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The early (pre-11 Ma) existence and disparate response of C4 plant in the Indian sub-continent: Evidences from n-alkane isotopic ratios of NW Indian Siwalik paleosol

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The appearance and expansion of C_4 plant during the late Miocene was first documented from Siwalik sections of Indian sub-continent using carbon isotope ratio of soil carbonate, soil organic matter and fossil tooth enamel. The timing and nature of C_4 plant evolution documented from different Siwalik sections of Indian sub-continent were not equivocal. Even from a particular region, the timing and nature of ecological shift was interpreted differently. The lack of modern data set from the Indian sub-continent might be one of the reasons for differences in results. Moreover the pristine isotopic character of soil organic matter and soil carbonate are prone to alteration during diagenesis. To resolve all the issues, NW Siwalik paleosol (n = 74) derived leaf wax long chain n-alkane δ^{13}C value, a robust proxy, has been used to reconstruct exact timing of C_4 plant appearance and its nature of expansion. The average long chain n-alkane δ^{13}C value of modern C_3-C_4 plants surviving in the Gangetic plain have been used as reference to understand the past vegetation survived in the Siwalik floodplain. The paleosol derived long chain n-alkane δ^{13}C values from Naladkhad (11.6 to 8.8 Ma) and Ranital (11.1 to 6.9 Ma) sections of Kangra sub-basin indicate presence of $\sim$ 40 % C_4 plants at $\sim$11 Ma. Such significant abundance of C_4 plants at $\sim$11 Ma indicate an early appearance of C_4 plants compared to the previously published data. The abundance of C_4 plants have increased gradually both in Ranital (9.7 Ma to 6.9 Ma) and Jabbarkhad (6.2 Ma to 2.7 Ma) sections of Kangra sub-basin whereas the C_4 plant abundance showed large fluctuations in the Haripur Khol section (5.7 Ma to 1.6 Ma) of Subathu sub-basin.

The paleosol derived leaf wax long chain n-alkane δD values measured from the Kangra and Subathu sub-basin indicate three phases of high monsoon at $\sim$ 9 Ma, $\sim$5.5 Ma and $\sim$ 3.5 Ma. The varied response of C_4 plant abundance with monsoonal rainfall amount and fluvial architectural element in different sections of Kangra and Subathu sub-basin suggest factors such as summer rainfall and substrate moisture might have controlled the abundance of C_4 plants during the late Miocene in the Siwalik floodplain.