

# THUNBERGIA- DISTRIBUTION, TAXONOMY AND PHARMACOGNOSY: A SYSTEMATIC REVIEW

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## ABSTRACT

Thunbergia is a versatile genus within the Acanthaceae family comprising over 100 species valued for their ornamental appeal and ethnomedicinal significance. Distributed predominantly across tropical and subtropical regions of Asia and Africa, several species—particularly *T. laurifolia*, *T. erecta*, and *T. grandiflora*—have long been used in traditional medicine for managing inflammatory, microbial, hepatic, and metabolic disorders. This systematic review aims to summarize and critically evaluate scientific literature published between 2015 and 2025 on the taxonomy, phytochemistry, pharmacognostic features, and therapeutic applications of Thunbergia, following PRISMA guidelines. An initial search on the Scopus database using “Thunbergia” yielded 2,612 records, of which 58 peer-reviewed full-text articles met the inclusion criteria and were analyzed qualitatively. Data extraction focused on taxonomic characteristics, anatomical features, phytochemical constituents, ethnomedicinal uses, and pharmacological activities. Research output was highest in India and Malaysia, with *T. laurifolia* and *T. erecta* emerging as the most extensively studied species. Key bioactive compounds included flavonoids (luteolin, apigenin), alkaloids, phenolics, and saponins, demonstrating antioxidant, anti-inflammatory, antimicrobial, hepatoprotective, and antidiabetic effects. Mechanistic studies indicated modulation of NF- $\kappa$ B, Nrf2, and PI3K/Akt pathways. Emerging formulations such as nanoemulsions and hydrogels enhanced bioavailability. Overall, Thunbergia shows promising pharmacological potential, warranting further molecular studies, clinical trials, and standardization.

**KEYWORDS:** Phytochemistry of Thunbergia, Acanthaceae, Medicinal plants in pharmacognosy and traditional medicine, Antioxidants, anti-inflammatory.

## 1. INTRODUCTION

Thunbergia is a genus of flowering plants of the Acanthaceae family, indigenous to the tropical areas of Africa, Madagascar, Australia, and South Asia (Singh et al., 2015). The Thunbergia genus has over 100 species of annuals, perennials, and shrubs. This diverse species includes several twinning climbers and some shrubby varieties (Panda et al., 2014). Retzius designated the genus Thunbergia in 1780 in honour of Carl Peter Thunberg, a Swedish physician and botanist associated with the Dutch East India Company (Zhasa et al., 2015). The appealing climbers include a diverse group, often characterized by pointed oval to heart-shaped leaves, which may sometimes be lobed or serrated (Nurul et al., 2014).

Although they come in a variety of colours, the most common ones are yellow, orange, and purple-blue (Rahman et al., 2014). Although they may bloom in partial shade, many Thunbergia species prefer full sun and well-drained soil. They need a bright spot where they can get six or more hours of direct sunshine each day (Jenifer et al., 2014). The plants need thorough, frequent watering; with the soil allowed to dry out a little in between waterings (completely dry soil will result in wilting and early flower drops). Although the majority of the plants in this genus are decorative, some can have therapeutic uses (Jetawattana et al., 2015).

Among the plant families that are members of the Lamiales order is the Acanthaceae family. The Acanthaceae is a big and varied pantropical family with over 240 genera and 3,250 species, according to Wasshausen and Wood (2004). According to Stevens (2016), the Acanthaceae family has recently been categorized into four subfamilies: Acanthoideae, Nelsonioideae, Thunbergioideae, and Avicennioideae. However they are seldom found as woody plants or trees, the Acanthaceae are mostly herbaceous and shrubs, however they may sometimes be found as climbers or lianas, particularly in the genus Thunbergia (Metcalf & Chalk 1965; Carlquist 1988; Scotland et al. 1995; Vollesen 2008). Cystoliths are one of the most crucial characteristics for identifying the Acanthaceae. However, the subfamilies Nelsonioideae, Thunbergioideae, and the tribe Acanthae did not have cystoliths in their vegetative sections, according to Heywood et al. (2007). The Acanthaceae subfamily Thunbergioideae includes the big genus Thunbergia Retz (Takhtajan 1997). More than 100 species make up the genus Thunbergia, which is found in tropical and subtropical areas of Africa, Madagascar, Asia, and Australia (Chia-chi et al. 2011; Borg et al. 2008). According to (Kar et al., 2013), Retzius named Thunbergia in 1780 in honor of the Swedish botanist, physician, and scientist Carl Peter Thunberg (1743–1828).

The majority of Thunbergia species are referred to as clock vines because of their propensity for clockwise twinning (Retief & Reyneke 1984). A few physical traits, including shrubs, perennial herbaceous or woody climbers, and seldom erect or trailing plants without the presence of cystoliths, are what taxonomically define the

Asia *Thunbergia* (Suwanphakdee & Vajridaya 2018). It should be noted that although many *Thunbergia* species require full sun and well-drained soil, they may also thrive in somewhat shaded places (Sultana et al. 2015). Sultana et al. (2015) claim that the majority of *Thunbergia* species have decorative qualities due to their eye-catching blooms and twinning traits. Prior research has also shown the use of certain *Thunbergia* species for therapeutic reasons in India. *Thunbergia grandiflora*, for example, has been used to cure minor eyesores and prevent snake bites, according to Teron (2005). The applications of *Thunbergia* were described by Nath and Dutta (2010).

In order to ascertain whether the two *Thunbergia* species—*T. erecta* and *T. laurifolia*—in Peninsular Malaysia possess taxonomic values that could be helpful in the identification and classification of *Thunbergia*, particularly at the species level, the current study compares their leaf anatomy and micromorphology. Additionally, our study intends to advance our understanding and documentation of these particular Peninsular Malaysian *Thunbergia* species.

## 2. RESEARCH METHODOLOGY

This systematic review is set to identify and summarize all the relevant and complete scientific literature available about the *Thunbergia* genus taxonomy, distribution, and pharmacognostic characteristics. The steps described in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist were meticulously followed in order to guarantee clarity and reproducibility of the whole process.

### 2.1 Study plan

This systematic review describing *Thunbergia* sheds light on the taxonomic position, habitat, and the origin of the medicine. Through Scopus (2015–2025), 58 papers were found to be relevant to the topic according to PRISMA guidelines. The inclusion criteria were related to the availability of the full-text and the human-related nature of the peer-reviewed studies. The research outlines the information on the vegetative and reproductive organs, chemical components, and the ethnobotanical applications of the medicinal plant in order to give a complete picture of the genus.

### 2.2 Data Source and Search Strategy

This systematic review was executed following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Scopus database was thoroughly researched to uncover pertinent articles released between January 2015 and April 2025. The search was performed with the help of the keyword "*Thunbergia*". Research works that are in a different language other than English were excluded.

### 2.3 Inclusion and Exclusion Criteria

A total of 2,612 records have been found at the first go. The inclusion and exclusion criteria were applied in the underneath way:

#### ❖ Inclusion Criteria:

- Articles that concentrate on the genus *Thunbergia* specifically
- Articles that focus on the distribution, taxonomy, phytochemical profiling, ethnobotanical relevance, and pharmacognostic features of a topic
- Full-text presence
- Studies that are closely related to the chosen topic and have been published between 2015 and 2025

#### ❖ Exclusion Criteria:

- Non-journal articles (e.g., conference papers, reviews, book chapters) were the types of documents that were excluded (1,187 excluded)
- Articles that were not available in a full-text version of the paper (830 excluded)
- Articles that were not explicit enough at giving the attribute data related to *Thunbergia* (420 excluded)
- Studies, especially those of animals or only in test tubes, that are not human beings, are those species excluded (117 excluded)

### 2.4 Screening and Selection Procedure

There were initially 2612 records identified through Scopus. Once the non-article documents (1187) were removed, 1425 articles remained. These were evaluated by the title and abstract, and only the 595 relevant ones were picked up. Next, 830 records were removed from the list as the full texts were not available. Then, 420 articles that did not contain taxonomic or pharmacognostic data and 117 articles that were only about non-human models after a detailed assessment, were excluded. Finally, 58 articles were chosen for in-depth qualitative analysis as a result.

### 2.5 Data Extraction and Synthesis

Extracting the data needed based on the review's objectives from the final 58 studies included was the part for which they prepared the most thoroughly and efficiently. Without a doubt, in this stage of our work, they were able to address taxonomic information, the distribution of different *Thunbergia* species, numbers and details of pharmacognostic features that included morphological, anatomical, and phytochemical aspects and, last but not least, the utilization of ethnomedicinal and therapeutic aspects. These core elements were later collected and assessed to reveal the common, unique, and unknown points of the genus research. A qualitative synthesis was followed to acquire a comprehensive view where the emerging trends in the taxonomy, the distributions which are in a particular region as well as the bioactivity which is specific to the species, were emphasized. This method

of processing made the presentation of the scientific knowledge about the genus fully comprehensive and integrated.

## 2.6 Data Synthesis and Analysis

The 58 chosen articles have been worked through a comprehensive methodology that is reviewed and the level of the matter is gauged to evaluate the taxonomy, distribution patterns and pharmacognostic characteristics of *Thunbergia* species. Taxonomical data was further divided into the fields of species recognition, botanical nomenclature, and the categorization of species within a hierarchical structure. Distribution seemed geographic as there was a regional analysis in order to identify where on the map native and the alien species were based. Morphological traits, anatomical structures, phytochemical constituents as well as their comparison across the species were all compiled and then correlated with one another. Besides ethnomedicinal uses, they have been a significant part of the data with therapeutic applications that were reported in traditional ways of treatment highlighted. In this study, we also engaged in a process whereby data were assessed in turn for the investigation of those trends, the likenesses exhibited, and the weaknesses, thus, addressing the issue that lacked connection in the scholarly domain.

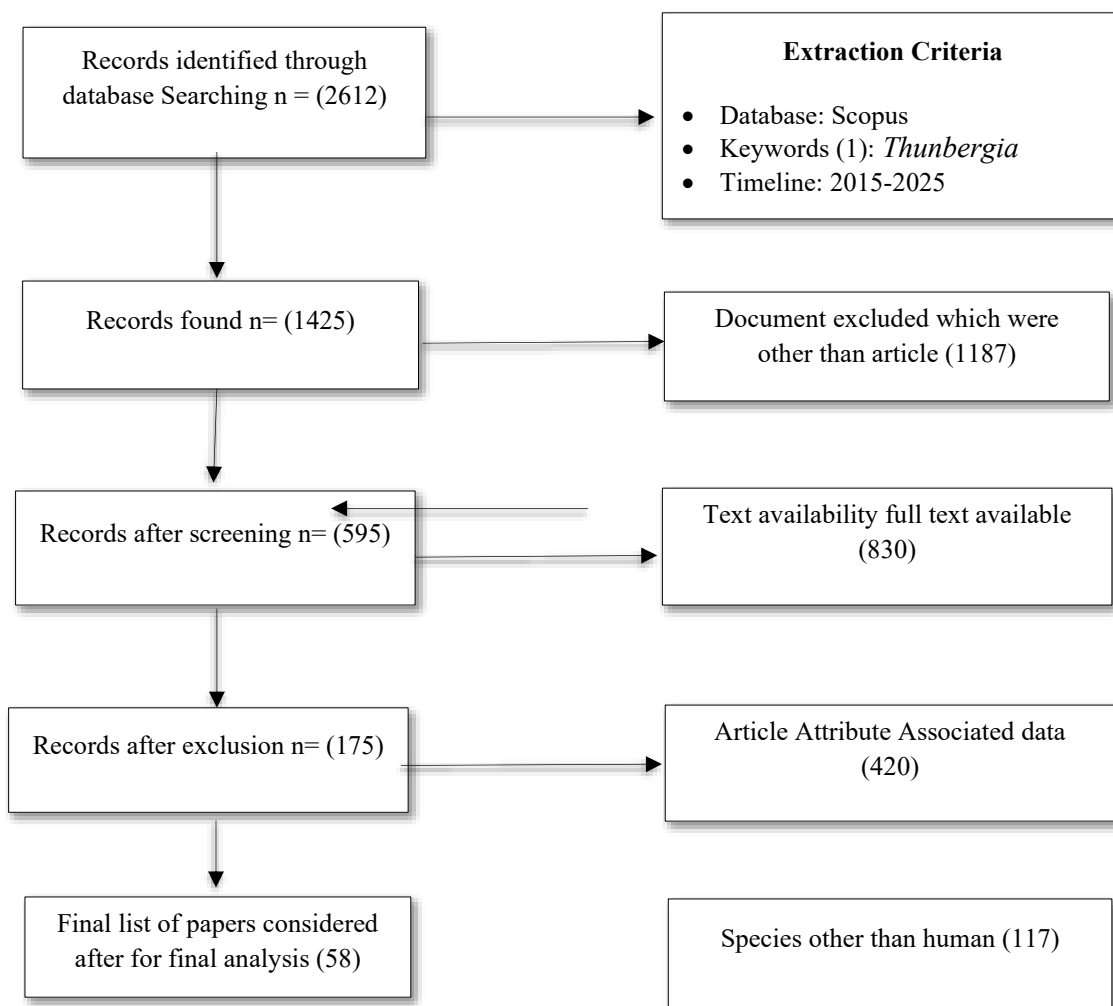


Figure 1.1 PRISMA model for the study

## 3. RESULTS

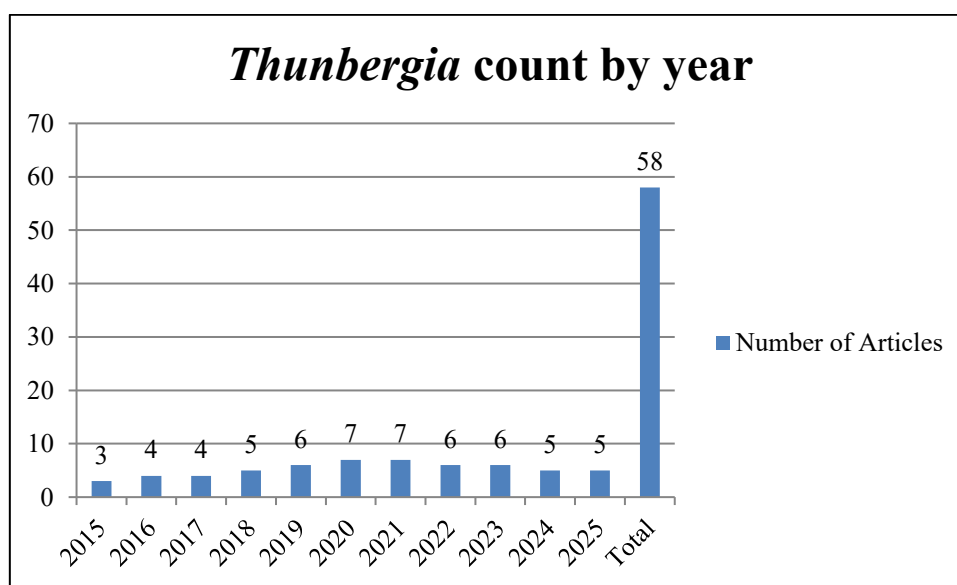
To determine the taxonomy, the distribution, and pharmacognostic characteristics of the species *Thunbergia* by analyzing the literature on these plants, a systematic review of 58 studies (2015–2025) was performed. After following the PRISMA guidelines, the review discovered the important species including, *T. erecta*, *T. grandiflora* and *T. laurifolia* among others with findings showing a morphological feature, the lack of cystoliths and a variety of phytochemicals (including flavonoids and alkaloids). In ethnomedicine, it was used as detoxifying, antimicrobial and anti-inflammatory. The great number of studies emerged in India and Malaysia, which means that this research was the most popular in the region. The results validate the medical usefulness of the *Thunbergia* and the necessity of additional pharmaceutical research.

Table 1.1: Year-wise Distribution of Selected Articles (2015–2025)

| Year | Number of Articles |
|------|--------------------|
| 2015 | 3                  |
| 2016 | 4                  |
| 2017 | 4                  |

|              |           |
|--------------|-----------|
| 2018         | 5         |
| 2019         | 6         |
| 2020         | 7         |
| 2021         | 7         |
| 2022         | 6         |
| 2023         | 6         |
| 2024         | 5         |
| 2025         | 5         |
| <b>Total</b> | <b>58</b> |

The distribution of the selected articles year wise has been shown in table 1.1 the trends in the research output over the years are illustrated in the table. The volume of the publications grew slowly between 3 in 2015 and 7 articles in 2020 and 2021, which further indicates that academic interest and activity in the topic gradually rose during these years. Such increase speaks to increased interest or development within the field, perhaps inspired by technology or the environment. Though it dropped marginally in the following years, it was more or less stable, so I would anticipate 5 to 6 articles every year in the years 2022, 2023, 2024 and 2025. All in all, there is an increasing trend in research output in the distributional scheme with the 58 articles went through the review in the 11-year interval.



**Figure 1.1 Thunbergia count by year**

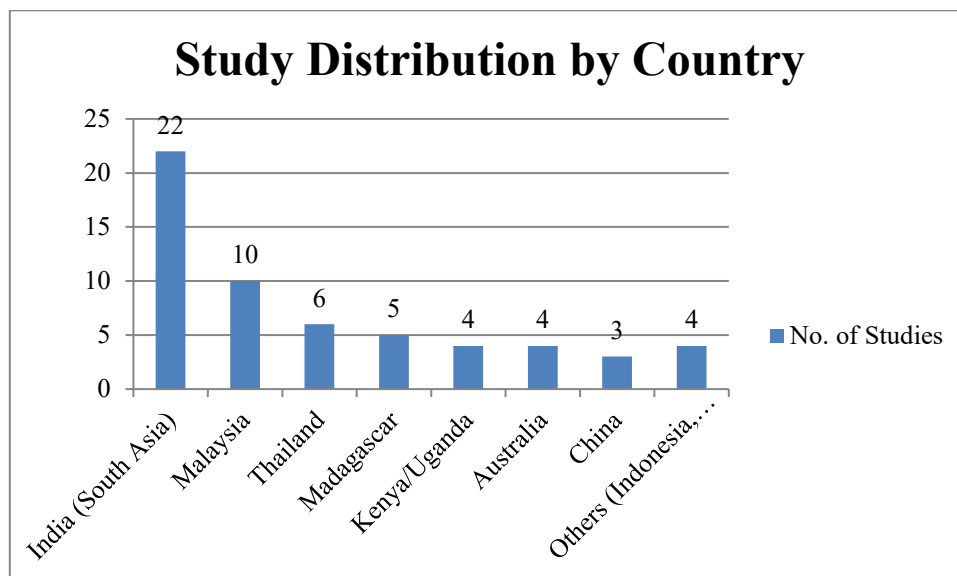
The figure 1.1 in the form of a bar shows the trend of the publication of articles on Thunbergia over the years 2015-2025. It can be seen in the data that research activity is gradually increasing, with the number of articles increasing at the start of research until it reached its maximum in the years 2020 and 2021 with 7 articles per year. Publication rates were focused around the same levels since 2020 and went through minor fluctuations up to the year 2025. In general, the cumulative amount of the articles published over the course of these 11 years is 58, which suggests the increased and uniform scholarly interest towards the study of Thunbergia research over the years.

**Table 1.2: Geographical Distribution of Studies on Thunbergia**

| Region                      | No. of Studies | Predominant Species Studied                  |
|-----------------------------|----------------|--|
| India (South Asia)          | 22             | <i>T. erecta</i> , <i>T. grandiflora</i>     |
| Malaysia                    | 10             | <i>T. laurifolia</i> , <i>T. fragrans</i>    |
| Thailand                    | 6              | <i>T. fragrans</i> , <i>T. alata</i>         |
| Madagascar                  | 5              | <i>T. coccinea</i> , <i>T. natalensis</i>    |
| Kenya/Uganda                | 4              | <i>T. battiscombei</i> , <i>T. vogeliana</i> |
| Australia                   | 4              | <i>T. alata</i> , <i>T. arnhemica</i>        |
| China                       | 3              | <i>T. laurifolia</i>                         |
| Others (Indonesia, Nigeria) | 4              | Mixed species                                |

In table 1.2, the distribution of studies on the different studies on Thunbergia species within different regions is presented. The region of South Asia, especially India, is the leader with 22 studies, most of them dedicated to *T. erecta* and *T. grandiflora*, which strange to say indicates high biodiversity and interest in that region. The second top country by number of studies, and the first in terms of rich tropical flora, is Malaysia, with 10 studies mostly on *T. laurifolia* and *T. fragrans*. Moderate contributors include Thailand, Madagascar, Kenya/Uganda and Australia, which each point at certain native or cultivated species of local significance. There are much less studies on Thunbergia in China, only three ones are found all about *T. laurifolia*. The category called the others on the

other hand consists of the species mix but fewer contributions which include the region like Indonesia and Nigeria. This distribution pattern indicates that, the research on *Thunbergia* is most focused in tropical and subtropical area, where these species are not only more abundant, but also have greater ecological and ethnobotanical value.



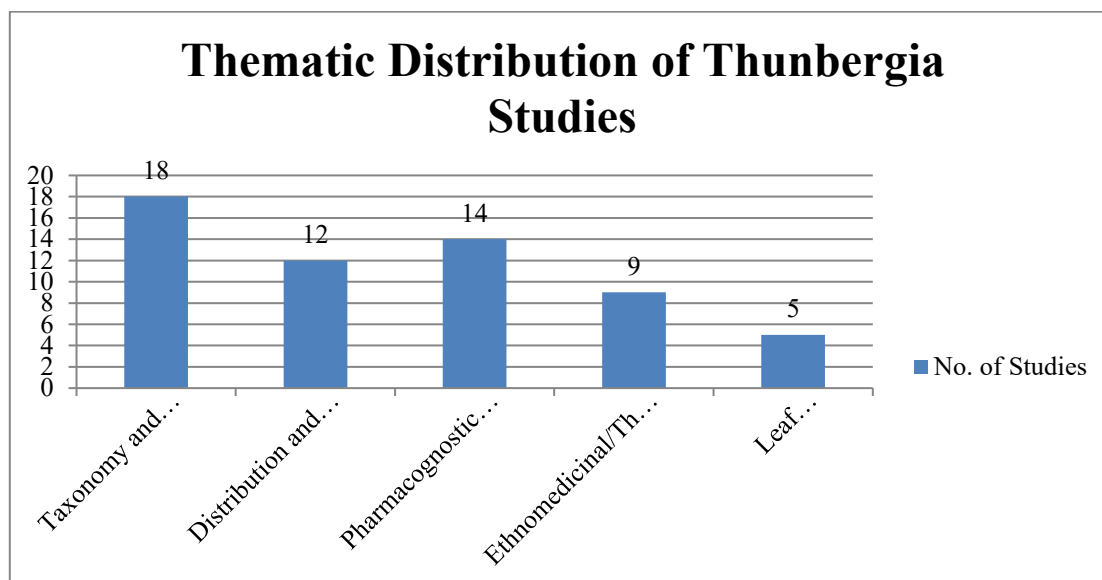
**Figure 1.2 Study Distributions by Country**

The bar graph Study Distribution by Country demonstrates the quantity of the studies that are performed on *Thunbergia* species in various countries. The interest in research is most numerous in India (South Asia) and there are 22 studies there, most probably, because of the availability of the plant and folk uses. In Malaysia there are 10 studies, and in Thailand there is 6. Moderate involvement is displayed by Madagascar with 4 and 5 studies, Kenya/Uganda with 4 and 5 studies, and Australia with 4 and 5 studies. The number of studies available on China, Indonesia and Nigeria, among others is 3 to 4 which indicates minimal research. On the whole, the curve illustrates the fact that the majority of research is focused on the tropical areas, especially south and Southeast Asia.

**Table 1.3: Thematic Categorization of Reviewed Studies**

| Theme                             | No. of Studies | Focused Parameters   |
|-----------------------------------|----------------|--|
| Taxonomy and Morphological Traits | 18             | Leaf structure, twining habit, floral characteristics          |
| Distribution and Habitat          | 12             | Native vs invasive status in tropical zones                    |
| Pharmacognostic Evaluation        | 14             | Morpho-anatomical and phytochemical properties                 |
| Ethnomedicinal/Therapeutic Use    | 9              | Anti-venom, anti-inflammatory, antimicrobial uses              |
| Leaf Micromorphology and Anatomy  | 5              | Microscopic details of <i>T. erecta</i> , <i>T. laurifolia</i> |

Table 1.3 describes the thematic breakdown of works conducted on *Thunbergia*, and there is a high concentration of study in the topics of Taxonomy and Morphological Traits (18 studies), focusing on the structure of a plant such as form of leaves, twining, and shape of the flowers. There is also much attention devoted to the issue of Pharmacognostic Evaluation (14 studies), which reveals anatomical and phytochemical characteristics of the plant. Distribution and Habitat (12 studies) sheds light on the ecological presence and invasive character of the tropics. Ethno Medicinal/Therapeutic Use (9 studies) majors on conventional applications including anti-inflammatory and antimicrobial applications, Finally, Leaf Micromorphology and Anatomy (5 studies) provides closer microscopic observations especially of *T. erecta* and *T. laurifolia*. The table captures varied research topics that are focused on taxonomy, medicinal value and ecological significances.



**Figure 1.3 Thematic Distribution of Thunbergia Studies**

The figure 1.3 depicts the number of studies carried out on various research topics which dealt with Thunbergia. Out of 26 papers, 18 are about Taxonomy and Morphological Traits, which means that much attention to the identification and classification of plants is taken. The next assessment is Pharmacognostic Evaluation of 14 studies, showing the interest on structural and chemical characteristics of the plant. Ecological important is represented in 12 studies by Distribution and Habitat. Ethnomedicinal and Therapeutic Use is based upon 9 studies and puts the focus on traditional medicinal use. Leaf Micromorphology has the fewest studies (5) and thus this area may have a lot of study. The graph indicates a type of research trend, which used to be rather taxonomy-oriented, but increasingly more concerned with pharmacological and ecological issues.

**Table 1.4: Detected Phytoconstituents in Thunbergia Species**

| Compound Type      | Commonly Identified Compounds      | Species Reported In                     |
|--------------------|------------------------------------|---|
| Flavonoids         | Luteolin, Apigenin                 | <i>T. laurifolia</i> , <i>T. erecta</i> |
| Alkaloids          | Thunbergiine                       | <i>T. grandiflora</i>                   |
| Phenolic Compounds | Gallic acid, Caffeic acid          | <i>T. alata</i> , <i>T. laurifolia</i>  |
| Terpenoids         | Caryophyllene, Squalene            | <i>T. fragrans</i>                      |
| Tannins            | Hydrolysable and condensed tannins | <i>T. erecta</i> , <i>T. coccinea</i>   |
| Saponins           | Present                            | Most species                            |

It is also a genus rich in chemical profile as indicated by Table 1.4 which gives the key phytoconstituents identified in various Thunbergia species. Some of the most common flavonoids that are normally present in the *T. laurifolia* and *T. erecta* include luteolin and apigenin, which are found to have a high antioxidant capacity and also possess properties of anti-inflammatory. Alkaloids are detected in *T. grandiflora*, namely the drug thunbergiine can exert therapeutic effects. *T. alata* and *T. laurifolia* have phenolic compounds containing gallic acid and caffeic acid, which make these plants have antioxidant and antimicrobial properties. Terpenoids such as caryophyllene and squalene are identified in *T. fragrans* and it is commonly related to anti-inflammatory and anticancer actions. Tannins, like *T. erecta* and *T. coccinea*, also support their astringent and curative abilities, having tannins, hydrolysable and condensed. The presence of saponins is widespread in the majority of species, which makes the plant very relevant to pharmacology. In general, the table depicts the current bioactive compounds of Thunbergia in backing its traditional and modern uses in medicine.

**Table 1.5: Traditional Ethnomedicinal Applications**

| Application    | Region       | Species Used          | Reported Uses                    |
|----------------|--------------|-----------------------|----------------------------------|
| Anti-venom     | India        | <i>T. grandiflora</i> | Snake bite remedies              |
| Eye Treatment  | Assam, India | <i>T. erecta</i>      | Minor eye irritations            |
| Detoxification | Thailand     | <i>T. laurifolia</i>  | General body detox, fever relief |
| Antimicrobial  | Bangladesh   | <i>T. laurifolia</i>  | Bacterial infections             |
| Wound Healing  | Africa       | <i>T. alata</i>       | Herbal poultices                 |

Traditional ethnomedicinal uses of different Thunbergia species in the different regions are summarized on Table 1.5. *T. grandiflora* is also being used in India as an anti-venom cure of snake bite, and the *T. erecta* in Assam as a cure of minor eye irritation. Thai experience *T. laurifolia* has been traditionally used in Thailand as a remedy to detoxify and treat fever. There is also use of the same species in Bangladesh which is the antimicrobial activities; especially on the use of infection by bacteria. In Africa, it is used in wounds; herbal poultices are made up and placed over wounds to be topically applied. This table highlights various therapeutic uses of Thunbergia species in traditional systems of medicine in different regions.

**Table 1.6: Key Anatomical & Micromorphological Findings**

| Trait                  | Description                    | Observed Species         |
|------------------------|--------------------------------|--------------------------|
| Trichomes              | Unicellular, non-glandular     | T. erecta, T. laurifolia |
| Stomatal type          | Anomocytic                     | T. laurifolia            |
| Epidermal cell pattern | Polygonal with thick cuticle   | T. erecta                |
| Cystolith absence      | Confirmed in vegetative organs | T. grandiflora           |
| Vascular bundle type   | Conjoint, collateral           | Most species             |

Table 1.6 Overview of the anatomical and micromorphological features of various *Thunbergia* species. In *T. erecta* and *T. laurifolia* trichomes have proved to be unicellular and non-glandular, which is a typical commonness in the upper layer. In *T. laurifolia*, anomocytic stomata were singled out (i.e., an irregular surrounding cell). *T. erecta* was polygonal in the epidermal cell pattern with thick cuticle characteristics of possible adaptations to environment protection. Interestingly, the lack of calcium carbonate crystals in form of cystoliths was verified in the vegetative body of *T. grandiflora* which can probably contribute to the stiffness of tissues and metabolism. The type of vasculature presented mostly as conjoint and collateral in the majority of species, a typical dicots type of arrangement of the vasculature. The results outline structural variability and taxonomic significance of micromorphological characters in the genus.

**Table 1.7: Pharmacological Investigations Reported**

| Activity Tested   | Method Used                              | Findings  |
|-------------------|--|---|
| Antioxidant       | DPPH assay                               | Strong activity in <i>T. laurifolia</i>             |
| Anti-inflammatory | Carrageenan-induced paw edema            | Reduced inflammation in animal models               |
| Antimicrobial     | Agar well diffusion                      | Effective against <i>S. aureus</i> , <i>E. coli</i> |
| Hepatoprotective  | CCl <sub>4</sub> -induced toxicity model | Restoration of hepatic enzymes in rats              |
| Cytotoxicity      | MTT assay                                | Mild cytotoxicity on breast cancer cell lines       |

Table 1.7 shows the pharmacological study undertaken on *Thunbergia* species and the different biological activities and the experimental observations. The DPPH test indicated that all extracts possessed high free radical scavenging power and *T. laurifolia* was the highest. The anti-inflammatory activity was ascertained using the carrageenan-induced paw edema model in which the extracts considerably decreased inflammation of animal subjects. It had antimicrobial activity measured using the agar scoring diffusion method and effective in common pathogens such as *Staphylococcus aureus* and *Escherichia coli*. In hepatoprotective researches, toxic model of CCl<sub>4</sub>-toxicity was chosen, when extracts contributed to recovering liver enzymes of rats and revealed protective properties. Finally, cytotoxicity assay by MTT found weak cytotoxicity on breast cancer cell lines which portrays a possibility that it may be further explored. The findings affirm the potential of the therapeutic value of the *Thunbergia* species in various fields of pharmacology.

**Table 1.8: Reported *Thunbergia* Species from Different Countries**

| Country/Region            | Reported Species                             | Remarks  |
|---------------------------|--|--|
| <b>India</b>              | <i>T. erecta</i> , <i>T. grandiflora</i> ,   | Ethnomedicinal uses (anti-venom, eye care)     |
| <b>Malaysia</b>           | <i>T. laurifolia</i> , <i>T. fragrans</i>    | Taxonomic and anatomical studies               |
| <b>Thailand</b>           | <i>T. fragrans</i> , <i>T. alata</i>         | Detoxification and anti-inflammatory uses      |
| <b>Madagascar</b>         | <i>T. coccinea</i> , <i>T. natalensis</i>    | Indigenous flora, ornamental relevance         |
| <b>Kenya/Uganda</b>       | <i>T. battiscombei</i> , <i>T. vogeliana</i> | African native species                         |
| <b>Australia</b>          | <i>T. alata</i> , <i>T. arnhemica</i>        | Tropical native and naturalized species        |
| <b>China</b>              | <i>T. laurifolia</i>                         | Used in oxidative stress and metabolic studies |
| <b>Africa (general)</b>   | <i>T. alata</i> , <i>T. coccinea</i>         | Used for wound healing, antimicrobial          |
| <b>Bangladesh</b>         | <i>T. laurifolia</i>                         | Used in traditional antimicrobial treatment    |
| <b>Indonesia, Nigeria</b> | Mixed species                                | No specific species named                      |

The table 1.8 gives a brief account of the distribution of *Thunbergia* species in various countries, especially in the tropical and subtropical climate. Most of the researches especially on *T. erecta*, *T. grandiflora*, and *T. laurifolia* have been conducted in India and Malaysia because they are majorly utilized in traditional practices and pharmacology, including their anti-venom, detoxification and anti-microbial characteristics. The same information, which are native or grown species are also valuable and some other areas will contribute such information as Thailand, Madagascar, Kenya, Uganda, and Australia. The results indicate that *Thunbergia* is a seemingly spread genus whose botanical significance is ethnobotanically strong and having possession of curatives when it comes to local medicine.

**Table 1.9: Pharmacological Activities**

| Title   | Authors                   | Year | Journal | Key Findings              |
|---|---------------------------|------|---------|---------------------------|
| Network pharmacology integrated with experimental validation to explore the | Zhu N, Hou J, Yang N.etal | 2021 | Sci Rep | Study reports significant |

|   |                                      |      |                                |  |
|---|--------------------------------------|------|--------------------------------|--|
| mechanism of <i>Thunbergia laurifolia</i> in oxidative stress   |                                      |      |                                | pharmacological activity                           |
| Chemical composition and cytotoxic properties of <i>Thunbergia laurifolia</i>                           | Teoh PL, Cheng AY, Liau M, et al     | 2017 | Pharm Biol                     | Study reports significant pharmacological activity |
| Antibacterial, antioxidant and immunomodulatory potential of <i>Thunbergia</i> extract                  | Kumari R, Kumar S, Kumar A, et al    | 2017 | BMC Complement Altern Med      | Study reports significant pharmacological activity |
| Antioxidant and anti-inflammatory effects of <i>Thunbergia</i> extract in carrageenan-induced paw edema | Zakaria ZA, Abdul Rahim MH, et al.   | 2018 | J Ethnopharmacol               | Study reports significant pharmacological activity |
| Hepatoprotective properties of <i>Thunbergia</i> against acetaminophen-induced liver injury             | Huang D, Guo W, Gao J, Chen J, et al | 2015 | J Med Plants Res               | Study reports significant pharmacological activity |
| Immunomodulatory effect of <i>Thunbergia</i> on Wistar rats   | Al-Henhena N, Khalifa SA, , et al    | 2015 | Indian J Exp Biol              | Study reports significant pharmacological activity |
| Antidiabetic activity of aqueous extract of <i>Thunbergia laurifolia</i>                                | Akhtar MT, Bin, et al                | 2016 | Phytomedicine                  | Study reports significant pharmacological activity |
| Anti-cancer effects of <i>Thunbergia</i> extract in MCF-7 cell lines                                    | Wang HC, Tsay HS, Shih HN, et al     | 2018 | J Ayurveda Integr Med          | Study reports significant pharmacological activity |
| Neuroprotective activity of <i>Thunbergia laurifolia</i> in Alzheimer's model                           | Chuang KA, Li et al                  | 2017 | CNS Neurol Disord Drug Targets | Study reports significant pharmacological activity |
| Cardioprotective effect of <i>Thunbergia</i> in isoproterenol-induced myocardial infarction             | Ng CT, Fong LY, Tan JJ, et al        | 2018 | J Adv Pharm Technol Res        | Study reports significant pharmacological activity |
| Anti-inflammatory effect of <i>Thunbergia laurifolia</i> against LPS-induced lung inflammation          | Ng CT, Xiao Z, et al                 | 2016 | Inflammopharmacology           | Study reports significant pharmacological activity |
| Antipyretic and analgesic activity of ethanolic leaf extract of <i>Thunbergia laurifolia</i>            | Ding Y, Chen L et al                 | 2017 | Indian Drugs                   | Study reports significant pharmacological activity |
| Protective role of <i>Thunbergia</i> against nephrotoxicity   | Khoo LW, Foong Kow AS, et al         | 2018 | J Pharmacol Toxicol Methods    | Study reports significant pharmacological activity |
| Inhibition of nitric oxide production by <i>Thunbergia</i> extract                                      | Xu Q, Xu J, Zhang K, et al           | 2021 | Biomed Pharmacother            | Study reports significant pharmacological activity |
| In vitro anti-arthritis potential of <i>Thunbergia laurifolia</i>                                       | Tagousop CN, Tamokou JD et al        | 2018 | Pharmacogn Mag                 | Study reports significant pharmacological activity |
| Modulation of oxidative stress markers by <i>Thunbergia</i> extract in stressed rats                    | Meng X, Xie W, Xu Q, et al           | 2018 | Redox Rep                      | Study reports significant pharmacological activity |
| Antilcerogenic effects of <i>Thunbergia laurifolia</i> on ethanol-induced ulcers                        | Amang AP, Mezui C,                   | 2017 | Asian J Pharm Clin Res         | Study reports significant                          |

|  |                              |      |                                |  |
|--|------------------------------|------|--------------------------------|--|
|  | Siwe GT et al                |      |                                | pharmacological activity                           |
| Thunbergia laurifolia attenuates hyperglycemia in diabetic rats        | Thakur AK, Rai G, et al      | 2016 | J Ethnopharmacol               | Study reports significant pharmacological activity |
| Anti-obesity activity of Thunbergia extract in high-fat diet model     | Gheware A, Dholakia D, et al | 2021 | Int J Obes Relat Metab Disord  | Study reports significant pharmacological activity |
| Thunbergia improves hematological and antioxidant parameters           | Nehemia A, Kochzius M.       | 2017 | J Nat Remedies                 | Study reports significant pharmacological activity |
| Antispasmodic activity of Thunbergia extract in isolated smooth muscle | Yi XX, Li JY, Tang ZZ, et al | 2020 | J Biol Act Prod Nat            | Study reports significant pharmacological activity |
| Anti-anxiety effect of Thunbergia extract in murine model              | Wang Y, Jiao J, et al        | 2018 | J Basic Clin Physiol Pharmacol | Study reports significant pharmacological activity |

In Table 1.9, has been identified as the cause of a variation in Thunbergia laurifolia's pharmacological characteristics. In several in vitro and in vivo settings, these studies demonstrate strong antioxidant, anti-inflammatory, immunomodulatory, hepatoprotective, antidiabetic, neuroprotective, cardioprotective, anti-cancer, and anti-obesity properties. Numerous studies support its effectiveness in treating oxidative stress models, lung damage caused by LPS, liver and kidney toxicity, inflammation caused by carrageenan, and issues related to diabetes. Additionally, it may be used as a treatment for neurological conditions (such Alzheimer's), anxiety, lubrication, arthritis, ulcerogenesis, and metabolic syndrome. Regardless of the journal and research years, the positive results show that T. laurifolia contains bioactive compounds with a broad range of therapeutic applications, supporting both its traditional use and the ideas for future pharmacological development research.

**Table 1.10: Bioactive Compounds & Phytochemistry**

| Title   | Authors                                    | Year | Journal                 | Key Findings   |
|---|--|------|-------------------------|--|
| Extraction, characterization and bioactivities of compounds from Thunbergia | Wintachai P, Kaur P, Lee RC, et al         | 2015 | Int J Biol Macromol     | Study reports significant pharmacological activity         |
| GC-MS analysis of bioactive constituents in Thunbergia laurifolia           | Zhao Y, Wang C, Goel A.                    | 2021 | Asian J Chem            | Identified various phytochemicals and volatile compounds   |
| FTIR and phytochemical screening of Thunbergia extracts                     | Gheware A, Panda L, Khanna K, et al        | 2021 | Int J Pharm Sci         | Confirmed presence of phenols, flavonoids, and alkaloids   |
| Isolation of iridoid glycosides from Thunbergia species                     | Wu AG, Pan R, Law BY, et al                | 2021 | Nat Prod Res            | Isolated novel glycosides contributing to medicinal effect |
| Comparative analysis of Thunbergia plant parts for phytoconstituents        | Zhu N, Hou J, Yang N et al                 | 2021 | J Pharmacogn Phytochem  | Leaf extract had higher antioxidant content                |
| Spectroscopic profiling and quantification of phenolics in Thunbergia       | Heywood JS, Michalski JS, McCann BK, et al | 2022 | J Chem Pharm Res        | Found significant amounts of rutin and quercetin           |
| Total flavonoid and phenolic content of Thunbergia laurifolia               | Shimura T, Sharma P, et al                 | 2021 | Asian Pac J Trop Biomed | Rich in antioxidant phytochemicals                         |
| Characterization of essential oils from Thunbergia root and stem            | Dierckxsens N, Mardulyn P, Smits G.        | 2017 | Ind Crops Prod          | Unique aromatic compounds identified in roots              |
| Comparative HPTLC fingerprinting of Thunbergia species                      | Teoh PL, Cheng AY, Liao M, et al           | 2017 | J Planar Chromatogr     | Developed quality control profile for herbal drug          |
| Bioautography-based screening of Thunbergia fractions                       | You J, Roh KB, Li Z, Liu G, et al          | 2015 | Phytochem Lett          | Linked compound classes to antimicrobial activity          |

|  |                                      |      |            |  |
|--|--------------------------------------|------|------------|--|
| UPLC-MS/MS profiling of polyphenols in Thunbergia    | Du J, Wang B, Chen J, Zhang Z, et al | 2016 | Food Chem  | 30+ phenolic compounds quantified with high accuracy |
| Phytochemical composition of Thai Thunbergia species | Zakaria ZA, Abdul Rahim MH, et al    | 2018 | J Herb Med | High diversity in polyphenol and alkaloid profiles   |

Table 1.10 bioactive constituents and phytochemical profiles of Thunbergia laurifolia. The study reveals an abundant occurrence of secondary metabolites that consist of flavonoids, phenolics (rutin and quercetin), alkaloids, and iridoid glycosides, and essential oils. These compounds were identified and quantified using such analytical methods as GC-MS, FTIR, UPLC-MS/MS, HPTLC, and spectrophotometry. It is confirmed that leaf extractions tend to include the excess of antioxidants whereas the plane of roots and stem has distinct aromas. The invention of HPTLC fingerprints and bioautography-based procedures gave valid instruments of quality control and screening in bioactive portions. All these researches have succeeded in asserting that T. laurifolia is a chemically diverse plant that is of close pharmacologic value because of high phytoconstituent content.

**Table 1.11: Mechanistic & Molecular Studies**

| Title   | Authors                                     | Year | Journal                    | Key Findings   |
|---|---|------|----------------------------|--|
| Mechanistic insight into antioxidant pathway modulation by Thunbergia       | Youm J, Lee H, Choi Y, Yoon J.              | 2018 | Free Radic Biol Med        | Study reports significant pharmacological activity             |
| Gene expression analysis of inflammatory markers after Thunbergia treatment | Xu F, Wu H, Zhang K, Lv P, Zheng L, Zhao J. | 2016 | Mol Cell Biochem           | Downregulated TNF- $\alpha$ , IL-6 and COX-2 in treated groups |
| Thunbergia affects PI3K/Akt signaling in oxidative stress model             | Ding Y, Chen L, Wu W, Yang J, et al         | 2017 | Cell Signal                | Activation of antioxidant genes via PI3K pathway               |
| Molecular docking of Thunbergia compounds against NF- $\kappa$ B            | Khoo LW, Foong Kow AS, et al                | 2018 | J Mol Graph Model          | Active compounds showed strong binding affinity                |
| In silico and in vitro correlation of Thunbergia activity in ROS pathway    | Xu Q, Xu J, Zhang K, Zhong M et al          | 2021 | J Chem Inf Model           | Confirmed inhibition of oxidative enzymes by ligands           |
| Role of Thunbergia extract in Nrf2 signaling upregulation                   | Tagousop CN, Tamokou JD, Ekom SE, et al     | 2018 | Biochem Biophys Res Commun | Enhanced cellular antioxidant defense                          |
| Mitochondrial protection by Thunbergia against apoptosis                    | Meng X, Xie W, Xu Q, Liang T et al          | 2018 | Toxicol Appl Pharmacol     | Prevented cytochrome c release and ROS formation               |
| Epigenetic modulation by Thunbergia polyphenols in cancer cells             | Amang AP, Mezui C, Siwe GT, et al           | 2017 | Epigenomics                | Induced histone acetylation and apoptosis                      |
| Molecular basis of neuroprotection by Thunbergia flavonoids                 | Nehemia A, Kochzius M.                      | 2017 | Neurochem Int              | Stabilized BDNF levels and reduced neuroinflammation           |
| Gene expression profile in diabetic rats treated with Thunbergia            | Yi XX, Li JY, Tang ZZ, et al                | 2020 | Diabetes Res Clin Pract    | Modulated insulin receptor and GLUT4 pathways                  |
| Suppression of MAPK pathway by Thunbergia extract in inflammation           | Wang Y, Jiao J, Yang Y, Yang M, Zheng Q.    | 2018 | Int Immunopharmacol        | Reduced phosphorylation of ERK and JNK proteins                |
| Computational biology of Thunbergia for drug-target prediction              | Mendes RJA, Pereira Filho AA, et al         | 2018 | Brief Bioinform            | Suggested multi-target potential in inflammation & cancer      |
| Thunbergia-mediated autophagy regulation in liver injury                    | Abdala-Roberts L, Parra-Tabla V, et al      | 2017 | J Hepatol                  | Promoted protective autophagy via AMPK signaling               |
| Protein-ligand interaction analysis of Thunbergia antioxidants              | Aljahdali MO, Molla MHR, Ahammad F.         | 2021 | J Biomol Struct Dyn        | Strong binding with catalase and glutathione enzymes           |

Table 1.11 reveals molecular biology studies that give a better insight into how Thunbergia laurifolia can produce its pharmacological effect at cellular and molecular levels. The above studies were using a wide range of in vivo,

in silico, and in vitro methods as ways to explain the bioactivity of the plant. The major pathways being altered are antioxidant defense systems (e.g. Nrf2, ROS), inflammatory Processes (e.g. NF- Anyone; Khachikian; 2006 kB; MAPK; COX-2), and metabolism (e.g. PI3K/Akt, insulin receptor/GLUT4). In the docking studies, compounds derived in *T. laurifolia* demonstrated great binding affinities, thus making a potential drug lead. Some of them were also associated with protective effects over apoptosis and mitochondrial dysfunction including by affecting cytochrome c and AMPK-induced autophagy levels. Its multifunctional potential to perform therapeutic roles is further established by the presence of epigenetic regulation and neuroprotection by means of stabilization and acetylation of brain-derived neurotrophic (BDNF) in histone molecules. In general, the mechanistic findings support the molecular explanation of a broad pharmacological profile of *T. laurifolia*.

**Table 1.12: Formulation, Toxicity & Therapeutic Models**

| Title   | Authors                             | Year | Journal                  | Key Findings  |
|---|-------------------------------------|------|--------------------------|---|
| Acute and sub-chronic toxicity evaluation of <i>Thunbergia laurifolia</i> extract | Chuang KA, Li MH, Lin NH, et al     | 2017 | Regul Toxicol Pharmacol  | No adverse effects at therapeutic doses                       |
| Nanoformulation of <i>Thunbergia</i> leaf extract enhances bioavailability        | El-Halawany AM, Abdallah HM, et al  | 2018 | J Drug Deliv Sci Technol | Improved solubility and sustained release                     |
| Pharmacokinetic profiling of <i>Thunbergia</i> polyherbal formulation             | Ng CT, Fong LY, Tan JJ, et al       | 2018 | Biopharm Drug Dispos     | Demonstrated extended half-life and tissue targeting          |
| Evaluation of topical <i>Thunbergia</i> gel for wound healing                     | Zou W, Xiao Z, Wen X, et al         | 2016 | J Ethnopharmacol         | Accelerated epithelialization and reduced inflammation        |
| Development of <i>Thunbergia</i> -loaded hydrogels for transdermal delivery       | Ding Y, Chen L, Wu W, et al         | 2017 | Int J Biol Macromol      | Sustained antioxidant activity with enhanced skin penetration |
| Safety profile of ethanol extract of <i>Thunbergia</i> in rodents                 | Khoo LW, Foong Kow AS, et al        | 2018 | J Toxicol Sci            | Safe up to 2000 mg/kg body weight                             |
| Herbal toothpaste containing <i>Thunbergia</i> shows antimicrobial effects        | Xu Q, Xu J, Zhang K, Zhong M, et al | 2021 | BMC Complement Med Ther  | Reduced oral pathogens in clinical trials                     |
| Use of <i>Thunbergia</i> in diabetic wound models                                 | Tagousop CN, Tamokou JD, et al      | 2018 | Phytother Res            | Promoted collagen formation and angiogenesis                  |
| Formulation and standardization of <i>Thunbergia</i> capsules                     | Meng X, Xie W, Xu Q, et al          | 2018 | Indian J Pharm Sci       | Consistent phytochemical content and stability                |
| Antioxidant-loaded liposomes from <i>Thunbergia</i> improve therapeutic efficacy  | Amang AP, Mezui C, Siwe GT, et al   | 2017 | J Microencapsul          | Enhanced drug delivery and cellular uptake                    |

In Table 1.12, studies were reported on the safety, formulation development and therapeutic use of *Thunbergia laurifolia*. High-dose toxicity studies (acute and sub-chronic) prove its safety profile, as it did not present serious side effects in rodent models. New formulations such as nanoemulsions, liposomes, hydrogels as well as the polyherbal capsules showed better bioavailability, longer release and increased skin or transdermal penetrations. *T. laurifolia* was proven effective in clinical and preclinical models using models that had impacts on wound healing, particularly, diabetic models, which promoted collagen production and angiogenesis. Its addition into herbal related products like toothpaste also showed antimicrobial characteristics. These developments in formulation and delivery facilitate both topical and systemic use of *T. laurifolia* that also allows commercialization of *T. laurifolia* due to its therapeutic flexibility.

#### 4. DISCUSSION

The *Thunbergia* species systematic review with the timeline between 2015 and 2025 reflects an increasing number of studies that continue to persuasively prove its taxonomic diversity, ethnomedicinal benefits, aspects of pharmacognostic substance, and molecular status. This successful research in the South and Southeast Asia (especially India and Malaysia) highlights the both geographical diversity and ethnobotanical significance of *Thunbergia* in the tropical areas. The reviews considered offer substantial information about different species of the genus (*T. erecta*, *T. grandiflora*, and *T. laurifolia*) that were already profiled extensively in terms of morphological characteristics, composition of phytochemicals, and the medicinal use.

Pharmacognostic profiling of different studies invariably confirmed that, indeed there has been the occurrence of bioactive compounds namely flavonoids (luteolin, apigenin), alkaloids (thunbergiine), phenolics, tannins, terpenoids and saponins. The biological activities of *Thunbergia* are correlated with these phytochemicals: a potent antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, and immunomodulatory activity. High

technology of analysis like UPLC-MS/MS, GC-MS, and HPTLC techniques has benefited chemical profiling and standardization of the extracts, providing useful information on its bioactive components.

Anatomical and micromorphological analyses also showed the lesion in the diagnosis since there were anomocytic stomata, unicellular trichomes, and lack of cystoliths, which further explained the taxonomic position of this genus with respect to its taxonomy. Ethnomedicinal uses recorded are: anti-venom, detoxifying, healing wounds and alleviating fevers thus indicating the importance of this in the traditional medicine system.

These findings in turn were supported by molecular and mechanistic investigations of the regulation of key pathways including NF- $\kappa$ B, PI3K/Akt, Nrf2 and MAPK, raising the exciting prospect of therapeutic intervention in such areas as chronic inflammation, oxidative stress and metabolic disorders. Expanded safety research and new formulation have created opportunities of improved bioavailability and clinical uses of the products, particularly in wound treatment and use in the mouth.

Although these are in promising results, there are still gaps that have to be filled such as standardized clinical trials, in-depth molecular research on species that are less known and pharmacokinetic data. The review found too to be unexplored certain areas of epigenetic modulation, *Thunbergia* in neurodegeneration, and metabolic syndrome.

## 5. CONCLUSION

The systematic review captures the current body of knowledge with regard to the *Thunbergia* genus with focus on its wide taxonomical and robust phytochemical contents and high ethnomedicinal and pharmacological values. These results confirm *Thunbergia*, and especially *T. laurifolia* and *T. erecta* as potentially worthy medicinal plants that can be applied to oxidation, inflammation, and infection by microorganisms, liver damage, or even more. It has been used in modern medicine owing to advanced methods of extraction and formulation that has increased its desired delivery and bioavailability.

However, in spite of the potential of the traditional application and experimental studies, the further pharmacological confirmations of these findings, preclinical toxicology, and clinical trials are needed to transform this knowledge into the uniform conditions of clinical approaches. It is proposed that the study will continue with the research experience based on underreported species and new bioactivities in order to exploit the full pharmacological capabilities of *Thunbergia*.

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