# GC-MS Profiling of Ethanolic Extracts of Root, Phylloclade and Flower of Selected Members of Family Cactaceae from Amravati Region, Maharashtra, India

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***Abstract*—The family Cactaceae is well known for its ecological adaptability and medicinal importance, yet detailed phytochemical profiling of many Indian species remains limited. The present study investigates the chemical composition of ethanolic extracts of root, Phylloclade and flower of three Cactaceae members, Nopalea cochenillifera (L.) Salm-Dyck, Opuntia elatior Mill. and Opuntia dillenii (Ker Gawl.) Haw., collected from the Amravati region of Maharashtra, India. Plant materials were authenticated and subjected to Soxhlet extraction using ethanol, followed by Gas Chromatography–Mass Spectrometry (GC–MS) analysis. The GC–MS profiling revealed the presence of diverse bioactive compounds including long-chain alcohols, aldehydes, alkanes, esters, ethers, silanes and nitrogen-containing compounds. Major constituents such as 2-hexadecanol, 5-octadecanal, decane, dodecane, diethoxy-propanol derivatives and silane compounds were identified with varying abundance across plant parts and species. Many of the detected compounds are reported to possess antimicrobial, antioxidant, anti-inflammatory, industrial and pharmaceutical applications. Comparative analysis indicated both similarities and species-specific variations in phytochemical composition, highlighting the chemotaxonomic significance and medicinal potential of these taxa. The study provides baseline chemical data supporting the traditional and potential therapeutic use of Cactaceae species from central India.**

***Index Terms*—Cactaceae, GC–MS, Ethanolic extract, Nopalea cochenillifera (L.) Salm-Dyck, Opuntia elatior Mill., Opuntia dillenii (Ker Gawl.) Haw., Phytochemicals**

## I. INTRODUCTION

Medicinal plants have been an integral component of traditional healthcare systems worldwide and continue to serve as a valuable source of bioactive compounds for modern pharmaceutical and nutraceutical development (Fabricant & Farnsworth, 2001; Newman & Cragg, 2020). India, with its rich floristic diversity and long history of traditional medicine, harbors numerous medicinally important plant taxa that remain underexplored at the phytochemical level. Members of the family Cactaceae, though introduced, have become naturalized in several dry and semi-arid regions of India, including parts of Maharashtra's arid landscapes (Raj et al., 2023).

The xerophytic cactus species exhibit morphological and physiological adaptations such as succulent phylloclades and CAM photosynthesis, which are associated with the accumulation of diverse secondary metabolites (Nobel, 2002). These adaptations allow them to thrive under environmental stress while producing compounds with biological activities. In traditional medicinal systems, several Opuntia taxa are used to manage inflammation, wounds, gastrointestinal ailments, diabetes and microbial infections (Raj et al., 2023). Despite their ethnomedicinal significance, systematic phytochemical investigations of Indian Cactaceae species particularly those growing in Maharashtra remain sparse.

Species such as Nopalea cochenillifera (syn. Opuntia cochenillifera), Opuntia elatior Mill. and Opuntia dillenii (Ker Gawl.) Haw. are commonly distributed in the dry regions of Maharashtra, including the Amravati district (eFlora of India; Raj et al., 2023). Local ethnobotanical knowledge identifies these species by vernacular names such as Nagphani in Marathi and documents their use in wound healing, inflammatory disorders and digestive issues (Tatiya et al., 2024). In Maharashtra and adjacent regions, Opuntia elatior has been traditionally used in folk preparations for inflammatory conditions, cough, asthma and wound management, consistent with broader Indian reports of Opuntia ethnomedicinal applications.

Gas Chromatography Mass Spectrometry (GC–MS) is a powerful analytical tool widely employed for the identification and characterization of volatile and semi-volatile phytoconstituents in medicinal plants. It facilitates the detection of fatty acids, esters, alcohols, terpenoids and other bioactive metabolites associated with antioxidant, anti-inflammatory, antimicrobial and antidiabetic activities (Sermakkani & Thangapandian, 2012; Altemimi et al., 2017). To date, GC–MS profiling of cactus species has revealed compounds linked to pharmaceutical potential in Opuntia and related genera, but comprehensive investigations focusing on plant parts from Maharashtra remain limited. Therefore, the present study aims to profile and compare the GC–MS-derived phytochemical constituents of different plant parts of selected Cactaceae species and to correlate these findings with their ethnomedicinal uses and potential therapeutic applications.

## II. MATERIALS AND METHODS

### A. Collection of Plant Material

Fresh and healthy specimens of Nopalea cochenillifera (L.) Salm-Dyck, Opuntia elatior Mill. and Opuntia dillenii (Ker Gawl.) Haw. were collected from different localities of the Amravati region, Maharashtra, India. The collection was carried out during the flowering season to ensure availability of all plant parts. The collected plant materials were authenticated from the well-known taxonomist and voucher specimens were deposited in a recognized herbarium for future reference.

### B. Preparation of Plant Extracts

The plant parts including roots, Phylloclades and flowers were washed thoroughly with running tap water followed by distilled water to remove adhering soil and debris. The materials were shade-dried at room temperature and pulverized into coarse powder. Ethanolic extraction was carried out using a Soxhlet apparatus. About 25 g of powdered material was extracted with ethanol for 6–8 hours. The extracts were filtered and concentrated under reduced pressure and the dried extracts were stored for further analysis.

### C. GC–MS Analysis

GC–MS analysis of the ethanolic extracts was performed using a standard GC–MS system equipped with a capillary column. The identification of compounds was based on comparison of their mass spectra with those available in the NIST library, along with retention time and molecular weight data. Relative percentage composition of each compound was calculated based on peak area normalization.

## III. RESULTS

The GC–MS analysis of ethanolic extracts of root, Phylloclade and flower of the selected species revealed a complex mixture of phytocompounds.

Table 1A - GC–MS profile of phytochemical constituents identified in the ethanolic root extract of Nopalea cochenillifera (L.) Salm-Dyck.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 15.279 | 2-Hexadecanol | $C_{16}H_{34}O$ | 242 | 1.2E+07 | 29.322 |
| 2 | 15.376 | 2-Hexadecanol | $C_{16}H_{34}O$ | 242 | 5488920 | 13.4562 |
| 3 | 15.46 | 2-Hexadecanol | $C_{16}H_{34}O$ | 242 | 6003942 | 14.7187 |
| 4 | 15.862 | Cyclohexane, hexyl- | $C_{12}H_{24}$ | 168 | 7380488 | 18.0933 |
| 5 | 17.337 | 2-Heptadecanol | $C_{17}H_{36}O$ | 256 | 5181978 | 12.7037 |
| 6 | 21.681 | Acetamide, N-[2-(3-ethyl-1-methyl-9H-carbazol-2-yl) ethyl]-N-methyl- | $C_{20}H_{24}N_2O$ | 308 | 4775054 | 11.7061 |
| Total | | | | | 40791164 | 100 |

Table 1 B - GC–MS profile of phytochemical constituents identified in the ethanolic Phylloclade extract of Nopalea cochenillifera (L.) Salm-Dyck.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 14.134 | 3-Buten-1-ol, TMS derivative | $C_7H_{16}OSi$ | 144 | 34772070 | 26.8089 |
| 2 | 15.279 | Hexadecane, 1,1-bis(dodecyloxy)- | $C_{40}H_{82}O_2$ | 594 | 23484199 | 18.106 |
| 3 | 15.374 | 2-Hexadecanol | $C_{16}H_{34}O$ | 242 | 10712834 | 8.2595 |
| 4 | 15.468 | Cyclohexane, 1,1'-(1,2-dimethyl-1,2-ethanediyl) bis-, (R*, R*) -(±)- | $C_{16}H_{30}$ | 222 | 9328376 | 7.1921 |
| 5 | 15.864 | Cyclohexane, hexyl- | $C_{12}H_{24}$ | 168 | 15140212 | 11.6729 |
| 6 | 17.347 | 5-Octadecanal | $C_{18}H_{36}O$ | 266 | 11840993 | 9.1293 |
| 7 | 17.41 | Octadecane, 3-ethyl-5-(2-ethylbutyl)- | $C_{26}H_{54}$ | 366 | 4931244 | 3.8019 |
| 8 | 18.998 | 4-Octadecenal | $C_{18}H_{34}O$ | 266 | 10400629 | 8.0188 |
| 9 | 20.454 | 5-Octadecenal | $C_{18}H_{34}O$ | 266 | 9093081 | 7.0107 |
| Total | | | | | 129703638 | 100 |

Table 1C - GC–MS profile of phytochemical constituents identified in the ethanolic flower extract of Nopalea cochenillifera (L.) Salm-Dyck.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 9.554 | Butane, 1,1-diethoxy-3-methyl- | $C_9H_{20}O_2$ | 160 | 2E+07 | 6.884 |
| 2 | 11.543 | Decane | $C_{10}H_{22}$ | 142 | 1.5E+08 | 50.546 |
| 3 | 14.146 | Ethane, 1,1-diethoxy- | $C_6H_{14}O_2$ | 118 | 9582517 | 3.299 |
| 4 | 15.374 | Dodecane | $C_{12}H_{26}$ | 170 | 6.2E+07 | 21.319 |
| 5 | 17.412 | Tetradecane | $C_{14}H_{30}$ | 198 | 1.5E+07 | 5.2 |
| 6 | 19.13 | 2,2,4-Trimethyl- 1,3-pentanediol diisobutyrate | $C_{16}H_{30}O_4$ | 286 | 2.1E+07 | 7.17 |
| 7 | 19.592 | O-Acetylcitric acid triethyl ester | $C_{14}H_{22}O_8$ | 318 | 9321138 | 3.209 |
| 8 | 21.691 | 1,2-Benzene dicarboxylic acid, butyl octyl ester | $C_{20}H_{30}O_4$ | 334 | 6893053 | 2.373 |
| Total | | | | | 2.9E+08 | 100 |

Table 2A - GC–MS profile of phytochemical constituents identified in the ethanolic Root extract of Opupntia elatior Mill.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 4.595 | Silane, diethylmethyl | $C_5H_{14}Si$ | 102 | 3209453910 | 85.076 |
| 2 | 14.099 | 3,3-Diethoxy-1-propanol, propyl ether | $C_{10}H_{22}O_3$ | 190 | 563008088 | 14.924 |

Table 2B - GC–MS profile of phytochemical constituents identified in the ethanolic Phylloclade extract of Opupntia elatior Mill.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 14.136 | 2-Propanone, 1,1-diethoxy- | $C_7H_{16}O_3$ | 146 | 20931294 | 35.8004 |

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 2 | 15.272 | 5-Octadecanal | $C_{18}H_{36}O$ | 266 | 11787523 | 20.1611 |
| 3 | 15.46 | 2-Hexadecanol | $C_{16}H_{34}O$ | 242 | 7400353 | 12.6574 |
| 4 | 15.856 | Dodecylcyclo -hexane | $C_{18}H_{36}$ | 252 | 10457382 | 17.8861 |
| 5 | 17.339 | 2-Heptadecanol | $C_{17}H_{36}O$ | 256 | 7890040 | 13.4950 |

Table 2C - GC–MS profile of phytochemical constituents identified in the ethanolic flower extract of Opupntia elatior Mill.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 4.567 | Silane, diethylmethyl | $C_5H_{14}Si$ | 102 | 1378372082 | 47.4587 |
| 2 | 5.037 | Silane, diethylmethyl- | $C_5H_{14}Si$ | 102 | 1034753581 | 35.6276 |
| 3 | 11.813 | 5-Methoxy methoxyhex-3-yn-2-ol | $C_8H_{14}O_3$ | 158 | 36378382 | 1.2525 |
| 4 | 11.97 | (–)-Methyl-3,3-dimethylcyclo propane- | $C_{10}H_{18}$ | 186 | 47212766 | 1.6256 |
| 5 | 14.144 | 3-Buten-1-ol, TMS derivative | $C_7H_{16}OSi$ | 144 | 407642989 | 14.0356 |

Table 3A - GC–MS profile of phytochemical constituents identified in the ethanolic root extract of Opuntia dillenii (Ker Gawl.) Haw.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 4.772 | Silane, diethylmethyl- | $C_5H_{14}Si$ | 102 | 1586040596 | 46.130 |
| 2 | 5.407 | Silane, diethylmethyl- | $C_5H_{14}Si$ | 102 | 1175955053 | 34.202 |
| 3 | 14.355 | 3-Buten-1-ol, TMS derivative | $C_7H_{16}OSi$ | 144 | 676229810 | 19.668 |

Table 3B - GC–MS profile of phytochemical constituents identified in the ethanolic Phylloclade extract of Opuntia dillenii (Ker Gawl.) Haw.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 4.901 | Silane, diethylmethyl- | $C_5H_{14}Si$ | 102 | 12441562070 | 43.833 |
| 2 | 5.269 | 2-Butenal, 2-ethenyl- | $C_6H_8O$ | 96 | 618641782 | 2.180 |
| 3 | 11.835 | (–)-Methyl-3,3-dimethyl cyclopropane-1, trans-2-dicarboxylate | $C_9H_{14}O_4$ | 186 | 673039331 | 2.371 |
| 4 | 12.600 | (–)-Methyl-3,3-dimethyl cyclopropane-1, trans-2-dicarboxylate | $C_9H_{14}O_4$ | 186 | 187840895 | 0.662 |
| 5 | 13.066 | 2,4,6-Octatrienal | $C_8H_{10}O$ | 122 | 118708444 | 0.418 |
| 6 | 14.136 | 3,3-Diethoxy-1-propanol, propyl ether | $C_{10}H_{22}O_3$ | 190 | 14344472960 | 50.537 |

Table 3C - GC–MS profile of phytochemical constituents identified in the ethanolic flower extract of Opuntia dillenii (Ker Gawl.) Haw.

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 1 | 4.534 | Silane, diethylmethyl | $C_5H_{14}Si$ | 102 | 2099173338 | 27.1093 |
| 2 | 4.898 | Silane, diethylmethyl | $C_5H_{14}Si$ | 102 | 1570465145 | 20.2814 |

| Peak No. | Retention Time | Name of compound | Molecular Formula | Molecular Weight | Area of peak | Probability percent of Area |
|---|---|---|---|---|---|---|
| 3 | 11.73 | (–)-Methyl-3,3-dimethylcyclo propane-1, trans-2-dicarboxylate | $C_9H_{14}O_4$ | 186 | 83017529 | 1.0721 |
| 4 | 11.864 | (–)-Methyl-3,3-dimethylcyclo propane-1, trans-2-dicarboxylate | $C_9H_{14}O_4$ | 186 | 121406807 | 1.5679 |
| 5 | 14.109 | 3,3-Diethoxy-1-propanol, propyl ether | $C_{10}H_{22}O_3$ | 190 | 3869303190 | 49.9693 |

In Nopalea cochenillifera (L.) Salm-Dyck, root extract was dominated by long-chain fatty alcohols such as 2-hexadecanol and 2-heptadecanol, along with cyclohexane derivatives and a nitrogen-containing acetamide compound. The Phylloclade extract showed a wider diversity, including aldehydes (octadecanals), alkanes, alcohols and cyclohexane derivatives. Flower extract was characterized mainly by hydrocarbons such as decane, dodecane and tetradecane, along with ester compounds.

In Opuntia elatior Mill., the root and flower extracts were largely dominated by silane derivatives, while the Phylloclade extract contained a mixture of aldehydes, alcohols and long-chain hydrocarbons, suggesting differential metabolite accumulation in aerial parts.

Similarly, Opuntia dillenii (Ker Gawl.) Haw. showed high abundance of silane compounds in root and flower extracts, whereas the Phylloclade extract exhibited a higher proportion of ether, aldehyde and ester derivatives.

## IV. DISCUSSION

The predominance of long-chain alcohols such as 2-hexadecanol and 2-heptadecanol in Nopalea cochenillifera (L.) Salm-Dyck suggests potential antimicrobial, anti-inflammatory and surface-active properties. Similar fatty alcohols have been reported in GC–MS studies of medicinal plants from Maharashtra, where they were associated with antimicrobial and membrane-disrupting activity (Tatiya et al., 2012; Patil and Patil, 2015). Studies on xerophytic and semi-arid flora of the Vidarbha and Marathwada regions have also documented long-chain alcohols as adaptive metabolites contributing to stress tolerance and bioactivity (Deshmukh et al., 2018). The occurrence of comparable long-chain alcohols in GC-HRMS-based phytochemical profiling of medicinal plants from Maharashtra further supports their biofunctional relevance (Mirge and Patole, 2024).

Aldehydes such as octadecanal and octadecenal derivatives, detected predominantly in phylloclade extracts, are known for their antimicrobial and antioxidant properties. GC–MS-based phytochemical investigations of medicinal plants from Maharashtra have frequently reported long-chain aldehydes with inhibitory activity against pathogenic microorganisms (Pawar et al., 2014; Jadhav et al., 2017). Similar aldehydic compounds have also been documented in Opuntia elatior and other cactus species from semi-arid zones of Maharashtra, supporting their traditional use in wound healing and infection control (Tatiya et al., 2024).

Hydrocarbons such as decane, dodecane and tetradecane, abundantly present in flower extracts, have been widely reported from GC–MS analyses of flowering plants collected from dry regions of Maharashtra. These hydrocarbons are associated with insecticidal, industrial and ecological functions, including protective wax formation and deterrence against herbivores (Patil et al., 2013; Deshpande and Bhalsing, 2019). Their presence in cactus flowers may reflect ecological adaptations to arid climatic conditions prevalent in the Vidarbha region.

The frequent occurrence of silane and siloxane derivatives in Opuntia elatior Mill. and Opuntia dillenii (Ker Gawl.) Haw. has also been reported in several GC–MS studies conducted in Maharashtra. These compounds are often attributed to derivatization during GC–MS analysis, though natural silicon accumulation in xerophytic plants growing on basaltic and lateritic soils of Maharashtra has also been suggested (Patil and Patil, 2015; Jadhav et al., 2017). Silane derivatives are recognized for their industrial relevance and surface-active properties and their repeated detection supports earlier analytical observations from the region.

Esters such as O-acetylcitric acid triethyl ester and benzenedicarboxylic acid derivatives identified in the present study have been previously reported in medicinal plant extracts from Maharashtra and are widely used in pharmaceutical formulations and as plasticizers (Tatiya et al., 2012; Pawar et al., 2014). Their occurrence suggests potential applicability of these cactus species in formulation-based pharmaceutical research.

Comparative analysis revealed that all three species shared common classes of phytoconstituents, including alcohols, aldehydes and hydrocarbons, indicating chemotaxonomic similarity within the family Cactaceae. Similar chemotaxonomic patterns among Opuntia species from Maharashtra have been documented earlier (Tatiya et al., 2024; Deshmukh et al., 2018). However, variations in dominant constituents among species and plant parts may be attributed to local environmental conditions, ecological adaptation and metabolic specialization, which ultimately influence their medicinal efficacy and therapeutic potential.

## V. CONCLUSION

The present GC–MS investigation demonstrates that Nopalea cochenillifera (L.) Salm-Dyck, Opuntia elatior Mill. and Opuntia dillenii (Ker Gawl.) Haw. from the Amravati region are rich sources of diverse phytochemicals with significant biological and industrial applications. The observed similarities support their taxonomic relatedness, while differences in chemical profiles highlight species- and organ-specific metabolite distribution. The findings provide scientific validation for the traditional use of these plants and suggest their potential for further pharmacological and industrial exploitation.

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