Fossil leaves belonging to the family Fabaceae and Lythraceae from the Siwalik sediments of Koilabas area, western Nepal

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Five dicotyledonous fossil leaves including *Millettia palaeomanii* sp. nov., *Canavalia siwalika* sp. nov., *Cynometra siwalika* Awasthi and Prasad, *Lagerstroemia mioparviflora* sp. nov., and *L. eomicrocarpa* sp. nov. have been described from the Lower Siwalik Formation of Koilabas area, Nepal. The modern comparable taxa of the fossil leaves indicate the existence of a evergreen forest under warm humid climate during Middle Miocene around Koilabas area in the Himalayan foots hills of western Nepal.

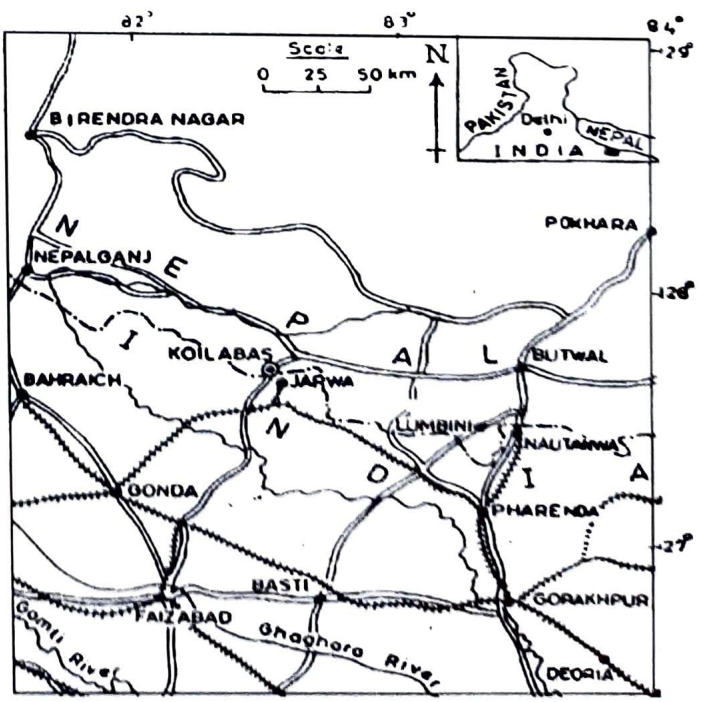
Key-words- Fossil leaves, Fabaceae, Lythraceae, Siwalik (Middle Miocene), Koilabas area, Nepal.

THE Siwalik sediments (Middle Miocene to Lower Pleistocene) of Nepal are rich in plant and animal fossils and are divisible into lower, middle and upper Siwalik. The fossil locality, Koilabas area represents one of the well exposed Siwalik section in western Nepal which is characterized by fresh water molasses clastic sediments in the alternation of sandstones and mudstone/shales (Sharma 1977, Gleinnie & Zeigler 1964).

The previous study on the plant mega fossils reveals the occurrence of a number of taxa in this area (listed in Prasad *et al.*, 1999). Recently well preserved leaf impressions were collected from the Lower Siwalik sediments of Darwaja in Koilabas area. The study suggests the presence of five new fossil genera showing resemblance with the extant taxa *Millettia, Canavalia* and *Cynometra* of Fabaceae and *Lagerstroemia* belonging to the family of Lythraceae.

MATERIAL AND METHOD

The fossil leaves were collected from near Darwaja situated in Koilabas nala, about 5 km north west of Koilabas town in western Nepal (Map-1). The fossil leaves are well preserved on grey as well as brown calcareous shales and are devoid of cuticles. Identification has been done by the consultation of several herbarium sheets of extant taxa at the herbarium of Central National Herbarium, Sibpur, Howrah, West Bengal. For the description of fossil leaves, the terminology given by Hickey (1973) and Dilcher (1974) has been followed. The photographs of both fossil and modern comparable leaves were taken on 35 mm B/W film with the help of SLR (Yashica) camera. Comparable leaves of extant taxa are provided along with fossil leaves to show their close similarity. All the figured specimens and their photo-negatives are kept at Post Graduate Department of Botany M.L.K. College, Balrampur, Uttar Pradesh.



Map – 1 Showing fossil locality, Koilabas in western Nepal.

SYSTEMATIC DESCRIPTIONS

Family - Fabaceae

Genus - ***Millettia*** W. & A.

Millettia palaeomanii sp. nov.

(Pl. 1, Figs 1, 3)

Material - This species consists of a single and almost complete specimen of leaflet impression which is devoid of cuticles.

Description - Leaflet symmetrical, wide ovate to elliptic; size 3.2 x 1.5 cm; apex slightly broken, seemingly acute; base obtuse slightly oblique; margin entire; texture, thin coriaceous; petiole preserved, less than 0.2 cm long, normal; venation pinnate, eucamptodromous; primary veins (1^0) single, prominent, moderate, straight; secondary veins (2^0) about 8 pairs, 0.3 to 0.6 cm apart, uniformly curved up, angle of divergence acute (50^0- 70^0), moderate, upper secondary veins acute than lower ones, alternate to subopposite, unbranched; inter secondary veins present, simple; tertiary veins (3^0) poorly preserved, fine with angle of origin RR, percurrent, usually straight, branched, oblique in relation to midvein, predominantly alternate and close.

Holotype - Specimen no. K- 3

Locality- Darwaja, Koilabas area, western Nepal.

Horizon & Age - Lower Siwalik Formation; Middle Miocene.

Etymology - By adding prefix 'palaeo,' to the name of modern comparable species.

Affinity - The most important features of the present fossil leaflet such as small, almost symmetrical, wide ovate to elliptic shape, small petiole, eucamptodromous type of venation, acute angle of secondary veins, presence of inter secondary veins and RR, percurrent tertiaries are found common among the leaflets of few species of the genus *Millettia* W. & A. of the family Fabaceae. In order to find out the nearest species, a large number of herbarium sheets of different species, of *Millettia* W. & A. has been examined and found that the leaflets of *Millettia manii* Backer show nearest affinity with the fossil leaflets (C.N.H Herbarium sheet no. 112687, Pl. 1, Figs 2,4).

Fossil records and comparison - About 16 fossil leaflets showing similarity with the extant genus *Millettia*. W. & A. are known from Tertiary sediments of India and abroad (Prasad *et al.*, 1999; Agarwal, 2002). Of these eight are known from Siwalik sediments of India and Nepal. These are *Millettia koilabasensis* Prasad,1990b; *M. siwalica* Prasad 1990a., *M. miobrandissiana* Prasad, 1994a and *M. imlibasensis* Prasad *et al.*, 1999 from the Siwalik sediments of Koilabas, western Nepal, *M. palaeoracemosa* Awasthi & Prasad, 1990 *M. churiensis* Prasad & Awasthi, 1996 and *M. koilabasensis* (Prasad) Prasad & Pandey, 2006 from Surai Khola western Nepal; *M. oodlabariensis* Antal & Prasad, 1996 from the Lower Siwalik sediments of Darjeeling District, West Bengal, India. *M. palaeoracemosa* Awasthi & Prasad (Prasad, 1994b) and *M. kathgodamensis* Prasad *et al.*, 2004 from Siwalik sediments of Kathgodam, India. *M.*

PLATE – 1

(All figures are of natural size unless otherwise mentioned)

1. *Millettia palaeomanii* sp. nov. Fossil leaflet showing shape, size and venation pattern.
2. *Millettia manii* Backer Modern leaflet showing similar shape, size and venation pattern.
3. *Millettia palaeomanii* sp. nov. A part of fossil leaflet magnified to show details of venation x2.5.
4. *Millettia manii* Backer A part of modern leaflet magnified to show similar details of venation x2.5.
5,7,9. *Cynometra siwalika* Awasthi & Prasad Fossil leaflets showing variation in shape, size and apex.
6,7. *Cynometra polyandra* Roxb. Modern leaflets showing similar variation in shape, size and apex.
10. *Cynometra siwalika* Awasthi & Prasad A part of fossil leaflet (Pl.1,fig.5) magnified to show details of venation x2.5.
11. *Canavalia siwalika* sp. nov. Fossil leaflet showing shape, size and venation pattern.
12. *Canavalia rosea* DC. Modern leaflet showing similar shape, size and venation pattern.
13. *Canavalia siwalika* sp. nov. Fossil leaflet magnified to show details of venation x3.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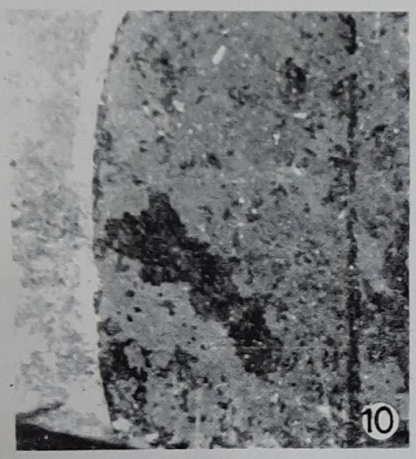
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PLATE - 1

koilabasensis Prasad from Siwalik sediments of Laxmi River beds, Bhutan (Prasad and Tripathi, 2000). The present fossil leaflets have been compared with all the above known species and it was observed that none of them show similarity with this fossil. They differ mostly in nature and course of secondary and tertiary veins.Two species such as *M. miobrandisiana*. and *M. imlibasensis* are although smaller in size as fossil leaflet but different in the orientation of secondary veins. The remaining other species differ in being larger size than the present fossil leaflet. Thus, the present fossil has been described under a new specific name, *Millettia palaeomanii.*

Present day distribution - The genus *Millettia* W. & A. consists of about 80 species of trees, shrubs, and climbers distributed in tropical regions of Africa, Asia, and Australia (Willis, 1973). About 30 species are found to occur in the Indian region, mostly distributed in West Bengal and Myanmar. *Millettia manii* Backer with which the present fossil leaflet resembles closely is a tree of Tropical Africa.

Family - Fabaceae

Genus - *Canavalia* DC.

Canavalia siwalika sp. nov.

(Pl.1, Figs 11, 13)

Material - This species consists of a single specimen of leaflet impression which is devoid of cuticles. The specimen is well preserved and complete.

Description - Leaf simple, asymmetrical, obovate; preserved size 2.2 x 1.6 cm; apex obtuse; base obtuse, inequilateral; margin entire; texture thin chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent, stout, curved; secondary veins (2^0) 6 pairs visible with angle of divergence acute (40^0- 50^0), less than 0.4 cm apart arising uniformly, moderate, almost straight curving upwards taking a long course towards apex to reach at margin, unbranched; tertiary veins (3^0) fine, percurrent, straight, oblique in relation to midvein, predominantly alternate and close.

Holotype - Specimen no. K-14.

Locality - Darwaja, Koilabas area, western Nepal.

Horizon & Age - Lower Siwalik Formation; Middle Miocene.

Etymology - After the Siwalik Formation to which fossil locality, Koilabas area belongs.

Affinity - Small asymmetrical, obovate shape, obtuse apex and base, eucamptodromous venation, acute angle of secondary veins which are running almost straightly towards margin, RR, percurrent tertiary veins of the present fossil leaflet undoubtedly indicate resemblance with the extant leaflets of *Canavalia rosea* DC. of the family Fabaceae (C.N.H. Herbarium Sheet no. 2015, Pl 1., Fig.12).

Fossil records and comparison - As far as author aware there is no record of any fossil leaflet resembling the genus *Canavalia* DC. This leaflet forms first record from Siwalik sediments of Koilabas area, western Nepal.

PLATE – 2

(All figures are of natural size unless otherwise mentioned)

1. *Lagerstroemia eomicrocarpa* sp. nov. Fossil leaf showing shape, size and venation pattern.
2. *Lagerstroemia microcarpa* Linn. Modern leaf showing similar shape, size and venation pattern.
3, 5. *Lagerstroemia eomicrocarpa* sp. nov. Other fossil leaves showing variation in shape and size.
4. *Lagerstroemia microcarpa* Linn. Modern leaf showing similar variation in shape and size.
6,8. *Lagerstroemia eomicrocarpa* sp. nov. A part of fossil leaves magnified to show details of venation x2.
7,9. *Lagerstroemia microcarpa* Linn. A part of modern leaves magnified to show similar details of venation x2.
10, 12. *Lagerstroemia mioparviflora* sp. nov. Fossil leaves showing shape, size and venation pattern.
11. *Lagerstroemia parviflora* Roxb. Modern leaf showing similar shape, size and venation pattern.
13. *Lagerstroemia mioparviflora* sp. nov. A part of fossil leaf (Pl.2, fig.10) magnified to show details of venation x3.

PLATE - 2

Present day distribution - The genus *Canavalia* DC. comprises 12 species widely distributed in the tropical regions of Asia, Africa and America. The extant species *Canavalia rosea* DC. with which the fossil resembles closely is a tree found to grow along the coasts of western peninsula, Sri Lanka, and Malaya peninsula (Hooker, 1879).

Family - Fabaceae

Genus - *Cynometra* Linn.

Cynometra siwalika Awasthi & Prasad, 1990

(Pl.1, Figs 5, 7, 9, 10)

Material - There are three leaflet impressions of different size. Two of them are almost complete and all the specimens are poorly preserved.

Description - Lamina and base asymmetrical, shape elliptic, three leaflets measure 3.5 x 1.6 cm, 3.7 x 1.3 cm and 9.0 x 3.0 cm; apex acute; forked; base acute, inequilateral, oblique; margin entire; texture coriaceons; venation pinnate, eucamptodromous; primary veins (1^0) single, prominent, stout; secondary veins (2^0) poorly preserved, 4-5 pairs visible, less than 1.0 cm apart, angle of divergence acute, narrow (40^0-50^0), uniformly curving upwards.

Specimen - Specimen no. K-62, K- 18 and K-19.

Locality - Darwaja, Koilabas area, western Nepal.

Horizon & Age - Lower Siwalik Formation; Middle Miocene.

Modern affinity - The shape, size and venation pattern, nature of apex and base of the fossil leaflet indicate resemblance with modern leaflets of *Cynometra polyandra* Roxb. of the family Fabaceae (C.N.H. Herbarium Sheet no. 138713, Pl.1, Figs 6,8)

Fossil records and comparisons - Four fossil leaflets resembling the genus *Cynometra* Linn. are reported from the Siwalik sediments of India and Nepal. e.g. *Cynometra siwalika* Awasthi & Prasad (1990) from Surai Khola, western Nepal; *C. tertiara* Antal & Awasthi (1993) from Oodlabari, Darjeeling District, West Bengal; *Cynometra palaeoeripa* from Koilabas area (Prasad *et al.*, 1999) and from Surai Khola, western Nepal (Prasad & Pandey, 2006). The present fossil leaflets have been compared with the known species in shape, size and venation pattern and resemble with *Cynometra siwalika* Awasthi & Prasad.

Present day distribution - The genus *Cynometra* Linn. consists of about 60 tropical species, of which five are found to occur in Indian regions. The extant taxon, *Cynometra polyandra* Roxb. with which fossil resembles closely is a large tree distributed in Khasi hills, Cachar hills, and Malayan peninsula (Brandis 1971).

Family - Lythraceae

Genus - *Lagerstroemia* Linn.

Lagerstroemia mioparviflora sp. nov.

(Pl. 2, Figs 10,12,13.)

Material - There are two well preserved and complete leaf impressions which are devoid of cuticles.

Description - Leaf simple, almost symmetrical, narrow elliptic; preserved size 5.4 x 2 cm, 4.2 x 1.7 cm; apex acute; base acute; margin entire; texture thin chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent, moderate, slightly curved; secondary veins (2^0) 6 pairs visible, 0.4 – 1.2 cm part with angle of divergence acute (45^0-60^0), moderate, seemingly branched, uniformly, curved; intersecondary veins present, rare; tertiary veins (3^0) fine, angle of origin RR, percurrent, straight, oblique in relation to mid vein, predominantly alternate and close, Further details could not be seen.

Holotype - Specimen no. K-45.

Paratype - Specimen no. K-36.

Locality - Darwaja, Koilabas area, western Nepal

Horizon & Age - Lower Siwalik Formation; Middle Miocene.

Etymology - By adding prefix 'mio' in the name of modern comparable species, *L. parviflora.*

Affinity - The diagnostic features of the present fossil leaf such as small, narrow elliptic shape, entire margin, eucamptodromous type of venation, acute angle of divergence of secondary veins, presence of

intersecondary veins, and RR, precurrent tertiary veins show closest affinity with the modern leaves of *Lagerstroemia parviflora* Roxb. of the family Lythraceae (C.N.H. Herbarium Sheet no. 9745; Pl.2, Fig.11).

Fossil records and comparison - Fossil leaves resembling the genus *Lagerstroemia* Linn. are known from India and Nepal. Of these, three represent fossil species e.g. *Lagerstroemia patelii* Lakhanpal and Guleria from Eocene of Kutch, western India (Lakhanpal & Guleria, 1981), Siwalik sediments of Oodlabari, Darjeeling District, West Bengal (Antal & Awasthi, 1993) and Kathgodam area in Nainital District, Uttaranchal (Prasad, 1994b). *Lagerstroemia siwalica* Prasad (1994a) from the Siwalik sediments of Koilabas, western Nepal and *Lagerstroemia jamraniensis* Prasad *et al* (2004) from the Siwalik sediments of Jamrani, Kathgodam area, Nainital District, Uttranchal, India. All the fossil leaves have been compared with the present fossil leaves and found that none of them show similarity with the present fossils. They differ mainly in having bigger size with different nature and course of secondary veins as compared to the present fossils. In view of this, the present fossil leaves have been described as a new species, *Lagerstroemia mioparviflora.*

Present day distribution - The genus *Lagerstroemia* Linn. consists of about 50 species and widely distributed in the tropical forests. *Lagerstroemia parviflora* Roxb. with which the fossil shows closest affinity is a large tree found to grow in the sub Himalayan tract, Assam, Lower Bengal, Central India, Western peninsula and Upper Myanmar (Brandis 1971).

Lagerstroemia eomicrocarpa sp. nov.

(Pl. 2, Figs 1,3,5,6,8)

Material : There are two well preserved, almost complete leaf impressions with their counterpart.

Description - Leaf simple, symmetrical, narrow elliptic; preserved size 4.5 x 2.0 cm., 4.7 x 2 cm; apex acute; base acute margin entire; texture thin chartaceous; petiole not preserved; venation pinnate, eucamptodromous; primary vein (1^0) single, prominent, stout, straight; secondary veins (2^0) about 8 pairs; 0.3 to 0.8 cm apart, alternate to subopposite, angle of divergence moderate acute (50^0- 65^0), uniformly curved up, unbranched; intersecondary veins present, simple, rare; tertiary veins (3^0) fine, angle of origin usually RR, rarely AO, percurrent, oblique in relation to midvein, predominantly alternate and close. Further details could not be seen.

Holotype - Specimen no. K-32.

Paratype - Specimen no. K-33.

Locality - Darwaja, Koilabas area, western Nepal.

Table-1: Present day distribution of modern taxa of the fossils recovered from the Siwalik sediments of Darwaja in Koilabas area, western Nepal

Fossil taxa	Modern equivalent taxa	Forest type	Present day distribution
Millettia palaeomanii sp. nov.	*M. manii* Backer	Evergreen	Tropical Africa
Cynometra siwalika Awasthi & Prasad	*C. polyandra* Roxb.	Evergreen	Khasi Hills, Cachar Hills, Malayan peninsula
Canavalia siwalika sp. nov.	*C. rosea* DC.	Evergreen	Western peninsula, Sri Lanka, Malayan peninsula
Lagerstroemia mioparviflora sp. nov.	*L. parviflora* Roxb.	Moist deciduous	N.E. India, central India, Myanmar
L. *eomicrocarpa* sp. nov.	*L. microcarpa* (Syn. *L. lanceolata*) Wall.	Evergreen	Malabar Hills, Travancore, S. India

Horizon & Age - Lower Siwalik Formation; Middle Miocene.

Etymology : By adding a prefix 'eo' to the name of modern comparable species, *L. microcarpa*.

Modern affinity - The most important features of the present fossil leaves are narrow elliptic shape, acute apex and base, entire margin, eucamptodromous venation, closely placed secondary veins with acute angle of divergence and RR-AO and percurrent tertiary veins. The features indicate affinity with the modern leaves of *Lagerstroemia microcarpa* Linn. (Syn. *L. lacnceolata* Wall.) of the family Lythraceae,. (C.N.H. Herbarium Sheet no. 62277 and 3303, Pl. 2 Figs 2,4,7,9).

Fossil records and comparison - The fossil leaves differ from the known fossil leaf of *Lagerstroemia* Linn. in being broader in size with different course of secondary veins. Accordingly, the leaves are described as new species *Lagerstroemia eomicrocarpa* sp. nov.

Present day distribution - The extant taxon, *Lagerstroemia microcarpa* Linn. (Syn. *L. lanceolata* Wall.) with which fossils show closest affinity is a large tree distributed in evergreen forests of Malabar, and western coast from Mumbai to Travancore (Brandis 1971).

DISCUSSION

The study on the fossil leaf assemblages of Koilabas area reveals the occurrence of five taxa of dicotyledonous leaves viz. *Millettia palaeomanii, Canavalia siwalika* and *Cynometra siwalika* of the family Fabaceae and *Lagerstroemia mioparviflora* and *L. eomicrocarpa* of the family Lythraceae. The fossil leaves of *Millettia, Cynometra* and *Lagerstroemia* are common in the Siwalik fore land basin in the Tertiary sediments and of India (Awasthi, 1992, Guleria, 1992). The fossil leaf of the genus *Canavalia* DC. reported for the first time from Tertiary sediment of India, comprises 12 species and distributed in the tropical regions of Asia, Africa and America. Its comparable species, *Canavalia rosea* DC. presently found to grow all along the coast of India, Sri Lanka and Malaya.

The predominantly evergreen taxa of the fossil leaf assemblage and present day distribution pattern (Table -1) indicate a tropical warm humid climate with comparatively high rate of precipitation during deposition of Siwalik sediment in the Koilabas area.

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