RESEARCH ARTICLE

Fossil Species of *Lagerstroemia* and *Millettia* from Miocene Strata of the Sarkaghat Region in the Sub-Himalayan Zone of Himachal Pradesh, India, and their Palaeobotanical Inferences

Alok[1*], Shashi[2], Shivendra Mohan Pandey[2] and Mahesh Prasad[3]

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Abstract

Palaeobotanical investigations were conducted on plant macrofossils obtained from the Middle Siwalik sediments of Sarkaghat, Mandi District, Himachal Pradesh, India as part of this current communication. This study discovered the existence of two previously unknown fossil species that correspond to the taxa that are now living, *Lagerstroemia* Linn. and *Millettia* Wight & Arn. of the families Lythraceae and Fabaceae, respectively. These modern comparable taxa of the macrofossils reported here are distributed in the tropical evergreen to moist deciduous forests of the south-east Asian region which may suggest that tropical forests under moist conditions were prevalent during the Upper Miocene times in this region in contrast to mixed deciduous forest under the reduced precipitation at present. It also indicates the prevalence of a humid tropical climate during the Miocene in the Sarkaghat area.

Keywords: Plant macrofossils, *Lagerstroemia* (Lythraceae) and *Millettia* (Fabaceae), Sarkaghat, Himachal Pradesh, Middle Siwalik, Palaeoclimate, phytogeography

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Introduction

The Siwalik range, which is also known as the Sub Himalayan region, is demarcated by the Main Frontal Thrust (MFT) to the south and the Main Boundary Thrust (MBT) to the north. It is predominantly composed of fluvial sediments that originated during the Neogene epoch (23-1.6 million years ago). This range stretches along the entire Himalayas and forms the southernmost range of hills with a width ranging from 8 to 50 km. Sub Himalayas zone is very rich in fossils. Macrofossils, including angiosperm leaves, fruit, and seed impressions, have been reported previously from the Siwalik sediments of Himachal Pradesh, India, (Lakhanpal (1965, 1967, 1968, 1969), Lakhanpal and Dayal (1966), Lakhanpal and Guleria (1987), and Lakhanpal and Awasthi, 1992; Praksh,1975, 1978, 1981; Yadav, 1989; Lakhanpal *et al.*, 1987: Ghosh & Ghosh, 1958; Prasad, 2006, 2010, 2012; Prasad *et al.* 2013; Tiwari *et al.*, 2022; Singh *et al.*, 2022). There have been minimal reports of fossilized leaves found in the Sarkaghat area's Siwalik deposits, and they bear a likeness to the genus, *Gynocardia* (Flacourtiaceae), *Millettia,* and *Cynometra* (Fabaceae), *Ventilago* (Rhamnaceae), *Terminalia* (Combretaceae) and *Daemonorops* (Arecaceae), *Antidesma* (Phyllanthaceae), *Cyclosorus* (Thelypteridaceae), *Parthenocissus* (Vitaceae), *Fissistigma* (Annonaceae) and *Berberis* (Berberidaceae). In view of the meager work done on this aspect from the Sarkaghat area exposing the Siwalik Group of sediments, the present investigation has been carried out to study the plant macrofossils from this locality to make complete fossil floristic of the area and to deduce palaeoclimate of the Himalayan foothills during the Miocene period. The study area Sarkaghat (N 31° 44′ 26″ E 76° 45'33'') lies along the National Highway 70 in Mandi District, Himachal Pradesh (Fig. 1). Many well-preserved fossil leaves were gathered from the Middle Siwalik beds located in the Sarkaghat area. A palaeobotanical analysis of these fossil leaves revealed the presence of two new fossil leaves that share similarities with existing taxa., *Lagerstroemia piriformis* Koehne of Lythraceae and *Millettia ovalifolia* Kurz of the family Fabaceae have been described and discussed in detail with their palaeobotanical inferences.

[1]Department of Botany, S.K.B.B. Govt. P.G. College, Harakh, Barabanki, Uttar Pradesh, India

[2]Department of Botany, Shivharsh Kisan Postgraduate College, Basti, Uttar Pradesh, India

[3]Birbal Sahni Institute of Palaeosciences, 53, University Road, Lucknow, Uttar Pradesh, India

***Corresponding author:** Alok, [1]Department of Botany, S.K.B.B. Govt. P.G. College, Harakh, Barabanki, Uttar Pradesh, India, Email: alok.sharma13@gmail.com

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Geology of the Study Area

The development of a crucial geological feature, a lengthy and slender depression along India's northern border, occurred during the Middle Miocene as part of the process of mountain formation. The aforementioned depression acted as a location where large quantities of alluvial material, derived from the surrounding mountains and transported via precipitation, rivers, and streams, were deposited, ultimately forming what is now known as Siwalik sediments. The term "Siwalik" was first used by Cautley in 1832 to describe the hill ranges beneath the

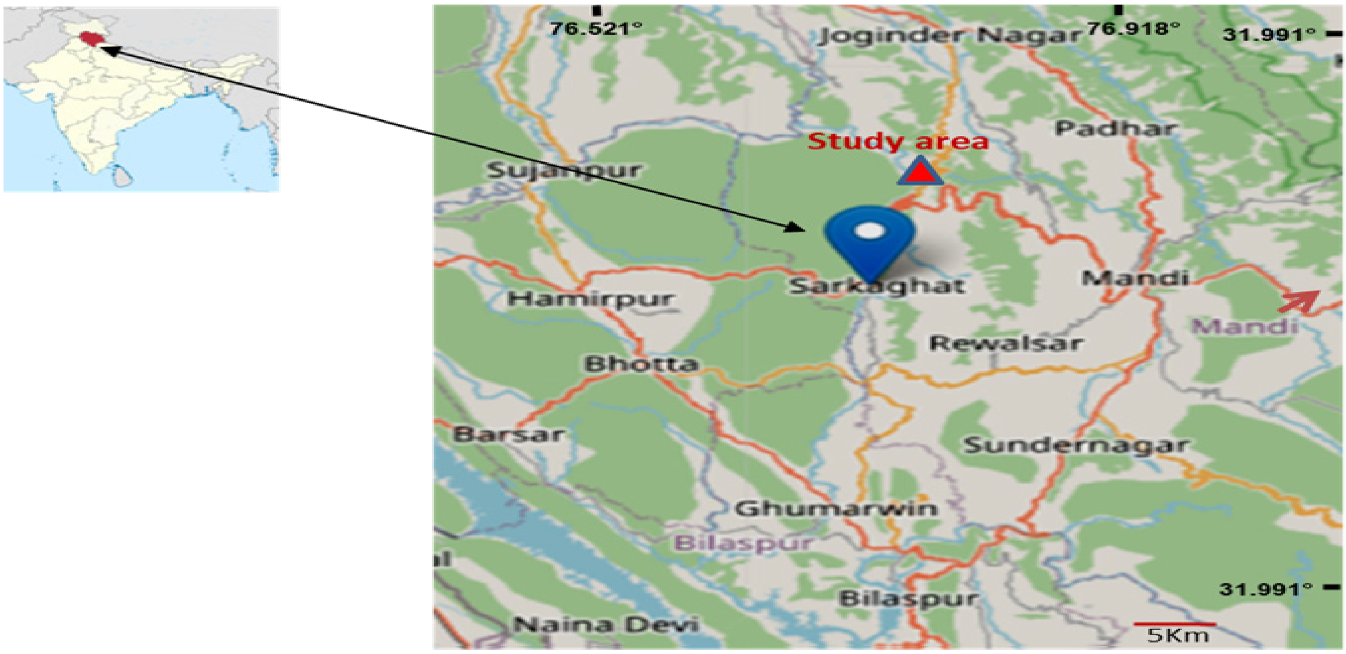

Fig. 1: Google map showing the location of the study area, Sarkaghat in Mandi district, Himachal Pradesh, India

Himalayan mountain range between the Ganga and Yamuna rivers. These hills are known for yielding significant vertebrate fossils in the Hardwar region. The expression "Siwalik" was also utilized by Falconer (1835) to describe the Tertiary deposits that stretch in an almost unbroken sequence from Punjab to the Irrawaddy. These formations are typically defined by the Main Boundary Fault (MBF) to the north and the Indo-Gangetic alluvium to the south in terms of their outcropping patterns. They usually have a width of 10 to 12 km and exhibit a steep incline on the south side and a gradual slope on the north.

Pilgrim (1913) provided a palaeontological base for the three-fold division (Lower, Middle, and Upper Siwalik and proposed the subdivision of three groups of the Siwalik into seven formations (Boulder conglomerate, Pinjor Formation, Tatrot Formation, Dhok Pathan Formation, Nagri Formation, Chinji Formation, and Kamalial Formation) based mainly on their faunal associations. The Lower Siwalik is composed of grey and green greywacke with clastics of varying grain sizes that contain a disseminated calcareous cement. These rocks are interbedded with well-developed chocolate and maroon-colored sandy clays and clay conglomerates. The lower part of the Lower Siwalik is marked by a rapid alternation of sandstones and clays, with nearly equal proportions of each. Between the Ganga and the Indo-Nepal border, the Lower Siwalik is primarily composed of thick sandstones with occasional clays and claystone.

The study area is located in the Middle Siwalik, which is primarily composed of light grey sandstones. These sandstones vary in thickness from 10 to 20m and are coarse-grained, transitioning from greywacke in the lower portion to arkoses in the higher portions (Fig. 2). The lack of calcareous matter in the

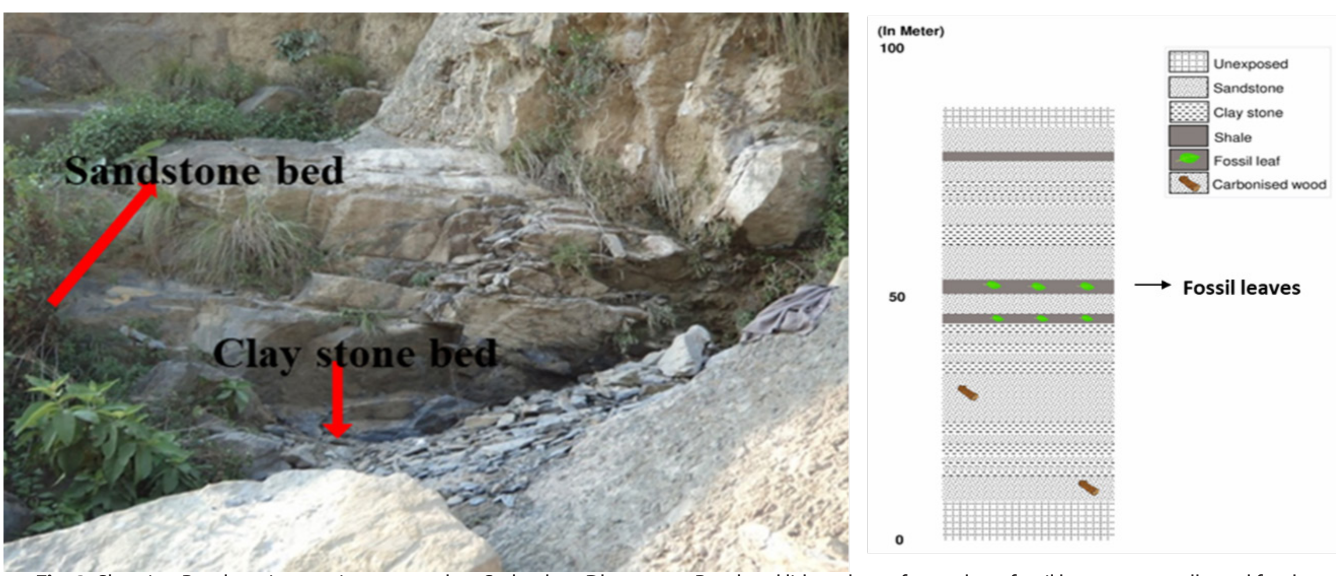

Fig. 2: Showing Road cutting section exposed on Sarkaghat–Dharampur Road and lithocolumn from where fossil leaves were collected for the present study (Thick arrow indicates the leaf-bearing bed)

Middle Siwalik makes the sandstones soft and crumbly. Coarser clastics, including pebbles, are common, especially in the upper portion where the clays are dull in color and more sandstone-like. The Upper Siwalik is a geologic formation that is characterized by its loose, friable, and incoherent sandstones and conglomerates. The upper part of the formation is primarily composed of conglomeratic rock, which is a mixture of pebbles, sand, and clay that have been cemented together. The sandstones in the Upper Siwalik are variegated, meaning they display various colors and shades, including grey and brown. These rocks are often huge and soft, making them easily weathered and eroded over time. The loose, friable nature of the sandstones and conglomerates in the Upper Siwalik makes them susceptible to landslides and other types of mass wasting, which can have significant impacts on the surrounding landscape and infrastructure.

Material And Methods

A substantial number of fossilized leaves were gathered from the Middle Siwalik strata (31º 44.265':76 º.43.339') found in a road-cutting section near Sarkaghat, a well-known town located in the Mandi District of Himachal Pradesh (Fig. 2). This fossil site can be easily reached by vehicle and is located on the left side of the main road heading towards Dharampur. The location of the fossil site is depicted in Fig. 1. The impressions of fossilized leaves lacked cuticles and were found on gray shales or clay stones. To analyze the morphological characteristics of the fossils, they were observed either with hand lens or low-power microscope using reflection of light. To classify these leaf impressions, the herbarium sheets of numerous present-day families and genera were examined at Central National Herbarium situated in Shibpur, Howrah, West Bengal. The description of leaf impressions utilized terminology put forward by Hickey (1973) and Dilcher (1974). In order to demonstrate their similarities with the fossil leaves, photographs of the leaves of comparable modern taxa were included.

Systematic Palaeobotany of *Lagerstroemia* Linn.

Phylum: *Tracheophyta* Sinnott ex Cavalier-Smit
Class: Magnoliopsida Brongen
Order: *Myrtales* Juss. ex Bercht & J. Presl
Family: *Lythraceae* J. St. Hil.
Genus- *Lagerstroemia* Linn.
Lagerstroemia himachalensis n. sp. (Figs. 3a, c)
Material- Single specimen.

Diagnosis- Leaf symmetrical, elliptic; size 6.0 x 3.5 cm; base wide acute; margins entire; venation pinnate; eucamptodromous; primary vein straight, stout; secondary veins 6-7 pairs visible, alternate to opposite, 0.6 to 1.2 cm apart, moderately to extensively sharp diverging angles; moderate to widely acute; Simple secondary veins are found, with tertiary veins that have an RR type angle of origin, this means that their orientation with reference to the mid vein is not at a right angle, but rather slanted or inclined. These tertiary veins are predominantly alternate and can be either close or distant.

Description - The leaf is simple, symmetrical, and elliptic in shape. Its preserved size is 6.0 x 3.5 cm and its apex is fractured. The base is broad and acute, while the margins are entire. The texture of the leaf is thick and chartaceous. The venation is pinnate and eucamptodromous, with a single prominent and stout primary vein (1˚). The secondary veins (2˚) are 6-7 pairs and are noticeable, alternating or opposite, and rarely sub-opposite. They are unbranched and spaced 0.6 to 1.2 cm apart, with a divergence angle that is moderately to widely acute (60˚-80˚), curving upwards to join the super adjacent secondaries at an obtuse angle. Inter-secondary veins are present and simple. The tertiary veins (3˚) originate at an angle of RR type and are medium-sized, extending all the way to the tip, they can be straight or wavy, with branches, and are oriented at an oblique to right-angled position relative to the mid-vein. They are mostly arranged in an alternate pattern and can be found either close together or far apart from one another.

Holotype- Specimen No. MLK/ S/301.

Locality - Road cutting section (31º 44.265':76 º.43.339') about 7 Km from Sarkaghat town (31º 44'26''N: 76 º 43´.33´´E) on the left side of the main road which leads to Dharampur, Mandi District, Himachal Pradesh.

Horizon and Age- Middle Siwalik Group, Upper Miocene.

Etymology- After the name of the state, Himachal Pradesh to which the fossil locality belongs.

Affinities- The fossilized leaf has a number of unique features that distinguish it from other leaves. These include its symmetrical and oval shape, smooth edges, venation that runs from the base to the tip of the leaf, secondary veins that alternate or occasionally appear almost opposite to each other at an angle of 60˚-80˚, and curve upwards to meet the adjacent veins. Additionally, there are small veins between the secondary veins, and the tertiary veins originate at an RR angle and can be either straight or wavy, running all the way to the tip of the leaf. These features collectively indicate that the fossil leaf is similar to modern leaves of *Lagerstroemia piriformis* Koehne of the family Lythraceae. (C.N.H. Herbarium Sheet No. 177286, Figs. 3b, d).

There have been reports of 18 fossil leaves that resemble various species of the genus *Lagerstroemia* Linn. This includes *Lagerstroemia patelii* from the Lower Eocene of Lignite mine in Panandhro, Kachchh, Gujarat (Lakhanpal & Guleria, 1981), Lower Siwalik of Kathgodam, Uttarakhand (Prasad, 1994b), Lower-Middle Siwalik of Darjeeling districts, West Bengal (Antal & Awasthi, 1993), and Middle Churia Formation, Arjun Khola, western Nepal (Prasad *et al*., 2019). There is also *L. neyveliensis* from Neyveli Lignite Mine-1, South Arcot district, Tamil Nadu (Agarwal, 2002), *L. jamraniensis* (Prasad *et al*., 2004), and *L. himalayaensis* (Srivastava *et al*., 2015) from Lower Siwalik of Kathgodam, Nainital district, Uttarakhand. Additionally, there is *L. siwalika* from Lower Siwalik of Koilabas, western Nepal (Prasad, 1994a) and Neyveli Lignite Mine-1, South Arcot district, Tamil Nadu (Agarwal, 2002). The fossil leaves *L. mioparvifolia* and *L. eomicrocarpa* (Dwivedi *et al*., 2006) were found in Siwalik sediments of the Koilabas area in western Nepal, while *L. mioparvifolia* Dwivedi *et al.* and *L. prakashii* were discovered in the Lower Siwalik of Tanakpur, Uttrakhand (Prasad *et al*., 2017). *L. imamurae* Tanai and Uemura (1991) was found in the Oligocene of Honshu, Japan, and *L. corvinusii* was reported in the Middle Churia Formation, Arjun Khola, western Nepal (Prasad, 2013). Finally, *L. parviflora* Roxb., *L. macrocarpa* Wall. ex Kurz, and *L. lanceolata* Wall. have been described from the Late Cenozoic sediments of the Mahuadanr Valley, Jharkhand (Singh & Prasad, 2009a, b, c). After analyzing the present fossil leaf in comparison to previously reported fossil species, it was determined that most of them have a relatively low angle of divergence in their secondary veins. Some species, such as *Lagerstroemia patelii*, *L. jamraniensis*, *L. siwalica*, *L. prakashii* and *L. corvinusii*, are larger in size with a surface area greater than 42 square cm, while others like *L. mioparvifolia*, *L. eomicrocarpa* and *L. parviflora* are smaller, with a surface area of around 10 square cm. Based on these findings, the fossilized leaf is considered new species and is hereby described as *Lagerstroemia himachalensis* n. sp. *Lagerstroemia* Linn. is a genus of trees and shrubs, with approximately 53 species that can be deciduous or evergreen, the areas where these plants are found include the Indo-Malayan region, tropical parts of Africa, Asia, Polynesia, and the Pacific Ocean region. In contemporary times, the equivalent species is *Lagerstroemia piriformis* Koehne, which is a sizeable tree that thrives in the moist deciduous forests of South-east Asia, as noted by Ridley in 1967.

Systematic palaeobotany of *Millettia* W. & A.

Phylum: *Tracheophyta* Sinnott ex Cavalier-Smith
Class: *Magnoliopsida* Brongen
Order: *Fabales* Bromhead
Family: Fabaceae Lindley
Genus- *Millettia* W. & A.
Millettia siwalica Prasad, 1990 (Figs. 3e, g)
Material-One impression.

Description- The leaf is somewhat asymmetrical, having an ovate to elliptic shape with a preserved size of 4.0 x 2.2 cm. Its apex is bluntly acute while the base is wide and acute, slightly unequal. The texture of the leaf is coriaceous. The venation of the leaf is eucamptodromous, with a single, prominent, and stout primary vein that is almost straight. About 9 pairs of visible secondary veins are present, which are branched, alternate to opposite, with an angle of divergence between 55^0 to 65^0, acute and moderately and uniformly curved. Simple inter-secondary veins are also present. The tertiary veins are fine and predominantly alternate and close, with an angle of origin usually AO-RR, percurrent, almost straight, and oblique about midvein, mostly branched.

Specimen- Specimen No. MLK/S/302.

Locality - Road cutting section (31º 44.265′:76 º.43.339′) about 7 Km from Sarkaghat town (31º 44′26′′N: 76 º 43′.33′′E) on the left side of the main road which leads to Dharampur, Mandi District, Himachal Pradesh.

Horizon and Age- Middle Siwalik Group, Upper Miocene.

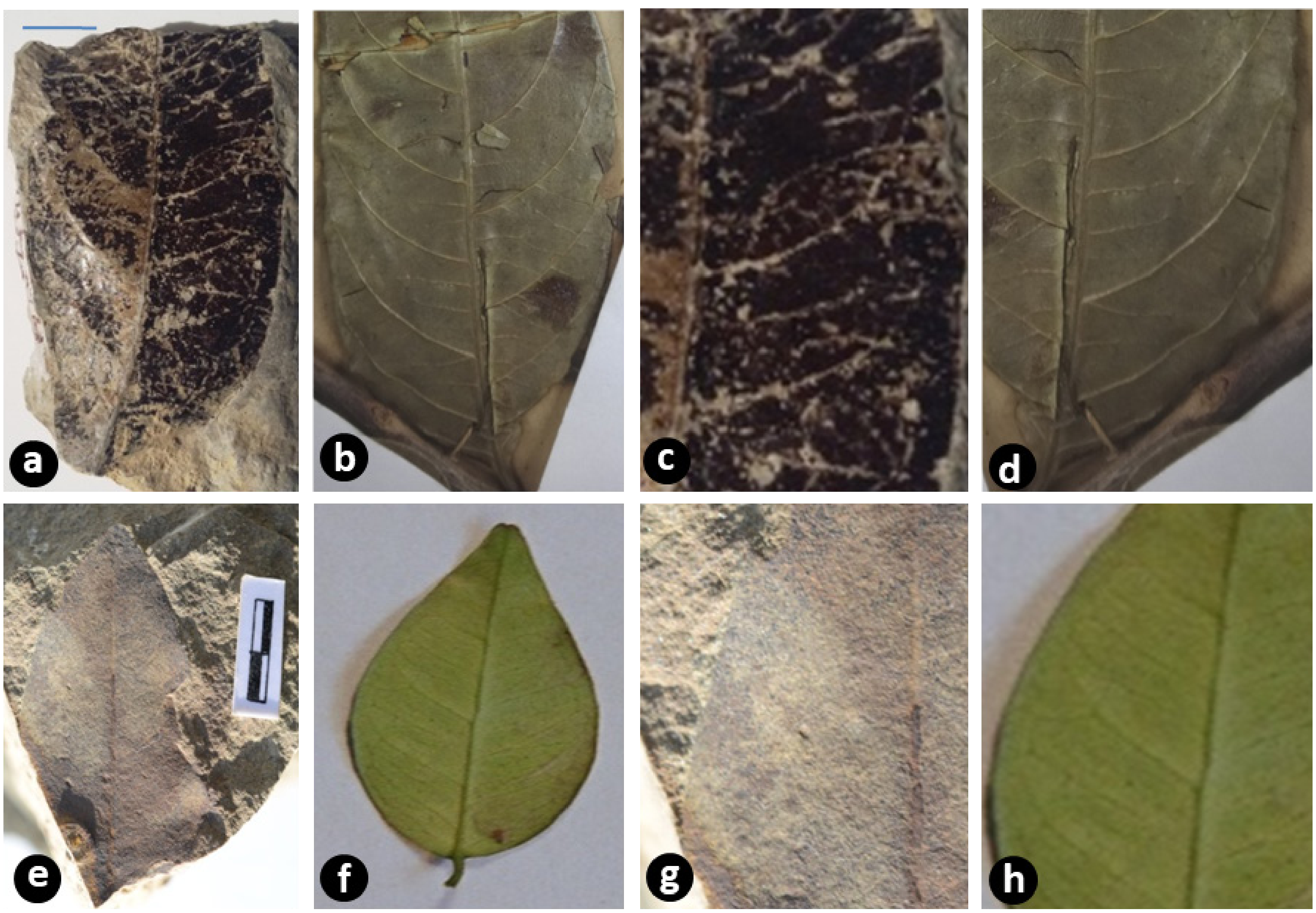

Fig. 3: a-d *Lagerstroemia himachalensis* n. sp. (**a**) Fossil leaf in natural size showing its morphological features. **(b)** Modern leaf, *L. piriformis* Kohne shows similar morphological features as the fossil. **(c)** A portion of the fossil leaf has been enlarged to show details of venation pattern **(d)** modern leaf enlarged to display comparable venational details. **e-h *Millettia siwalica*** Prasad 1990a **(e)** Fossil leaf in natural size showing its morphological features. **(f)** Modern leaf, *Millettia ovalifolia* W. & A. modern leaf showing similar morphological features as the fossil. **(g)** Magnified fossil leaf displaying the venation pattern in detail. **(h)** To display identical venation pattern features, a portion of a modern leaf has been enlarged. (Scale bar 1cm)

Table 1: Showing the fossil species of *Millettia* from Tertiary sediments of India and abroad and their differentiated characters.

Fossil species	Locality/ Horizon	Differentiated Characters
M. auriculata Bande and Srivastava, 1990	Late Cenozoic of Mahuadanr, Jharkhand	Ovate shape, secondaries upturned gradually diminishing near margins and connecting super-adjacent secondaries by a series of cross-veins.
M. asymmetrical Lakhanpal and Guleria, 1982	Miocene of Kachchh, western India	Small size (3.9 x 2.7 cm), ovate shape.
M. bilaspurensis Prasad, 2006.	Siwalik of Bilaspur, Himachal Pradesh, India	Large size (13.6 x 2.7 cm), narrowly oblong shape, numerous (18 pairs) closely placed secondaries.
M. churiensis Prasad and Awasthi, 1996; Agarwal, 2002	Siwalik of Surai Khola, Nepal; Miocene of Neyveli lignite, south India	Small size (4.2 x 1.2 cm), lanceolate shape, acuminate apex, the higher number of secondaries (about 8 pairs).
M. imlibasensis Prasad *et al.,* 1999	Siwalik of Koilabas, Nepal	Small size (4.3 x 1.6 cm), narrowly elliptical shape, obtuse base, angle of divergence 60˚.
Millettia impressa Menzel, 1920	Tertiary of West Africa	Unaccompanied by description and photograph.
M. kathgodamensis Prasad *et al*., 2004;	Siwalik of Kathgodam, Uttarakhand, India	Oblique base, tertiaries forming orthogonal meshes, oblique to right angled about midvein.
M. koilabasensis Prasad 1990b; Prasad and Tripathi, 2000; Prasad and Pandey, 2008	Siwalik of Koilabas, Nepal; Siwalik of Bhutan; Siwalik of Surai Khola, Nepal	Narrowly obovate shape, the higher number of secondaries, AR-RO angle of origin of tertiary veins.
M. miocenica Lakhanpal and Guleria, 1982	Miocene of Kachchh, western India	Small size (5.6 x 3.2 cm), oblong shape.
M. miobrandisiana Prasad, 1994a	Siwalik of Koilabas, Nepal	Small size (2.3 x 1.1 cm), brochidodromous venation, angle of divergence of secondaries acute to the right angle.
Millettia mioinermis Prasad *et al*., 2017b	Siwalik of Tanakpur, Uttarakhand, India	Obovate shape, size 5.0x2.8cm, attenuate base, angle of origin of tertiaries AO.
M. notoensis Ishida, 1970	Middle Miocene of central Japan	Ovate shape.
M. oodlabariensis Antal and Prasad, 1996	Siwalik of Darjeeling District West Bengal, India	Large size (14.3 x 3.5 cm), elliptical to lanceolate, texture coriaceous, rarely brochidodromous venation.
M. ovatus Tripathi *et al*., 2002	Siwalik of Koilabas, near Jarwa	Small size (3.5 x 2.5 cm), ovate shape.
M. palaeocubithii Awasthi and Prasad, 1990	Siwalik of Surai Khola, Nepal	Oblanceolate shape, almost few secondaries (4 pairs).
M. palaeopachycarpa Agarwal, 2002	Miocene of Neyveli lignite, south India	Small size (5.0 x 2.1 cm), lanceolate shape, more number of secondaries
M. palaeomanii Dwivedi *et al.,* 2006b	Siwalik of Koilabas, Nepal	Small size (3.2 x 1.5 cm), widely ovate shape, texture coriaceous.
M. palaeoracemosa Awasthi and Prasad, 1990; Prasad 1994b	Siwalik of Surai Khola, Nepal, Siwalik of Kathgodam, Uttarakhand	Widely obovate shape, texture coriaceous, rarely AO angle of origin of tertiary veins.
M. purniyagiriensis Shashi *et al.,* 2006	Siwalik of Tanakpur, Uttarakhand, India	Secondary veins 7-8 pairs, angle of origin of tertiaries AR-RR.
M. prakashii, Shashi *et al.,* 2008	Siwalik of Tanakpur, Uttarakhand, India	Large size (10 x 3.8 cm), the higher number of secondaries (7-8 pairs), and angle of origin of tertiaries usually AR.
M. singhii Mathur *et al.,* 1996	Kasauli Formation, H.P., India	Small size (4.0 x 1.5 cm), secondaries about 7 pairs.
M. siwalica Prasad, 1990a; Prasad 1994a; Prasad *et al.,* 2017b	Siwalik of Koilabas, Nepal, Siwalik of Kathgodam, Uttarakhand, India	Small size (3.1 x 2.0 cm), Ovate, asymmetrical, texture coriaceous, presence of inter secondary veins, AO-RR angle of origin of tertiary veins.
Millettia sp. Mathur *et al.,* 1996	Kasauli Formation, H.P., India	Small size (2.2 x 0.8 cm), the number of secondaries is about 6 pairs.
Millettia sp. Huzioka & Takahasi, 1970	Eocene of SW Honshu, Japan	Lanceolate asymmetrical shape, base obtuse.
Millettia cf. *extensa* Khan *et al*., 2011)	Siwalik of Papumpare, Arunachal Pradesh	Large size, obovate shape, angle of divergence of secondary veins widely acute.
M. miosericea Prasad *et al.,* 2015	Middle Siwalik, Darjeeling district, West Bengal, India	Large size (7.8 x 3.2 cm), elliptical shape, secondary veins numerous 10-11 pairs, alternate to sub-opposite.
M. sevokensis Prasad *et al*., 2015	Middle Siwalik, Darjeeling district, West Bengal, India	Large size (6.5-10.0 x 5.9-6.5 cm), asymmetrical, narrowly elliptical, angle of divergence of secondaries acute to right-angled.
M. miocineria Prasad *et al.,* 2016	Lower Siwalik of Arjun Khola, western Nepal	Size 7.2 x 3.2 cm, elliptical, with 7 pairs of secondary veins.
M. arjunkholaensis Prasad *et al*., 2019	Lower Siwalik of Arjun Khola, western Nepal	Large size,5.8x4.9cm, secondary veins 4-5 pairs, angle of divergence 45 º -55 º, RR percurrent, close to distant tertiary veins

Affinity- The unique characteristics of the fossilized leaf, such as their asymmetrical elliptic to ovate shape, apex bluntly acute, wide acute base, entire margin, venation is eucamptodromous, presence of inter-secondary veins, and AO-RR, percurrent tertiary veins, suggest that these fossil leaves are most similar to the present-day leaves of *Millettia ovalifolia* Kurz, which belongs to the family Fabaceae. (C.N.H. Herbarium Sheet Nos. 112378, 112379; Figs. 3 f, h).

Till date, 37 fossil leaves resembling the *Millettia* W. & A. genus have been discovered in Tertiary sediments both in India and abroad. After an extensive comparative analysis of all the known fossil leaves of *Millettia* W. & A. (as shown in Table 1), it has been determined that the present fossil leaf bears the closest resemblance to *M. siwalica* Prasad, 1990, in terms of almost all its morphological characteristics. Consequently, the present fossil leaf has been identified as belonging to the same species, *M. siwalica* Prasad.
Millettia W. & A. is a genus comprising approximately 90 species of trees, shrubs, and climbers that can be found in tropical regions of Africa, Asia, and Australia (Mabberley 1997). One of the comparable present-day species is *M. ovalifolia* Kurz, which is an evergreen tree found in both lower and upper Myanmar, as documented by Gamble (1972).

Discussion

A paleobotanical examination of Middle Siwalik strata from the Sarkaghat area include fossilised leaves. showed the presence of two new fossil leaves that resemble currently existing species, *Lagerstroemia piriformis* Koehne from the Lythraceae family and *M. ovalifolia* Kurz from the Fabacea family. *Lagerstroemia piriformis* Koehne is a big tree that can be found in moist deciduous forests in South-east Asia, while *M. ovalifolia* Kurz. is an evergreen tree that is widely distributed in both lower and upper Myanmar. The forest characteristics and current distribution of the aforementioned extant comparable species indicate that the The Upper Miocene epoch saw a tropical and humid environment in the Sarkaghat area. It further inferred that there are evergreen to moist deciduous forests during those times compared to deciduous forests there at present. Both the above comparable taxa are phytogeographically important because they have some interesting patterns of distribution in the present as well as during the Miocene.

The family Lythraceae is comprised mainly of woody plants that have worldwide distribution mostly in tropical to the sub-tropical region, (Dahlgren and Thorne 1984). The majority of these species may be found in damp to wet areas including mangroves, rainforests, and marshes. The family has an extensive fossil record that includes both living and extinct taxa (Tiffney, 1981).*Lagerstroemia* Linn. is a genus that consists of approximately 53 species of trees and shrubs that can be either deciduous or evergreen, and they can be found in the Indo-Malayan region, Africa, Asia, Polynesia, and the Pacific region. Several fossil species of *Lagerstroemia* Linn. are well known to occur in the many locations in India and Nepal have Tertiary sediments. (Prasad, 2008; Prasad *et al*., 2019). The most ancient evidence of *Lagerstroemia* in India comes from the Deccan Intertrappean beds in the late Cretaceous period, consisting of both leaves and fruits that have been fossilized in silica. (Mehrotra et al., 2007) were recorded. This suggests that the genus is of Gondawanian origin. It originated somewhere on Gondwana land and entered into the Indian landmass and spread throughout Indian subcontinents (Table 1).

Fabaceae (Legume) is an economically important family of flowering plants and comprises about 670 genera of trees, shrubs, and herbs distributed both in temperate and tropical regions of the world. The published literature on fossil records from all the Siwalik localities of India and Nepal showed the dominance of fabaceous taxa (Prakash and Tripathi 1992; Prasad, 2008). The reported taxa *Millettia* W. & A. taxa are also common in all the fossil localities of the Siwalik foreland Basin not recorded earlier, from Paleocene-Eocene sediments of Indian subcontinents, suggesting a late entry of this taxa into the Indian sub-continent, probably before the Miocene, only after the development of land connections that allowed free movement of elements from regions where they were flourishing most probably South-east Indian regions. The presence of taxa in the Indian sub-continent during the Palaeogene period until the end of the Oligocene or early Miocene has not been reliably documented. However, evidence from the middle Miocene suggests that they arrived later, after land connections were established with the south-east Asian region. This has been suggested by Smith and Briden in 1979 and later confirmed by Smith *et al*. (1994). It is believed that the early Miocene period was a suitable time for south-east Asian elements to enter the Indian sub-continent via its northeast region (Agarwal *et al.,* 2006). These taxa then flourished and became abundant during the Neogene across India (Guleria, 1992; Prasad, 2008). The family Fabaceae also experienced rich growth at the end of the Oligocene due to the peak of global warming during the middle Miocene (Zachos *et al*., 2001; Punyasena *et al*., 2008). Phylogenetic evidence suggests that the family Fabaceae evolved in tropical/sub-tropical regions along the Tethys seaway during the Palaeogene period (Schrine et al., 2005). Based on the research by Prasad *et al.* (2019), it appears that there were no other types of plants in the Fabaceae family found in India, Nepal, or Bhutan during the Palaeogene sub-period. This implies that Asian plants from this family may have migrated to the Indian subcontinent during the Miocene epoch, after the establishment of land bridges with South-east Asia.

Conclusions

An analysis of fossilized leaves from the Middle Siwalik deposits in the Sarkaghat region uncovered two previously unknown fossil leaves that have been recognized as belonging to two living plant species: *Lagerstroemia piriformis* Koehne and *M. ovalifolia* Kurz. These plant species are classified under the Lythraceae and Fabaceae families, respectively.

The current distributions of the a fore mentioned extant taxa indicate that, in contrast to the deciduous forests that are present today, the Sarkaghat area experienced a tropical humid climate during Upper Miocene times. They also suggest that evergreen to moist deciduous forests were present in the area during that time.

The Tertiary layers of several locations in India and Nepal are known to contain the fossilized remnants of *Lagerstroemia Linn*., and the first mentions of this species date from the late Cretaceous.
According to fossil evidence, the family Fabaceae developed

during the Palaeogene period along the Tethys Seaway in tropical and subtropical areas. Additionally, the fabaceous taxa were not authentically found in India, Nepal, or Bhutan during the Palaeogene sub-period, suggesting that the Asian elements may have arrived in the Indian subcontinent later, during the Miocene period, only after the establishment of land connections with south-east Asia.

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Author's Contribution

Alok, Shashi and S. M. Pandey contributed to the design and implementation of the research, perform fossil collection, data collection, data analysis, interpretation, and drafted the article. Mahesh Prasad done a critical revision of the article.

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