**Centella asiatica** (L.) Urb: A comprehensive bibliometric analysis of published studies between 1857 and 2022

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**Abstract**

*Centella asiatica* (L.) Urban (*C. asiatica*) is a medicinal plant that generates terpenes, phenols, vitamins, minerals, polyacetylene and fatty acids among other phyto-constituents. This review focuses on the bibliometric analysis of 1164 documents on *C. asiatica* that were retrieved from the Scopus database. Harzing Publish or Perish and VOSviewer were used for citation and network analyses. According to the bibliometric analysis, publications are on the rise, particularly in the fields of pharmacology, toxicology and pharmaceutics, medicine, biochemistry, genetics and molecular biology, agricultural and biological sciences, and chemistry. "Phytoremediation", "secondary metabolites", "Andrographis paniculata", and "cognitive impairment" are emerging areas for *C. asiatica* research. However, currently there is a lack of international collaboration in *C. asiatica* research among contributing countries. Researchers can utilise the findings cited in this review to locate potential collaborators, top authors, countries and documents.

**Keywords**

*Centella asiatica*; bibliometric analysis; Harzing’s Publish or Perish; VOSviewer

**Introduction**

*Centella asiatica* (L.) Urban (*C. asiatica*) or *Hydrocotyle asiatica* L. is a member of the plant family *Apiaceae* (*Umbelliferae*). The species is stoloniferous, perennial, flowering, mildly aromatic, low-growing, creeping herbaceous plant with prostrate or semi-erect stems and nodal roots (1). Its reniform, shovel-shaped leaves emerge in rosettes at nodes (2) and this plant reproduces by seeds or runners (3). It is also known as pegaga in Malaysia, pegagan or *kaki kuda* in Indonesia, in India, *luei gong gen* or *tung chaim* in China, and Indian pennwort or *gouto kola* in Europe and United States (4). This plant is native to Asia, India and Oceania countries such as Malaysia, Indonesia, Thailand, China, Bangladesh, Sri Lanka, Northern Papua New Guinea, Australia, South America, South Africa and Madagascar (5).

*C. asiatica* is commonly eaten fresh as a raw vegetable (ulam and salad) or prepared as juice or tea among the locals in Malaysia, Indonesia and Thailand (6). It contains various phyto-constituents such as terpenes, phenols, vitamins, minerals, polyacetylene, and fatty acids, which contribute to its medicinal values (5). In addition, it has been used to treat a variety of conditions such as neurological, endocrine, skin, cardiovascular, diges-
tive, respiratory, gynaecological, rheumatoid and other diseases (7). Owing to its enormous therapeutic potential mainly derived from asiaticoside, asiatic acid, madecassoside, and madecassic acid, the demand for Centella herb is constantly expanding in the global herbal market and it is one among the 178 species of medicinal plants that are consumed in quantity > 100 MT per year in India (8).

*Centella asiatica* has a variety of clinical and therapeutic properties. These can be beneficial in the form of being strong wound healing (9), antimicrobial (10), anti-inflammatory (11), antioxidant (12), anti-cancer (13), anti-diabetic (14), insecticidal (15), immunomodulatory (16), hepatoprotective (17), cardioprotective (18) and neuroprotective (19). Despite being one of the important medicinal herbs, there is a lack of systematic and chronological studies to show how *C. asiatica* research has progressed and evolved. Puttarak et al. (20) and Kongkaew et al. (21) published a systemic review and meta-analysis on the effects of *C. asiatica* on cognitive and mood-related outcomes, and its efficacy and safety, respectively. Yusof et al. (22) had published a systematic literature review on the use of *C. asiatica* among the Malay community. Despite these reviews, there have been no bibliometric or network visualization studies on *C. asiatica* literature. Therefore, this review aims to utilize bibliometric analysis and network visualization to determine the global trend of *C. asiatica* research concerning the research trends, most prominent authors and most cited papers, evolution in authors’ keywords as well as research collaboration.

**Materials and Methods**

The data were retrieved on 19th July 2022 from the Scopus database. The following search query in the article title was used: “*Centella asiatica*” or “*C. asiatica*” or “*Hydrocotyle asiatica*” or pegaga or pennywort or "gotu kola" or mandookaparni. Data for 2023 (n = 1), retracted document (n=1) and the erratum (n = 13) were excluded to avoid incomplete data for the respective year and double counting, respectively.

A total of 1164 documents were extracted from the Scopus database in Microsoft Excel (.xlsx), Research Information systems (.ris) and Comma-separated values (.csv) format. The data in .ris and .csv format were analysed using Harzing’s Publish or Perish or VOSviewer for descriptive and network analysis, respectively.

**Results**

**Research Trends**

A total of 1164 documents on *C. asiatica* were retrieved from a search carried out for documents published until 19th July 2022, with no specified starting year. The first traceable document from the Scopus database on *C. asiatica* was published in 1857. The number of documents started to increase from the mid-90s onwards. The highest productivity was observed in 2021 with 123 documents (Fig. 1).

The types of document included article (1024 or 88.0%), conference paper (69 or 5.9%), review article (45 or 3.9%), book chapter (13 or 1.1%), note (5 or 0.4%), letter (4 or 0.3%), short survey (2 or 0.2%), data paper (1 or 0.1%) and editorial (1 or 0.1%).

The majority of retrieved documents were published in English (1079, 92.4%), followed by French (22, 1.9%), Chinese (22, 1.9%), Italian (18, 1.5%) Spanish (7, 0.6%), Portuguese (6, 0.5%), Korean (4, 0.3%), German (3, 0.3%), Turkish (2, 0.2%) and others (5, 0.5%). Four of the documents were published in dual languages.

**Prominent Authors**

Table 1 shows the most authors ranked by total documents, detailing the number of citations, h-index and g-index. Belcaro G. from University of Studies G. d’Annunzio Chieti, Italy was the most productive author followed by Soumyanath A. from Oregon Health & Science University, the United States and Tantisira MH. from Burapha Univer-

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**Fig. 1.** The annual publications on *C. asiatica* from 1857 to 2020.
sity, Thailand. The top countries by author affiliation in Table 1 were the University of Studies G. d’Annunzio Chieti in Italy and Oregon Health & Science University in the United States.

**Most Cited Papers**

According to the Scopus database, the most cited article was a review article, “Chemical, pharmacological and clinical profile of the East Asian medical plant *Centella asiatica*” which appeared in Phytomedicine with 333 citations. The second-ranked article was an original article, “In vitro and in vivo wound healing activity of asiaticoside isolated from *Centella asiatica*” which was published in Journal of Ethnopharmacology (316 citations) followed by a review article, “Pharmacological review on *Centella asiatica*: A potential herbal cure-all” which appeared in Indian Journal of Pharmaceutical Sciences (272 citations) as in Table 2.

**Co-occurrence network of authors’ keywords**

Fig. 2a shows the co-occurrence network of authors’ keywords. “Centella asiatica” appeared 658 times and was the most frequent keyword used by authors. This was followed by “asiaticoside” (114 times), “antioxidant” (58 times), “madecassoside” (49 times) and “asiatic acid” (49 times). The author keywords were further analysed using techniques described by Cobo *et al.* (32) and Feng *et al.* (33) to identify core, mature, emerging and declining topics related to *C. asiatica* research (Fig. 2b).

**Research Collaboration**

Fig. 3 shows the co-authorship network of countries co-publishing on *C. asiatica*. The size of nodes in the network map is proportionate to each country’s total number of co-publications. India has the largest node followed by Malaysia, Thailand, Indonesia and China. These countries were grouped in three different clusters (green, purple and yellow clusters). Table 3 summarises the number of documents produced by each country, the number of citations these documents have acquired, and the total link strength (TLS), which is the sum of all links generated by each

### Table 1. Most productive authors, institutions and countries (total documents > 10)

<table>
<thead>
<tr>
<th>Author’s name</th>
<th>Institution</th>
<th>Country</th>
<th>TD</th>
<th>TC</th>
<th>h</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belcaro G</td>
<td>University of Studies G. d’Annunzio Chieti</td>
<td>Italy</td>
<td>22</td>
<td>463 (3)</td>
<td>15 (1)</td>
<td>21 (1)</td>
</tr>
<tr>
<td>Tantisira MH</td>
<td>Burapha University</td>
<td>Thailand</td>
<td>20</td>
<td>388 (7)</td>
<td>11 (6)</td>
<td>19 (3)</td>
</tr>
<tr>
<td>Soumyanath A</td>
<td>Oregon Health &amp; Science University</td>
<td>United States</td>
<td>20</td>
<td>605 (1)</td>
<td>12 (3)</td>
<td>20 (2)</td>
</tr>
<tr>
<td>Gray NE</td>
<td>Oregon Health &amp; Science University</td>
<td>United States</td>
<td>16</td>
<td>425 (4)</td>
<td>10 (7)</td>
<td>16 (4)</td>
</tr>
<tr>
<td>Quinn JF</td>
<td>Oregon Health &amp; Science University</td>
<td>United States</td>
<td>16</td>
<td>408 (5)</td>
<td>10 (8)</td>
<td>16 (5)</td>
</tr>
<tr>
<td>Cesarone MR</td>
<td>University of Studies G. d’Annunzio Chieti</td>
<td>Italy</td>
<td>15</td>
<td>399 (6)</td>
<td>14 (2)</td>
<td>15 (6)</td>
</tr>
<tr>
<td>De Sanctis MT</td>
<td>University of Studies G. d’Annunzio Chieti</td>
<td>Italy</td>
<td>12</td>
<td>349 (8)</td>
<td>12 (5)</td>
<td>12 (7)</td>
</tr>
<tr>
<td>Caruso M</td>
<td>Oregon Health &amp; Science University</td>
<td>United States</td>
<td>12</td>
<td>175 (9)</td>
<td>8 (9)</td>
<td>12 (8)</td>
</tr>
<tr>
<td>Khotimah H</td>
<td>Brawijaya University, Malang</td>
<td>Indonesia</td>
<td>12</td>
<td>26 (10)</td>
<td>2 (10)</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Kim OT</td>
<td>Rural Development Administration</td>
<td>South Korea</td>
<td>12</td>
<td>503 (2)</td>
<td>12 (4)</td>
<td>12 (9)</td>
</tr>
</tbody>
</table>

**Table 2. Most cited articles**

<table>
<thead>
<tr>
<th>Title</th>
<th>Year</th>
<th>Source</th>
<th>TC</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical, pharmacological and clinical profile of the East Asian medical plant <em>Centella asiatica</em></td>
<td>2000</td>
<td>Phytomedicine</td>
<td>333</td>
<td>23</td>
</tr>
<tr>
<td>In vitro and in vivo wound healing activity of asiaticoside isolated from <em>Centella asiatica</em></td>
<td>1999</td>
<td>Journal of Ethnopharmacology</td>
<td>316</td>
<td>24</td>
</tr>
<tr>
<td>Pharmacological review on <em>Centella asiatica</em>: A potential herbal cure-all</td>
<td>2010</td>
<td>Indian Journal of Pharmaceutical Sciences</td>
<td>272</td>
<td>25</td>
</tr>
<tr>
<td>Antioxidative activity and total phenolic compounds of leaf, root and petiole of four accessions of <em>Centella asiatica</em> (L.) Urban</td>
<td>2003</td>
<td>Food Chemistry</td>
<td>258</td>
<td>26</td>
</tr>
<tr>
<td>Pentacyclic triterpenoids from the medicinal herb, <em>Centella asiatica</em> (L.) Urban</td>
<td>2009</td>
<td>Molecules</td>
<td>238</td>
<td>27</td>
</tr>
<tr>
<td>Total phenolics and antioxidant activities of fenugreek, green tea, black tea, grape seed, ginger, rosemary, gotu kola, and ginkgo extracts, vitamin E, and tert-butylhydroquinone</td>
<td>2004</td>
<td>Journal of Agricultural and Food Chemistry</td>
<td>236</td>
<td>28</td>
</tr>
<tr>
<td>Effect of different extracts of <em>Centella asiatica</em> on cognition and markers of oxidative stress in rats</td>
<td>2002</td>
<td>Journal of Ethnopharmacology</td>
<td>197</td>
<td>29</td>
</tr>
<tr>
<td>Effect of <em>Centella asiatica</em> on pentyleneetetrazole-induced kindling, cognition and oxidative stress in rats</td>
<td>2003</td>
<td>Pharmacology Biochemistry and Behavior</td>
<td>189</td>
<td>30</td>
</tr>
<tr>
<td>Cytotoxic and anti-tumour properties of certain taxa of Umbelliferae with special reference to <em>Centella asiatica</em> (L.) Urban</td>
<td>1995</td>
<td>Journal of Ethnopharmacology</td>
<td>174</td>
<td>31</td>
</tr>
<tr>
<td>Effects of <em>Centella asiatica</em> extract on dermal wound healing in rats</td>
<td>1996</td>
<td>Indian Journal of Experimental Biology</td>
<td>168</td>
<td>9</td>
</tr>
</tbody>
</table>

**TD** = total number of documents; **TC** = total citations; **h** = h-index; **g** = g-index. In parenthesis, ranking according to **TC**, **h** and **g** indices, respectively.
Japan (0.64), the United States (0.23), Thailand (0.16), South Korea (0.15), and France (0.11).

Fig. 2. (a) Co-occurrence network of authors’ keywords. A minimum of 5 co-occurrences was set, resulting in 83 keywords that reach the threshold out of 2487 total keywords, and (b) Core, mature, emerging and declining types of keywords found in the scientific articles on C. asiatica (34).
had high TLS in proportion to the number of documents, implying international collaboration. TLS were low in proportion to the number of documents in countries like India (0.05), Malaysia (0.10), Indonesia (0.07) and China (0.08), indicating a smaller weight of international collaboration.

Fig. 4 shows the co-authorship network of authors. Authors were grouped into 21 clusters. Most of the clusters are isolated clusters and the bigger of these isolated clusters are the red and green clusters. The red cluster included 14 authors, three of whom (Belcaro G, Cesarone MR, and De Sanctis MT) were listed as the most productive authors. All of them were from the University of Studies G. d'Annunzio Chieti, Italy. While, the green cluster included nine authors, four of whom (Gray NE, Quinn JF, Soumyanath A and Caruso M) were also listed as the most productive authors. They were all from the same institution, Oregon Health & Science University in the United States.

**Discussion**

The first traceable paper, "Hydrocotyle asiatica" was a note that appeared in Lancet in 1857. However, there was no author name and abstract available. The number of documents on *C. asiatica* increased over time mainly in areas of pharmacology, toxicology and pharmacetics, medicine, biochemistry, genetics and molecular biology, agricultural and biological sciences as well as in chemistry. The majority of the most productive authors were from the Oregon Health & Science University in the United States followed by the University of Studies G. d’Annunzio Chieti, Italy. These could be due to the co-authors from the same institution.

The most cited papers are thought to be of scientific merit, high performance, and useful for benchmarking research performance in a specific area, with a high number of citations per article (36). "Chemical, pharmacological and clinical profile of the East Asian medical plant *Centella asiatica*" was the most cited paper which ap-

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**Table 3.** Top 10 countries co-publishing on *C. asiatica*.

<table>
<thead>
<tr>
<th>Country</th>
<th>Documents</th>
<th>Citations</th>
<th>Total link strength</th>
<th>International collaboration*</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>339</td>
<td>7297</td>
<td>17</td>
<td>0.05</td>
</tr>
<tr>
<td>Malaysia</td>
<td>144</td>
<td>2702</td>
<td>15</td>
<td>0.10</td>
</tr>
<tr>
<td>Indonesia</td>
<td>121</td>
<td>407</td>
<td>8</td>
<td>0.07</td>
</tr>
<tr>
<td>Thailand</td>
<td>107</td>
<td>1677</td>
<td>17</td>
<td>0.16</td>
</tr>
<tr>
<td>China</td>
<td>80</td>
<td>1490</td>
<td>6</td>
<td>0.08</td>
</tr>
<tr>
<td>South Korea</td>
<td>59</td>
<td>1111</td>
<td>9</td>
<td>0.15</td>
</tr>
<tr>
<td>Italy</td>
<td>58</td>
<td>915</td>
<td>2</td>
<td>0.03</td>
</tr>
<tr>
<td>United States</td>
<td>43</td>
<td>1813</td>
<td>10</td>
<td>0.23</td>
</tr>
<tr>
<td>France</td>
<td>27</td>
<td>621</td>
<td>3</td>
<td>0.11</td>
</tr>
<tr>
<td>Japan</td>
<td>22</td>
<td>722</td>
<td>14</td>
<td>0.64</td>
</tr>
</tbody>
</table>

*A higher total link strength/number of documents indicates more international research collaboration in a given country (35).*
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The most frequent authors’ keywords that appeared in the literature were “Centella asiatica”, “asiaticoside”, “antioxidant”, “madecossoside” and “asiatic acid”. The core keywords identified were “antioxidant”, “neuroprotective”, “antibacterial”, “gotu kola” and “diabetes” suggesting the current relevant topics of C. asiatica research. A few recent publications highlighted the medicinal potential of C. asiatica including its potential use for the treatment of diabetes mellitus (37, 38) while the emerging keywords related to C. asiatica research were “phytoremediation”, “rat”, “secondary metabolites”, “andrographis paniculata” and “cognitive impairment”.

C. asiatica has been found to have a phytoremediation potential, an alternate method for minimising water pollution that can be used to treat industrial effluent (39, 40). The different secondary metabolites generated from...
C. asiatica were reviewed by Kunjunom et al. (41) and have potential to be used in future chemistry, biosynthesis, chemical transformation and biological activity research. There are other novel components of C. asiatica, such as araliiadiol, which was recently found to have neuroprotective effects that may prevent cognitive dysfunction (42). Even though this study identified several major metabolites such as "asiaticoside," "asiatic acid," and "madecassoside" as mature keywords. In a recent investigation, phytoconstituents from C. asiatica (43) and Andrographis paniculata were also investigated (44). The in silico technique used by the authors revealed that both substances have the ability to prevent renal (43) and breast (44) cancers, and interact with the progesterone receptor to the fullest.

The co-authorship analysis is a popular method for evaluating scientific collaboration trends (45). Nodes in co-authorship networks reflect authors, organizations or countries that are linked when they co-author an article. India had the largest node in the co-authorship network of countries, with the most co-publications, followed by Malaysia, Indonesia, Thailand, and China. However, based on their TLS and the number of documents, except for Thailand, these countries had low international collaboration. Countries such as Japan and the United States, on the other hand, have shown strong international collaboration. The authors’ clusters were isolated in the co-authorship network of authors, implying that the prolific authors conducted studies locally in the same institution or country, with limited collaboration with other countries (international collaboration).

Conclusion
This study showed that research on C. asiatica is becoming more popular, particularly in the domains of Pharmacology, toxicology, and pharmaceutics, Medicine, Biochemistry, genetics, and molecular biology, Agriculture and biological sciences, and Chemistry. Emerging areas of C. asiatica research include "phytoremediation," "secondary metabolites," "andrographis paniculata," and "cognitive impairment," which could be investigated in the future.

Authors contributions
All authors collaborated in the writing and editing of the manuscript.

Compliance with ethical standards
Conflict of interest: The authors declare no conflict of interest.
Ethical issues: None.

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