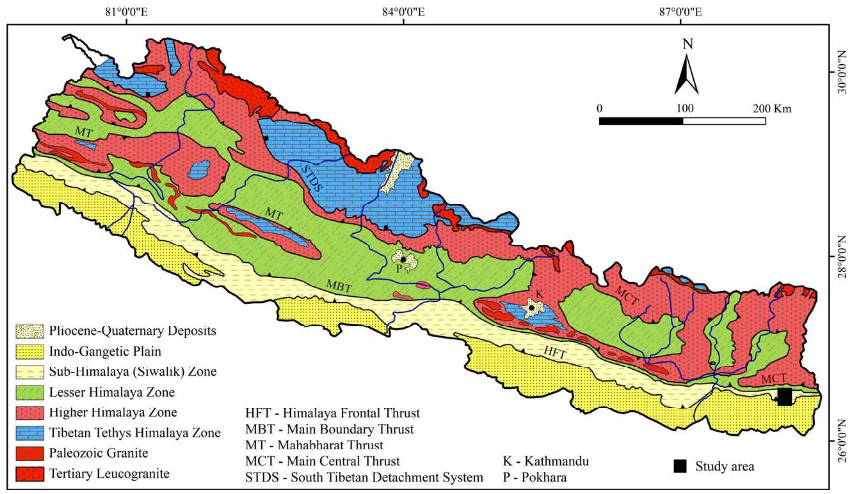

Fig. 1: Geology of the Nepal Himalaya (modified after Martin et al., 2005) and black rectangle shows study area.

2. Geological setting of study area

Since the middle Miocene to early Pleistocene, the Himalayan foreland basin has accumulated a huge pile (up to 6000 m thick) of molasse-like sedimentary succession made up muds, silts, sands, and gravels. These sedimentary strata named as Siwalik Group, is located between the Indo-Gangetic Plain and the Lesser Himalayan sequence in the south and north respectively (Gansser, 1964; Valdiya, 2002). The Siwalik Group continuous from Suram Basin in eastern Himalaya to the Potwar Basin in western Himalaya (Lin et al., 2022) covering a longitudinal distance of about 2400 km with dominantly coarsening upward succession, however individual beds exhibit fining upward sequence (Prakash *et al.,* 1980; Nakayama & Ulak, 1999). The Siwalik succession in Nepal can be classified into the Lower, Middle and Upper Siwaliks (Auden, 1935; Hagen, 1969) and called as the Churia Group (Tokuoka & Yoshida, 1984).

The study area lies in the eastern Nepal along the Kankai Mai River section (26.68° N; 87.9° E) (Fig. 1). The Siwalik Group of the study area can be classified into the Lower Siwalik (lower and upper members), the Middle Siwalik (lower, middle and upper members) and the Upper Siwalik (lower and upper members) based on the lithological variation and their thickness (Ulak, 2009; 2016). The Main Boundary Thrust (MBT) from the Lesser Himalayan in the north and the Himalayan Frontal Thrust (HFT) from the Indo-Gangetic Plain in the south define the boundaries of the Siwalik Group (Ulak, 2009, 2016; Dhital, 2015) (Fig. 2).

Variegated mudstone, greenish grey to light grey mudstone and grey siltstone interbedded with very fine- to medium-grained, greenish grey to light grey sandstone with calcareous cementing elements are found in the Lower Siwalik. The upper part shows medium- to coarse-grained, grey to greenish grey, 'salt and pepper' like appearance in sandstone beds. The Middle Siwalik is made up of medium- to very coarse-grained, light grey, 'pepper and salt' sandstone with pebbles interbedded with fine grained, greenish grey to gray, sandstone and greenish grey to dark grey mudstone and grey siltstone. At its upper part, loose and multi-storied sandstone beds are found. The Upper Siwalik is represented by poorly to well sorted, matrix to clast supported, cobble pebble boulder sized conglomerate interbedded with medium to very coarse grained, reddish brown to grey 'pepper and salt' sandstone with pebbles and grey to dark grey mudstone and grey siltstone. The lens of sandstone beds is frequently observed in the upper part (Ulak, 2009; 2016) (Fig. 2). Monocot leaves bearing horizon have been found in thinly laminated, light grey siltstone beds of the upper member of the Lower Siwalik sediments (Fig. 3).

3. Materials and methods

The fossil leaf impressions studied here were extracted from the upper member of the Lower Siwalik sediments of the Kankai Mai River section, eastern Nepal (26.68° N; 87.9° E) (Figs. 1 and 2). A soft brush, fine chisel, and hammer were used to remove the fossil impressions before taking photographed with a digital camera (Canon PowerShot G7 Mark II) in low-angle, natural light. The terminology of leaf architecture used follows the description by Dilcher (1974) and Ellis *et al.* (2009). The fossil impressions were identified at the Central National Herbarium (CNH), Howrah, India. All fossils are stored in the laboratory of the Department of Geology at Birendra Multiple Campus, Bharatpur, Chitwan.

Systematic

Order: Arecales
Family: Arecaceae
Genus: *Amesoneuron* (Göppert) Read & Hickey, 1972
Species: *Amesoneuron* sp. (Fig. 4: a-b)
Number of specimens Examined: One
Figured specimen No.: KMA44 (a part), KMA47 (counterpart)
Locality: Left bank of the Kankai Mai River, about 100 m downstream from the Kankai Mai Dam Site, Domukha
Stratigraphic horizon: Upper member of Lower Siwalik
Age: Middle Miocene

Description Leaf incomplete without an apex and base, chartaceous, preserved lamina length and width 5.65-5.8 cm and 1.5-1.7 cm respectively; margin entire; primary vein parallelodromous; mid vein almost straight, stout; preserved lateral primary veins 3 pairs, lateral primary vein moderately thick, straight, 3.6-2 mm apart; major secondary vein 8 pairs, thin, running parallel to adjacent veins, 0.6-1 mm apart; finer veins ill preserved in between two major secondary veins; closely spaced, 0.2-0.4 mm apart; further fine detailed not preserved.

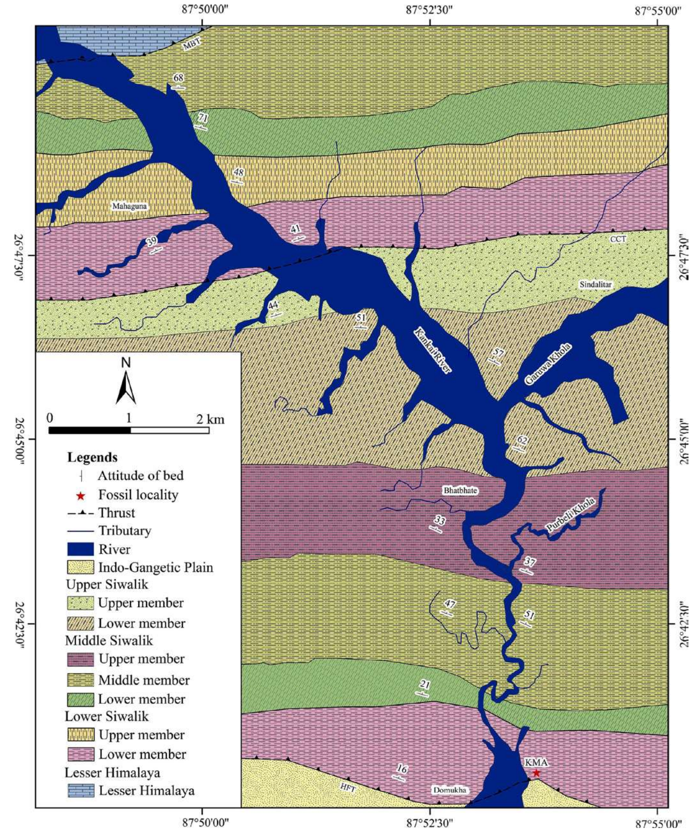

Fig. 2: Geological map of the Kankai Mai River area (modified after Ulak, 2009).

Affinities

The characteristic features of the fossil impression such as its entire margin, parallelodromous venation, strap shape lamina with distinct primary veins suggest its affinities with the family Arecaceae. However, fossil specimen incompleteness makes it, difficult to identify its affinity up to the generic level. The present fossil cannot be compared with the modern analog of palm taxa. Under the circumstances, they have the isolated fragmentary nature of lamina with parallel veins but fragments of fossils lack their main rachis attachment, showing difficulty in identifying their original shape of palmate or Pinnate. Therefore, the given fossil has been described under the artificial genera of *Amesoneuron* (Göppert) Read and Hickey (1972).

The genus *Amesoneuron* was reported from the Maastrichtian–Danian sediments of India (Bond, 1986; Guleria & Mehrotra, 1998; Prasad *et al.,* 2013a), while it has also been reported from the lower Miocene of Himachal Pradesh, India (Guleria *et al.,* 2000), upper Paleocene of Meghalaya, India (Mehrotra, 2000), late Eocene of Manipur, India (Guleria *et al.,* 2005), late Eocene-Oligocene of Ladakh, India (Mehrotra et al., 2007). Similarly, the genus *A. siwalicus* and *A. miocenica* are reported from the Siwalik sediments of India (Prasad, 2006; Prasad *et al.,* 2013b).

4. Discussion and conclusion

The growth of the Arecaceae family is significantly influenced by the presence of excessive water conditions and sufficient sunlight and usually lies in the tropical zones in the middle of 5° N and 5° S latitudes that show about 90 percent of their distributions (Svenning *et al.,* 2008; Couvreur *et al.,* 2011; Srivastava *et al.,* 2014). Previous research indicates that temperature is the major factor that resists their growth in the region, with a mean temperature of the cold month (CMT) of 5 °C as the limit (Greenwood & Wing, 1995; Greenwood & West, 2017; Reichgelt *et al.,* 2018). However, a comprehensive analysis of the present-day distribution of the climatic condition of the Arecaceae survival threshold reveals a cold month mean temperature (CMT) of below 5.2 °C (Greenwood & Wing, 1995).

Quantitative estimation of palaeoclimate reconstruction based on the Coexistence Approach of the Lower Siwalik of Darjeeling area, which is close to our fossil locality indicates a mean annual temperature (MAT) of 27.2 °C ± 0.3 °C, however the temperature was 28.2 °C ± 0.1 °C of the warmest months (WMT) and 25.6 °C ± 0.3 °C of the coldest months (CMT). The reconstructed precipitation indicates that a mean annual precipitation (MAP) was 2269.5 ± 58.5 mm, while the precipitation was 31 ± 12 mm for of the driest month (LMP), 147 ± 47 mm for the warmest months (WMP), and 367 ± 4 mm for the wettest months (HMP) (Bhatia *et al.,* 2022). As evidenced by the overall habit, habitat and modern distribution and climatic conditions, tropical to sub-tropical wet evergreen forests were growing in humid swampy lowland areas when the sediments were being deposited.

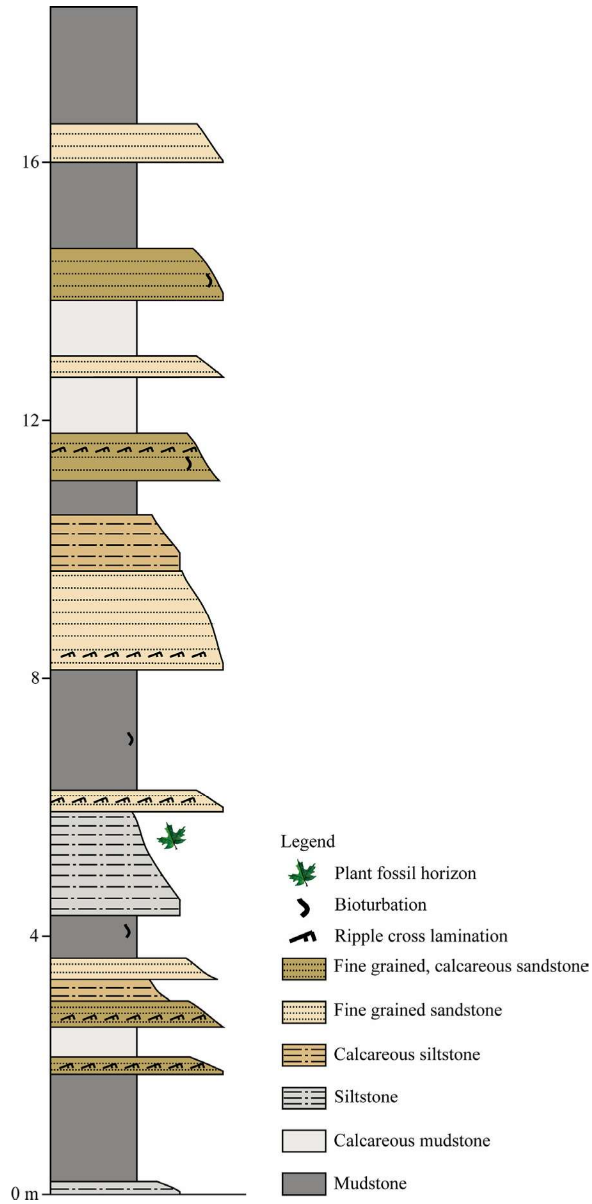

Fig. 3: Lithological details of the fossil locality showing interbedded mudstone, sandstone, siltstone beds.

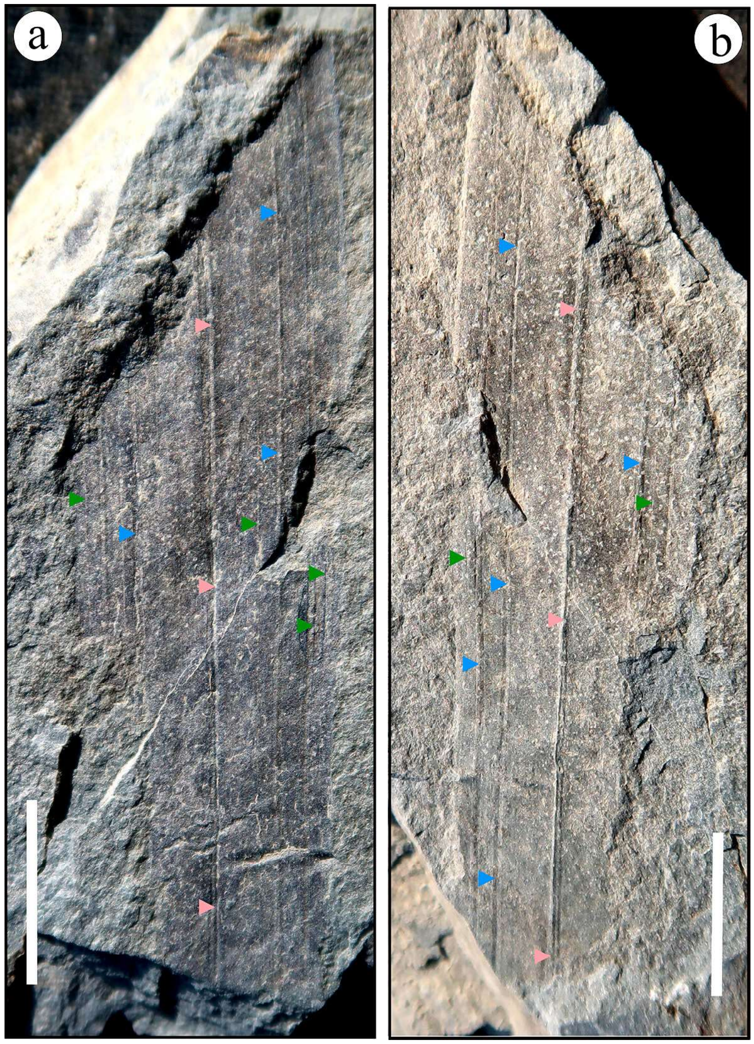

Fig. 4: Fossil leaf *Amesoneuron* sp. (a) Fossil leaf (specimen no. KMA44) showing shape, size, primary vein (pink arrow), lateral primary vein (blue arrow) and secondary vein (green arrow). (b) Fossil leaf (specimen no. KMA47) showing shape, size, primary vein (pink arrow), lateral primary vein (blue arrow) and secondary vein (green arrow) (scale bar = 1 cm).

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References

Auden, J. B. (1935). Traverses in the Himalaya. *Records of Geological survey of India*, *69*, 123–167.

Awasthi, N., & Prasad, M. (1989). Siwalik plant fossils from Surai Khola area, western Nepal. *Palaeobotanist, 38*, 298–318.

Banerjee, D. (1968). Siwalik microflora from Punjab (India). *Review of Palaeobotany and Palynology*, *6*(2), 171–176.

Bhatia, H., Srivastava, G., Adhikari, P., Tao, S., Utescher, T., Paudayal, K., & Mehrotra, R. (2022). Asian monsoon and vegetation shift: Evidence from the Siwalik succession of India. *Geological Magazine, 159*(8), 1397–1414.

Bonde, S. D. (1986). *Amesoneuron borassoides* sp. nov. A borassoid palm leaf from the Deccan Intertrappean bed at Mohgaonkalan, India. *Biovigyanam, 12,* 89–91.

Chase, M. W., Fay, M. F., Devey, D. S., Maurin, O., Rønsted, N., Davies, T. J., Pillon, Y., Peterson, G., Tamura M. N., Asmussen, C. B., Hilu, K., Borsch, T., Davis, J. I., Stevenson, D. W., Pires, J. C., Givnish, T. J., Systma, K. J., McPherson, M. A., Graham, A. W., & Rai, H. S. (2006). Multigene analyses of monocot relationships. *Aliso: A Journal of Systematic and Floristic Botany*, *22*(1), 63–75.

Couvreur, T. L., Forest, F., & Baker, W. J. (2011). Origin and global diversification patterns of tropical rain forests: inferences from a complete genus-level phylogeny of palms. *BMC biology*, *9*(1), 1–12.

Davis, J. I., Petersen, G., Seberg, O., Stevenson, D. W., Hardy, C. R., Simmons, M. P., Michelangeli, F. A., Goldsman, D. H., Campbell, L. M., Specht, C. D., & Cohen, J. I. (2006). Are mitochondrial genes useful for the analysis of monocot relationships?. *Taxon*, *55*(4), 857–870.

Dhakal, R., Humagain, S., Adhikari, P., and Paudayal, K. N. (2022). Palynological study along the Triyuga River section from the Upper Siwalik sediments and its Paleoclimatic condition. *Journal of Nepal geological Society, 63* (In press).

Dhital, M. R. (2015). *Geology of the Nepal Himalaya: regional perspective of the classic collided orogen*. Springer.

Dilcher, D. L. (1974). Approaches to the identification of angiosperm leaf remains. *The botanical review*, *40*(1), 1–157.

Dransfield, J., Uhl, N. W., Asmussen, C. B., Baker, W. J., Harley, M. M., & Lewis, C. E. (2008). *Genera Palmarum-The Evolution and Classification of the Palms*. Kew Publishing.

Dransfield, J., Uhl, N. W., Asmussen, C. B., Baker, W. J., Harley, M. M., & Lewis, C. E. (2005). A new phylogenetic classification of the palm family, Arecaceae. *Kew Bulletin*, *60*, 559–569.

Ellis, B., Daly, D. C., Hickey, L. J., Johnson, K. R., Mitchell, J. D., Wilf, P., & Wing, S. L. (2009). *Manual of leaf architecture*. Ithaca and New York.

Gansser, A. (1964). Geology of the *Himalayas*. Interscience, New York.

Govaerts, R., & Dransfield, J. (2005). *World checklist of palms*. Royal Botanic Gardens.

Greenwood, D. R., & West, C. K. (2017). A fossil coryphoid palm from the Paleocene of western Canada. *Review of Palaeobotany and Palynology*, *239*, 55–65.

Greenwood, D. R., & Wing, S. L. (1995). Eocene continental climates and latitudinal temperature gradients. *Geology*, *23*(11), 1044–1048.

Guleria, J. S., & Mehrotra, R. C. (1998). On some plant remains from Deccan Intertrappean localities of Seoni and Mandla districts of Madhya Pradesh, India. *Palaeobotanist, 47,* 68–87.

Guleria, J. S., Singh, R. K., Mehrotra, R. C., Soibam, I., & Kishor, R. (2005). Palaeogene plant fossils of Manipur and their palaeoecological significance. *Palaeobotanist, 54*(1–3), 61–77.

Guleria, J. S., Srivastava, R., & Prasad, M. (2000). Some fossil leaves from the Kasauli Formation of Himachal Pradesh, north-west India. *Himalayan Geology*, *21*(1–2), 43–52.

Hagen, T. (1969). Report on the Geological survey of Nepal, Vol. 1: preliminary reconnaissance. *Denkschriften der Schweizerischen Naturforschenden Gesellschaft Memoires de la Societe Helvetique des Sciences Naturelles*, *84*(1), 1–185.

Hoorn, C., Ohja, T., & Quade, J. (2000). Palynological evidence for vegetation development and climatic change in the Sub-Himalayan Zone (Neogene, Central Nepal). *Palaeogeography, Palaeoclimatology, Palaeoecology*, *163*(3–4), 133–161.

Kulkarni, A. R., & Mulani, R. M. (2004). Indigenous palms of India. *Current science*, *86*(12), 1598–1603.

Mabberley, D. J. (1997). *The plant-book: a portable dictionary of the vascular plants*. Cambridge university press.

Mehrotra, R. C. (2000). Study of plant megafossils from the tura-formation of Nangwalbibra, Garo Hills, Meghalaya, India. *Palaeobotanist, 49,* 225–237.

Mehrotra, R. C., Ram-Awatar, S. A., & Phartiyal, B. I. N. I. T. A. (2007). A new palm leaf from the Indus suture zone, Ladakh Himalayas, India. *Journal of Palaeontological Society of India*, *52*, 159–162.

More, S., Paruya, D. K., Taral, S., Chakraborty, T., & Bera, S. (2016). Depositional environment of Mio-Pliocene Siwalik sedimentary strata from the Darjeeling Himalayan Foothills, India: A palynological approach. *PLoS One*, *11*(3), e0150168.

Mukherjee, M. (2015). Palyno-petrographical study of the Siwalik rocks of some areas of Arunachal Pradesh, North-Eastern India to understand palaeo-climatic evolution of this region. *Journal of Earth Science & Climatic Change, 6*(9), 307.

Nakayama, K., & Ulak, P. D. (1999). Evolution of fluvial style in the Siwalik Group in the foothills of the Nepal Himalaya. *Sedimentary Geology*, *125*(3–4), 205–224.

Parkash, B., Sharma, R. P., & Roy, A. K. (1980). The Siwalik Group (molasse) –sediments shed by collision of continental plates. *Sedimentary Geology*, *25*(1–2), 127–159.

Paudayal, K. N. (2012). Middle to late Miocene vegetation and climate from the Siwalik sediments (Karnali River section), far Western. *Journal of Nepal Geological Society*, *44*, 33–44.

Paudayal, K. N. (2013a). Palaeolclimatic significance of palynological assemblages from the Siwalik sediments in the Dudhaura Khola section, central Nepal. *Journal of Nepal Geological Society*, *46*, 111–120.

Paudayal, K. N. (2013b). Palynology of the Baka Formation (Middle Siwalik), Karnali River section, west Nepal. *Journal of Institute of Science and Technology*, *18*(1), 65–70.

Prasad, M. (1987). A fossil palm wood from the Lower Siwalik beds of Kalagarh, Uttar Pradesh, India. *Geophytology*, *17*(1), 114–115.

Prasad, M. (2006). Siwalik plant fossils from the Himalayan foot hills of Himachal Pradesh, India and their significance on palaeoclimate. *Phytomorphology*, *56*(1–2), 9–22.

Prasad, M., Khare, E. G., & Singh, S. K. (2013a). Plant fossils from the Deccan Intertrappean sediments of Chhindwara district, Madhya Pradesh, India: their palaeoclimatic significance. *Journal of Palaeontological Society of India*, *58*(2), 229–240.

Prasad, M., Mohan, L., & Singh, S. K. (2013b). First record of fossil leaves from Siwalik (Upper Miocene) sediments of Mandi District, Himachal Pradesh, India: palaeoclimatic and phytogeographical implications. *Palaeobotanist, 62*(1–2), 165–180.

Prasad, M., Rao, M. R., & Khare, E. G. (2011). Palynological investigation of the Lower Siwalik sediments (Middle Miocene) exposed at Koilabas, western Nepal. *Geophytology, 40*(1–2), 47–53.

Prasad, M., Singh, H., & Singh, S. K. (2013c). Middle Miocene palynoflora from the Lower Siwalik sediments of Darjeeling District, West Bengal and their palaeoenvironmental implications. *Himalayan Geology*, *34*, 9–17.

Press, J. R., Shrestha, K. K., & Sutton, D. A. (2000). *Annotated checklist of the flowering plants of Nepal*. Natural History Museum Publications.

Read, R. W., & Hickey, L. J. (1972). A revised classification of fossil palm and palm-like leaves. *Taxon*, *21*(1), 129–137.

Reichgelt, T., West, C. K., & Greenwood, D. R. (2018). The relation between global palm distribution and climate. *Scientific Reports*, *8*(1), 1–11.

Sahni, B. (1931). Materials for a monograph of the Indian petrified palms. In *Proceedings of the Academy of Sciences, 1,* 140–144.

Singh, R. R., & Patnaik, R. (2012). A fossil palm leaf impression from ~11.2 Ma old, Siwalik deposits of Kangra Valley, Himachal Pradesh. *Journal of the Geological Society of India*, *79*(1), 85–88.

Song, A., Liu, J., Liang, S. Q., Van Do, T., Nguyen, H. B., Jia, L. B., Rio, C. D., Srivastava, G., Feng, Z., Zhou, Z.-K., Huang, J., & Su, T. (2021). Leaf fossils of *Sabalites* (Arecaceae) from the Oligocene of northern Vietnam and their paleoclimatic implications. *Plant Diversity, 44*(4), 406–416.

Srivastava, R., Srivastava, G., & Dilcher, D. L. (2014). Coryphoid palm leaf fossils from the Maastrichtian–Danian of Central India with remarks on phytogeography of the Coryphoideae (Arecaceae). *PLoS One*, *9*(11), e111738.

Ulak, P. D. (2009). Lithostratigraphy and late Cenozoic fluvial styles of Siwalik group along Kankai River section, East Nepal Himalaya. *Bulletin of the Department of Geology*, *12*, 63–74.

Ulak, P. D. (2016). Evolution of fluvial system and reconstruction of paleohydrology of late Cenozoic Siwalik Group, related to tectonic uplift of Himalaya and climatic change, Kankai River section, east Nepal Himalaya. *Journal of Nepal Geological Society*, *51*, 59–72.

Valdiya, K. S. (2002). Emergence and evolution of Himalaya: reconstructing history in the light of recent studies. *Progress in Physical Geography*, *26*(3), 360–399.

Zhou, W., Liu, X., Xu, Q., Huang, K., & Jin, J. (2013). New coryphoid fossil palm leaves (Arecaceae: Coryphoideae) from the Eocene Changchang Basin of Hainan Island, South China. *Science China Earth Sciences*, *56*(9), 1493–1501.