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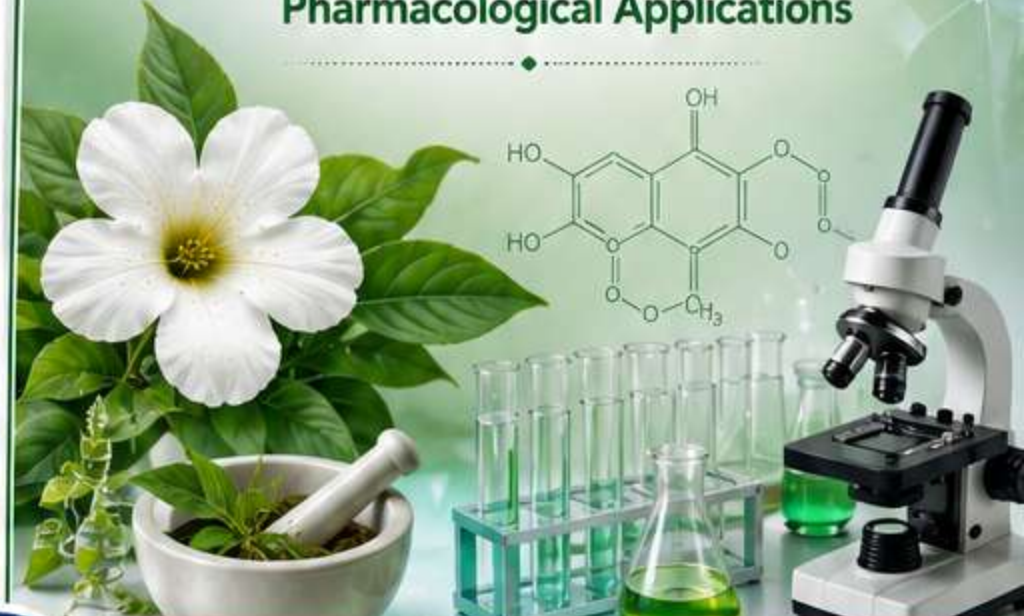
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# Geopolitics Over Science: How Politics is Reshaping Global Agri-Food Systems?

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## The Geopolitics of Agri-Food Systems

Geopolitics has become a major force transforming agri-food systems worldwide, as international tensions have risen [1]. Agri-food systems refer to the dynamic production, processing, distribution, consumption, and waste management of food, and involve the interdependence of economic, environmental, and political factors [2]. Geopolitics is a concept that describes the interplay of power among states over resources, territories, and influence, and is evident in these systems through conflicts, trade issues, and rivalry over strategic resources [3]. This relationship can be understood through several key mechanisms:

(a) trade policies and restrictions such as tariffs and export bans which affect food availability and prices; (b) control over critical agricultural inputs and natural resources including land, water, and fertilizers; (c) geopolitical conflicts and sanctions that disrupt production and supply chains; and (d) infrastructure damage and supply-chain fragmentation caused by political instability. These geopolitical shifts are not merely theoretical; they produce real disruptions in food supply chains (See Table. 1). For example, due to geopolitical rivalry, competition over agricultural resources can contribute to international trade, which is crucial to food security, and expose them to politically instigated disruptions from abroad [4].

**Table 1 Geopolitical Shocks and Global Food System Responses (2020-2025)**

| Year      | Geopolitical / System Shock                          | Global Agri-Food System Response                                             |
|-----------|------------------------------------------------------|------------------------------------------------------------------------------|
| 2020      | COVID-19 pandemic and initial trade restrictions     | Disruption of global food supply chains; increased shipping costs and delays |
| 2021      | Pre-war geopolitical tensions and recovery asymmetry | Rising food prices and uneven recovery in import-dependent regions           |
| Feb-22    | Russia-Ukraine war begins                            | Black Sea blockades; >90% drop in Ukraine grain exports initially            |
| 2022      | Export bans by >20 countries                         | Sharp global price spikes; destabilisation of import-dependent countries     |
| Mar-22    | Commodity market shock                               | Wheat futures rise 25% to €396.5/tonne; vegetable oil prices +80% (2020-22)  |
| 2022      | Fertiliser supply shock (Russia-Belarus)             | Fertiliser prices rise >50%; reduced fertiliser use and yield loss           |
| 2022      | FAO Food Price Index peak                            | FAO Food Price Index increases by 14.3%, highest since 1990                  |
| 2023      | Failure of Black Sea Grain Initiative                | Led to global supply disruptions and price volatility                        |
| 2023-2024 | El Niño-linked climate extremes                      | Crop failures, pest outbreaks, and compounding price volatility              |



|                       |                                             |                                                                        |
|-----------------------|---------------------------------------------|------------------------------------------------------------------------|
| 2024                  | Global food crisis intensifies              | 295.3 million people face acute food insecurity globally               |
| 2024                  | Conflict-linked famine                      | Famine declared in Sudan; risks linked to Gaza conflict                |
| 2025 (projected)      | Rising geopolitical tensions & funding cuts | Food sector funding projected to drop 45%; 14 million children at risk |
| 2025-2026 (projected) | Prolonged geopolitics-climate nexus         | Escalation of food insecurity and trade fragmentation                  |
| 2030 (projected)      | Long-term consequence                       | 582 million people projected to face chronic undernutrition            |

### How Rising Geopolitical Tensions Are Threatening Global Food Security in 2025-2026?

Increased risks due to the modern geopolitical landscape, with 59 active conflicts in 2023, weaponization of food trade, and vulnerabilities in import-dependent regions [5]. The editorial is a critical assessment of how geopolitics is redefining agri-food systems, using verifiable facts based on recent events, including the Russia-Ukraine war and the U.S.-China trade tensions. It claims that although these forces create instability and inequality, they also reflect the demands for resilience and diversification. Nevertheless, lacking coherent policy measures, the intersection of geopolitics and climate change may undo decades of progress toward Sustainable Development Goal 2 (Zero Hunger) and leave 582 million people, 6.8% of the global population, in chronic undernutrition by 2030 [6, 7].

### Weaponization of Food Exports: Export Bans, Price Spikes, and Impacts on Low-Income Countries

Over the course of history, agri-food systems have been intertwined with geopolitics, whether through colonial resource extraction, soft power via food aid during the Cold War, or similar tactics [8,9]. This entanglement is now exacerbated by globalisation, which exposes highly interconnected supply chains to shocks. Geopolitical risks hamper supply chains by increasing shipping costs, redistributing freight, and extending lead times, which usually result in empty shelves and higher prices [10]. To

illustrate, geopolitical events that result in harvest failures can cause a policy reaction, e.g., export bans, which cause price spikes and political instability. This can be traced in the weaponisation of food exports, where states use agricultural power as a lever to gain influence, as occurred during Russia's strategic grain deliveries to Africa during the Ukraine conflict. Importantly, those measures have a disproportionate effect on low-income countries, where dependence on food imports subjects' populations to exogenous shocks that continuously amplify the cycle of poverty and instability [11,12].

### Geopolitical Risks Reshaping Agri-Food Supply Chains

Geopolitics is redefining agri-food systems by altering trade flows, resource access, and production incentives. States are concerned with self-sufficiency in a fragmented world, with the environment as a casualty, and MNCs having to navigate trade tariffs and sanctions. This is guided by increasing geopolitical risks, which are at the top of the executive surveys in the food and agriculture industry. The war in Ukraine, Red Sea disruptions, and cybersecurity threats are examples that affect US trade policy, which in turn affects consumer confidence and investment.

Examples of this reframing include trade wars and tariffs. Protectionist measures, including U.S.-China tariffs, cause supply chain disruption, and China is less dependent on US products since it has to strengthen food security [12,13]. A possible retaliation in the form of a 60



percent tariff on Chinese imports might escalate the retaliation against US agricultural products and push the world toward self-sufficiency and diversified sourcing [14]. This opens prospects to emerging markets but undermines US competitiveness. In the same way, agricultural infrastructure is literally attacked by armed conflict, as in Ukraine [15], where the total loss amounted to USD 40.2 billion by March 2023, with a further USD 380.5 billion in losses to irrigation infrastructure. This destruction not only suppresses local production but also spills over into the rest of the world, as fertilizer shortages continue into 2024.

More importantly, these upheavals showcase institutional inequities. It disproportionately affects low- and middle-income countries that depend on imports from their breadbasket regions, such as Russia and Ukraine (25% of global wheat and barley exports), when those countries are impacted [16]. Geopolitical tensions increase costs and lead times, leading to food insecurity. For example, export restrictions after the 2022 war disrupted trade networks, and modularity rose and connectance fell, especially for wheat to Africa and Asia [17,18]. The countries with upper-middle income lost more than 46.58 million tonnes of wheat imports, and low-income groups lost 25.59 million tonnes [16]. This example of geographic vulnerability highlights how geopolitics strains the vulnerabilities of remote countries that rely on imports.

In addition, geopolitics overlaps with other crises, including pandemics and economic volatility, which exacerbate their effects. For the sixth consecutive year, the 2024 Global Report on Food Crises has reported 295.3 million persons experiencing acute food insecurity, with conflict (principal in worst crises), climate extremes (e.g., 2023/24 El Niño droughts), and economic shocks (e.g., inflation) the leading causes of acute food insecurity. There was a displacement of 95.8 million, including 95 percent of internally displaced persons in countries with food crises. The number of children exposed to a nutrition crisis in 21

countries was 37.7 million, and pregnant/breastfeeding women were 10.9 million [33]. In 2025, it is projected to be worse due to geopolitical tensions and funding changes that may see food sector allocations drop by 45 per cent, putting 14 million children at risk [19].

### **Case Study: Russia-Ukraine War - Impacts on Global Wheat, Grain Supplies, and Fertilizer Markets**

The Russia-Ukraine war, which has persisted since February 2022, is an example of the disruptive effects of geopolitics on agri-food systems [20]. Ukraine, a key exporter of grains, has seen a 29 per cent drop in its output, to 61.8 million tonnes in the 2022/2023 crop, compared to 86.7 million tonnes in 2021/2022; the 2023/2024 crop is expected to drop to 58.8 million tonnes, which is lower than the 5-year average of 67.68 million tonnes [32]. In early 2022, exports fell by over 90 per cent due to Black Sea blockades, and by mid-2023, solidarity lanes had moved 90 per cent of pre-war sea exports on land (to 60 per cent). The Black Sea Grain Initiative helped to export about 27-33 million tonnes of grain, including 8-10 million tonnes of wheat (around 4-5% of global wheat exports). The initiative collapse in 2023 led to significant supply disruptions, price volatility, and export shortfalls amounting to millions of tonnes globally [15,33].

The yield loss was sharp: without war losses, the yield of winter cereals fell by 5.42 million tonnes; with a 30% input loss, the yield fell by 15.04 million tonnes [28]. This was equivalent to 12.89 million tonnes of wheat, 2.09 million tonnes of barley, and 0.07 million tonnes of oats. The total winter cereals lost in regions affected by the war, such as Kharkiv and Donetsk, exceeded 7.68 million tonnes [16]. Decreases in production were 26 per cent for wheat, 21 per cent for maize, and 32 per cent for soybeans [18]. Projected exports of Ukraine in 2023/24 are estimated to fall by 10 to 15 million tonnes of wheat and corn, respectively, compared to the 2020/21 level [12].



High price increases characterized the international consequences. In March 2022, wheat futures rose by 25 percent to €396.5 per tonne; cereals rose by 33 percent, and vegetable oil prices rose by 80 percent between January 2020 and 2022 [21]. In 2022, the FAO Food Price Index rose by 14.3%, the highest level since 1990 [15]. Prices of fertilisers soared by more than 50 percent, with mono-ammonium phosphate (MAP) increasing by 53 percent and diammonium phosphate (DAP) by 36 percent between February and April 2022, due to 20 percent of global trade being supplied by Russia/Belarus. This increase led to a decline in fertiliser use and yield, and to a shift toward crops with lower fertiliser intensity [22].

The situation around food security has become more threatening in the Middle East and North Africa (MENA) and in sub-Saharan Africa, where Russia and Ukraine provide accounts for about 25-30% of global wheat exports but supply over 40-50% of imports in several vulnerable regions [21,35]. Undernutrition may increase to one million in MENA and three million in sub-Saharan Africa. By 2030, the war would have added 119 million people to projections of chronic undernourishment; acute insecurity would have risen by 7.3 million in the Asia-Pacific and 10.5 million in Eastern Africa by June 2022 [15]. In 2024, famine broke out in Sudan, and the risk was linked to Gaza. More importantly, Russia uses the war to increase its wheat exports, which are projected to rise by 30 to 51 million tonnes in 2023/24 and shift supplies to Africa to influence them [12]. Export prohibitions imposed by more than 20 countries destabilized distribution channels and led to 75-100 percent cuts in imports in countries like Somalia. This war has caused the one of the most significant food insecurity in history in relation to the military [16]. Further, the disruption of Ukraine's agricultural exports speeded global trade diversification, mainly in oilseed markets. Countries like Brazil and Argentina expanded their soybean exports, reducing supply gaps created by the decline in

Black Sea shipments. China, the world's largest soybean importer, increased its reliance on South American suppliers, thereby reducing dependence on traditional sources [34]. There is need for policy implications focused on trade stability, diversification, and resilience-building in global agri-food systems.

### **Case Study: US-China Trade Tensions - Effects on Soybean Exports, Diversification, and US Farmer Losses**

The case of U.S.-China trade tension can be used to explain how geopolitics can redefine the agri-food trade relations. Since 2018, the imposition of tariffs has diverted trade, resulting in a loss of 27.2 billion dollars (13.2 billion/year), with China being the biggest loser (25.7 billion) [23]. Soybeans (71 percent) were the biggest losers; soybean exports dropped by 77 percent, with wheat (61 percent) and corn (88 percent) following [23]. Export to China fell in January by 6.8 billion dollars (73 percent); soybean exports plummeted from 985 million bushels (January-May) to 218 million in 2025, with no exports in June or August, and no new crop purchases. The tariffs will reach 34% in April 2025, making US products uncompetitive, and farmers will lose 5.7 billion dollars in soybean exports until October 2025[31]. Exports of beef dropped more than 90 per cent since March 2025 because of lapsed licences. Almond tariffs were 45 per cent, which affected 80 per cent of the worldwide almond supply in California. The exports of corn, wheat, or sorghum declined in 2025, and overall exports were projected to fall to 17 billion US dollars, a 30 per cent decrease from 2024, and further to 9 billion US dollars by 2026 [24,25].

Any 60% tariff would kill all US oilseed exports to China, with an overall loss of 39 and a 4.2% loss in world oilseed trade. Brazil, in turn, will be able to address those shortages, as it will be able to export 2.5 billion bushels of soybeans to China in 2025. Such restructuring is a win for competitors but a heavy burden on US farmers, and rural economies feel the ripple effect [14]. More importantly, such tensions highlight the



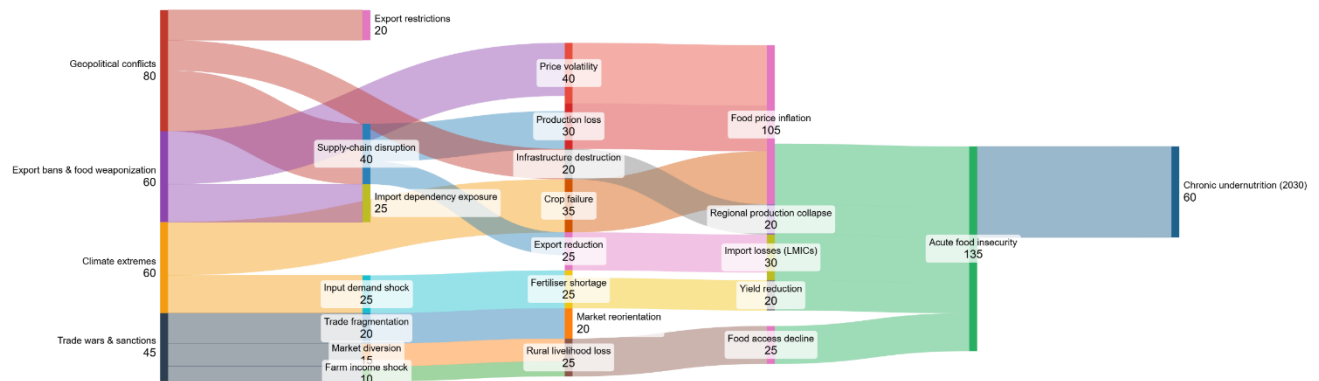
risks of dependency. The strategy of diversification in China reduces the United States' market share, and the strategy of retaliation has been applied to the agricultural market, as it is used as leverage, given surpluses in the United States. Nebraska, which exports 4.6 percent and loses 5.6 percent in the United States, indicates regional inequalities. Wider consequences include higher food prices and supply chain exposures, highlighting the role of geopolitics in unequal access to food worldwide [23]. As China reduced imports from the United States due to tariffs, it expanded its export shares to Brazil and Argentina. This reduced US market share and increased the risks of reliance on single markets. Hence, the policy implications must be focused on diversification, reducing dependence on single trading partners, and strengthening resilience in global agri-food systems.

#### **India -US Trade Tensions- Emerging Dynamics in Agricultural Trade Diversification**

Recent trade tensions between India and the United States on agricultural products have shown that geopolitics directly affects agri-food systems. The disputes on tariffs, market access, and subsidies have forced both countries to consider their dependence on each other. India started to align with new trade partners and strengthen domestic capacity, while the United States also finds alternative markets for its farm exports. These shifts reflect a trend where even long-standing partners adjust policies in response to political and economic pressures. Finally, such changes indicate that the global politics have major effects on the food production, its trade, and the benefits from these evolving relationships.

#### **The Geopolitics-Climate Nexus: Compounding Threats to Agri-Food Systems and Pathways to Resilience**

The extremities of geopolitics and climate change threaten food systems worldwide. Effects of climate, such as floods and droughts, spread through trade and result in price shocks and instability. By 2022, an extra 100 million people were hungry compared to 2019, and it is estimated that 582 million people will be undernourished by 2030. This is exacerbated by geopolitical tensions, as seen in Ukraine, where climate hazards interact with war [11]. Climate change is transforming production, and agri-food systems are the primary sources of greenhouse gases. Extreme weather disrupts harvests, and geopolitics plays on shortages; e.g., the floods in Pakistan will trigger a rice shortage in Europe [30]. Droughts and floods associated with El Niño occurred in 2024, causing crop failures and pest outbreaks. Investment choices are subject to geopolitics, and food insecurity has been turned into a political commodity, as was the case with Russia's behavior [26]. This nexus expands Sustainable development goals (SDG) achievement amid uncontrolled upheaval in export centers, more likely under 1.5°C warming. Poor countries are at increased risk due to the urbanisation and population growth exacerbating climate change. Among the possible mitigation measures are climate-resilient farming, promoting plant-based eating, and minimizing waste [27]. Figure 1 illustrates the transmission of geopolitical conflicts, trade tensions, export bans, and climate extremes through agri-food systems, resulting in supply-chain disruptions, production losses, and price volatility, ultimately culminating in severe food insecurity. Climate shocks and trade fragmentation make these pathways stronger by causing crop failures, fertilizer shortages, and less access to food, especially in areas that rely on imports. The final flow into chronic undernutrition (2030) shows how long-term geopolitical and climate pressures on global food systems can affect people's health.



**Figure 1 Geopolitics-Climate Nexus Reshaping Global Agri-Food Systems and Food Security**

### Recommendations and Future Implications

Geopolitics also reinstates agri-food systems on a path of fragmentation, where powers like Russia will be advantaged at the expense of the Global South. Such a relationship promotes inequality, and low-income countries lose 25.59 million tonnes of wheat imports due to post-ban restrictions [29]. The positive aspects are innovation through diversified sourcing and resilient practices, but this is not counterbalanced by equitable policy interventions that result in increased risks. The escalating tensions can further exacerbate

undernourishment among millions of people, which, combined with climatic factors, results in a polycrisis. The prescriptions in the policies should incorporate resilience, with open trade enhanced to reduce the impact of shocks. Geopolitics is permanently transforming agri-food systems and requires immediate, evidence-based action. Through building resilience and cooperation, the stakeholders can overcome these challenges to achieve equitable food security.



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During the preparation of this work, the author(s) used Grammarly and Quillbot to correct grammatical errors and improve readability, content flow, and language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.



# Thunbergia fragrans: An Overview of Phytoconstituents and Pharmacological Applications

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## Summary

*Thunbergia fragrans* Roxb. (Acanthaceae) is used in Siddha medicine, for the management of various ailments. The present review aims to compile and critically analyse the available information on the phytochemical composition, traditional uses, and pharmacological activities of *T. fragrans*. Traditionally, the plant has been used to treat stomach disorders, wounds, headache, fever, giddiness, and eye diseases. Phytochemical investigations have reported the presence of phenols, flavonoids, tannins, steroids, alkaloids, and fatty acids. Specific compounds such as hexadecanoic acid, neophytadiene, and linoleic acid derivatives have been identified and are considered to contribute to its biological activities. Pharmacological studies have demonstrated that *T. fragrans* exhibits diverse therapeutic properties including antioxidant, antimicrobial, antidiabetic, antidiarrhoeal, anti-inflammatory, and anticancer activities. Toxicological studies suggest that the plant is safe at high doses in animal models; however, long-term toxicity and clinical studies are required to confirm its safety and efficacy in humans. This review consolidates the existing knowledge on *T. fragrans*, highlights current research gaps, and provides a scientific basis for future pharmacological and clinical investigations of this medicinal plant.

## Keywords

Antioxidant, Pharmacological activities, Phytochemistry, Thunbergia fragrans, Traditional medicine.

## Introduction

India is one of the world's megadiverse countries and possesses a rich repository of plant biodiversity. It is estimated to have approximately 45,000 plant species, of which nearly 7,500 are used for medicinal or aromatic purposes. Among these, around 15,000 species are flowering plants, representing nearly 6% of the global angiosperm diversity. Plant-derived materials have been used for centuries in traditional healthcare systems and continue to serve as valuable resources for the modern pharmaceutical industry. Numerous therapeutic agents used in contemporary medicine are derived directly or indirectly from plants, emphasizing their significance as sources of bioactive compounds and their continuing relevance in global healthcare. Therefore, systematic scientific investigation of medicinal plants is essential to explore their pharmacological potential and identify novel bioactive molecules [1].

One such underexplored plant is *Thunbergia fragrans* (*T. fragrans*), a large woody climber belonging to the Acanthaceae family, found in India, Burma, Vietnam, and China, as well as on several islands in the Indian and Pacific Oceans [2,3]. It commonly grows in moist and disturbed habitats, particularly along roadsides, where it is often regarded as a weed [4]. *T. fragrans* is



popularly known as white lady, sweet clock vine, and white thunbergia [5]. In traditional Indian Siddha medicine, the plant is used for the management of several ailments. A paste prepared from tender twigs is applied to the body to reduce fever, leaf juice is used to relieve giddiness, and root juice is used as eye drops. Leaf paste is also applied to wounds and the forehead to alleviate headaches [6].

The present review provides a comprehensive overview of the existing scientific knowledge on the botany, traditional uses, phytochemical constituents, pharmacological activities, and toxicological aspects of *T. fragrans*. Information was collected from major scientific databases including Scopus, PubMed, and Google Scholar to synthesize the available literature. This review highlights the therapeutic potential of *T. fragrans* while also identifying important research gaps, particularly the need for detailed toxicological evaluation and well-designed clinical investigations. The findings presented here aim to support future research and promote further scientific exploration of this medicinal plant.

### Botanical description and taxonomy

*T. fragrans* is a fast-growing woody climber characterized by slender, twining stems that can reach up to approximately 3 m in length. The leaves are oppositely arranged, ovate to triangular in shape, measuring about 6.5–11 cm in length and 1.8–6 cm in width, with arrow-shaped (sagittate) or occasionally truncate bases and finely toothed to nearly entire margins. The plant bears white, tubular flowers that appear singly or occasionally in small clusters. Flowering occurs throughout the year in many regions, with peak blooming typically observed from June to October, while fruiting mainly occurs between August and December. The fruit is a capsule with a characteristic beak-like tip that dehisces to release globose, pubescent seeds [5].

*T. fragrans* (Figure 1) belongs to the family Acanthaceae, a group of flowering plants

characterized by opposite leaves, zygomorphic flowers, and bilocular capsules. The genus *Thunbergia* was first described by Carl Linnaeus, and later expanded through the work of William Roxburgh, who formally described *T. fragrans* based on specimens collected from India [7].



Figure 1 *Thunbergia fragrans* plant showing characteristic white tubular flowers and opposite leaves. [Source: Author's photograph].

Morphologically, *T. fragrans* is distinguished by its solitary or paired white tubular flowers, opposite ovate leaves with sagittate bases, and beak-shaped fruit capsules that dehisce to release pubescent seeds. These morphological characteristics are typical diagnostic features used to identify species within the genus *Thunbergia* [5]. The genus includes several species such as *T. alata*, *T. annua*, *T. battiscombei*, *T. coccinea*, *T. cordata*, *T. erecta*, *T. elegans*, *T. fragrans*, *T. grandiflora*, *T. gregorii*, and *T. vogeliana*, many of which have been reported to possess diverse biological activities [8].

Over time, several taxonomic synonyms have been associated with *T. fragrans* due to historical reclassification and varying interpretations of morphological characteristics. These include *Thunbergia volubilis* Pers., *Roxburghia rostrata* Russell ex Nees, and *Meyenia longiflora* Benth [7,8].

### History and uses

In traditional Indian Siddha medicine, *T. fragrans* has been used in several simple remedies for the management of common



ailments. A paste prepared from tender twigs is traditionally applied externally to reduce fever. Leaf juice is sometimes instilled into the nose, while leaf paste is applied to relieve dizziness and headache. Fresh root juice has also been used externally as eye drops for certain eye disorders [6]. In addition, a decoction prepared from the leaves is traditionally used to treat stomach-related ailments and fungal infections [2]. The traditional uses of *T. fragrans* are summarized in Table 1.

| Sr. No. | Plant Part Used | Traditional Uses                                                                                          |
|---------|-----------------|-----------------------------------------------------------------------------------------------------------|
| 1       | Leaves          | Leaf paste applied on wounds and forehead to relieve headache; leaf juice used for giddiness (dizziness). |
| 2       | Tender twigs    | Paste of tender twigs applied externally to reduce fever.                                                 |
| 3       | Roots           | Root juice used as eye drops for eye disorders in traditional medicine.                                   |
| 4       | Whole plant     | Used traditionally for the treatment of stomach-related ailments.                                         |

Table 1 Traditional uses of *Thunbergia fragrans*

Active constituents from *T. fragrans* have traditionally been extracted using simple preparation methods such as decoction and maceration. Ethnomedicinal reports and literature surveys suggest that the plant has been used in traditional medicine for the management of various conditions, including inflammation, fever, cardiovascular disorders, neurological conditions, skin diseases, diarrhoea, diabetes, giddiness, and headache [2,9,10].

### Phytochemistry

Various parts of *T. fragrans*, including leaves, seeds, and tender twigs, contain several

phytochemical constituents that may contribute to the biological properties reported for this plant [11]. GC–MS analysis of *T. fragrans* extracts has identified several fatty acid derivatives,

terpenoids, and alcohols, including neophytadiene, hexadecanoic acid derivatives, and linoleic acid esters (Table 2 and Figure 2) [5,11]. Fatty acid methyl ester (FAME) analysis of the plant extract revealed that *T. fragrans* contains approximately 90.16% unsaturated fatty acids and 9.84% saturated fatty acids, indicating the predominance of unsaturated lipid components [5].

Further studies are required to isolate and characterize the bioactive compounds present in *T. fragrans* and to elucidate their mechanisms of action. Such investigations may provide insights into the relationship between chemical constituents and their pharmacological properties, supporting the potential development of this plant as a source of therapeutic agents [12,13].

| Sr. No. | Phytoconstituents                      |
|---------|----------------------------------------|
| 1.      | Propane, 1,1,3-triethoxy [13]          |
| 2.      | 1-Tetradecanol [13]                    |
| 3.      | Neophytadiene [13]                     |
| 4.      | Hexadecanoic acid, methyl ester [13]   |
| 5.      | n-Hexadecanoic acid [13]               |
| 6.      | 9-Octadecenoic acid, methyl ester [13] |
| 7.      | Linoleic acid ethyl ester [13]         |
| 8.      | Ethyl 9,12,15-octadecatrienoate [13]   |

Table 2 Major Chemical Constituents of *Thunbergia fragrans*

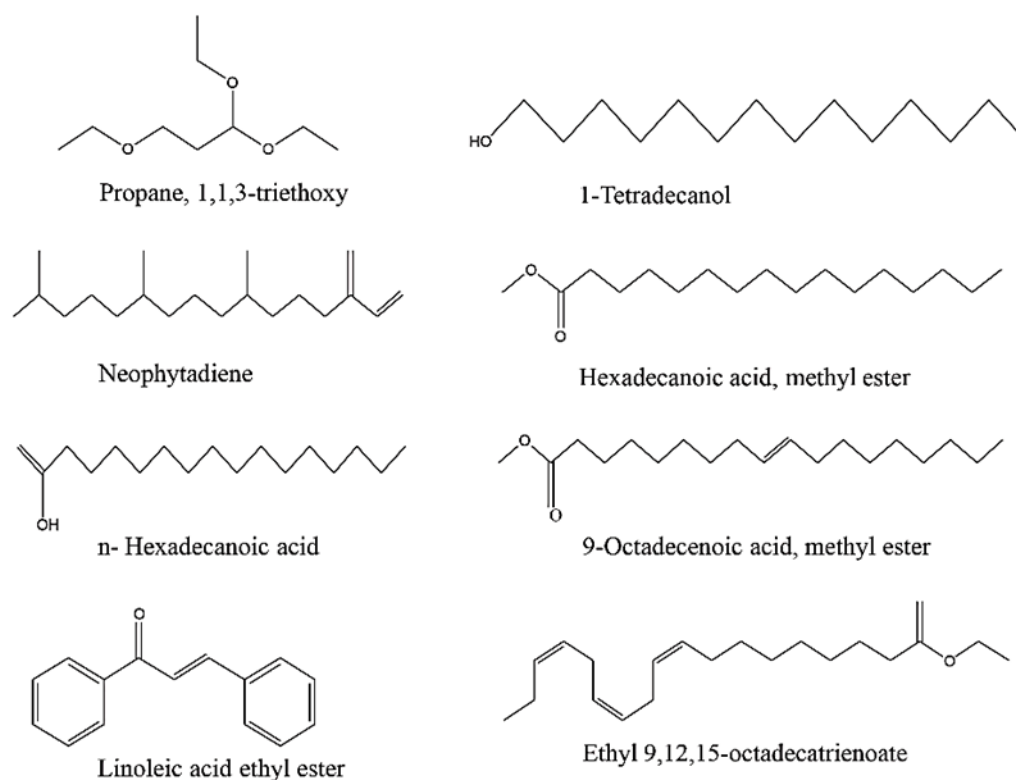


Figure 2 Major Chemical Constituents Present in the *Thunbergia fragrans*

### Pharmacological activities

The pharmacological activities of *T. fragrans* are given in Figure 3.

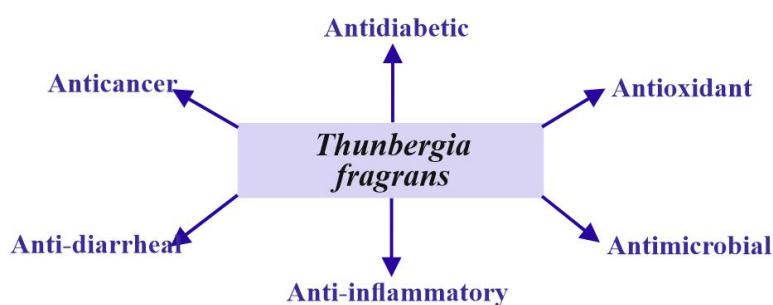


Figure 3 Pharmacological properties of *T. fragrans*

#### Antidiabetic

Ethanollic and hydroalcoholic extracts of *T. fragrans* have demonstrated significant antidiabetic activity in experimental animal models. In alloxan-induced diabetic rats, oral

administration of the extracts at doses of 150–400

mg/kg body weight resulted in a reduction in blood glucose levels ranging from 21.8% to 35% after two to four weeks of treatment. In addition,



improvements in body weight and white blood cell count were observed, suggesting an overall improvement in diabetic symptoms [14].

The extracts also improved biochemical markers associated with liver and kidney function and enhanced antioxidant enzyme activities such as superoxide dismutase (SOD), glutathione peroxidase (GPx), catalase, and reduced glutathione (GSH), indicating protection against oxidative stress. Furthermore, normalization of hepatic glycogen levels and preservation of the histological structure of the pancreatic islets of Langerhans were reported, suggesting protective effects on pancreatic  $\beta$ -cells [14].

The antidiabetic activity of *T. fragrans* is likely associated with the presence of bioactive phytochemicals such as flavonoids, chlorogenic acid, and alkaloids, which may enhance insulin secretion and improve peripheral glucose utilization. Importantly, the extracts did not produce significant toxic or adverse hematological effects in experimental animals, indicating a favorable safety profile in these studies [14].

### **Antioxidant**

Extracts of *T. fragrans* contain several bioactive phytochemicals that contribute to its antioxidant potential. In vitro studies have shown that ethanolic leaf extracts exhibit significant and dose-dependent free-radical scavenging activity against DPPH radicals. Phytochemical screening indicates the presence of flavonoids, phenolic compounds, and other antioxidant constituents that may be responsible for this activity. Fourier transform infrared (FTIR) analysis has further revealed functional groups corresponding to alkenes, alcohols, aromatic compounds, aliphatic amines, and alkanes, suggesting the presence of diverse bioactive molecules within the extract. These phytochemicals may contribute to the neutralization of reactive oxygen species and help protect biological systems from oxidative stress associated with various pathological conditions. Overall, the antioxidant activity of *T.*

*fragrans* supports its potential as a natural source of therapeutic agents [11].

### **Antimicrobial**

Leaf extracts of *Thunbergia fragrans* have demonstrated notable antimicrobial activity against several pathogenic microorganisms. Both alcoholic (ethanolic and methanolic) and aqueous extracts have shown inhibitory effects against bacterial strains such as *Staphylococcus aureus* and *Escherichia coli*. The observed antimicrobial activity is attributed to the presence of bioactive phytochemicals capable of disrupting microbial cell membranes and interfering with essential metabolic processes. In certain studies, the inhibition exhibited by the plant extracts was comparable to that of standard antimicrobial agents such as streptomycin [6]. These findings support the traditional medicinal use of *T. fragrans* and highlight its potential as a source of natural antimicrobial compounds [4].

### **Anti-inflammatory**

Phytochemical analysis of *T. fragrans* extracts collectively contributes to its significant anti-inflammatory activity. Traditional Indian Siddha medicine utilizes the *T. fragrans* for treating open wounds, and occasionally, leaf paste is applied on the forehead to reduce headaches, indicating its utility in inflammation-related conditions. Scientific studies show that these phytoconstituents can help suppress the inflammatory pathways. These effects are due to their antioxidant properties and modulation of pro-inflammatory mediators. However, despite promising preliminary evidence, further in-depth studies, including in vivo and clinical investigations, are necessary to confirm and clarify the exact anti-inflammatory mechanisms and therapeutic efficacy of *T. fragrans* extracts [12].

### **Antidiarrheal**

The acetonic and ethanolic leaf extracts of *T. fragrans* have demonstrated significant antidiarrhoeal activity in Swiss albino mice at an



oral dose of 500 mg/kg body weight. The activity was evaluated using the charcoal meal test and the castor oil-induced diarrhoea model. Both extracts significantly reduced gastrointestinal motility, as evidenced by the decreased distance travelled by the charcoal meal through the intestine. The inhibition percentages were 55.51% for the acetonic extract and 59.34% for the ethanolic extract, compared with 48.92% for the standard drug loperamide. In the castor oil-induced diarrhoea model, both extracts provided complete protection (100%) against diarrhoea, comparable to loperamide. The observed antidiarrhoeal activity may be attributed to the presence of tannins, which are known to exert an astringent effect on the intestinal mucosa and reduce intestinal motility and secretion. These findings support the traditional use of *T. fragrans* in the management of diarrhoeal disorders. However, further studies are required to isolate the active constituents and clarify their mechanisms of action [2].

### Anticancer

Studies have reported that the ethanolic extract of *T. fragrans* leaves exhibits cytotoxic activity against cancer cell lines such as A549 (lung carcinoma) and SiHa (cervical cancer). Cytotoxicity assays have demonstrated moderate antiproliferative activity with  $EC_{50}$  values of approximately 81.31  $\mu\text{g/mL}$  for A549 cells and 91.51  $\mu\text{g/mL}$  for SiHa cells. The extract contains various bioactive phytoconstituents, including phenolic compounds and flavonoids, which may contribute to the observed cytotoxic effects. These compounds are believed to interfere with cellular signaling pathways involved in cancer cell proliferation and survival, thereby inhibiting tumour growth. Additionally, treatment with the extract has been associated with morphological changes in cancer cells, suggesting potential apoptotic or growth-inhibitory effects. Although these findings indicate promising anticancer potential, further investigations, including detailed mechanistic studies and *in vivo* evaluations, are necessary

to validate the therapeutic potential of *T. fragrans* extracts in cancer treatment [15].

### Toxicity studies

Toxicological investigations on *T. fragrans* are limited but suggest relatively low acute toxicity. Acute oral toxicity studies conducted in Swiss albino mice have shown that ethanolic and acetone leaf extracts are well tolerated at doses up to 2000 mg/kg body weight, with no observed mortality or significant behavioural changes. These findings indicate that the  $LD_{50}$  value is greater than 2000 mg/kg body weight, suggesting a relatively wide safety margin for acute exposure. Although these results indicate a favourable safety profile, comprehensive toxicological data are still lacking. Further investigations, including sub-chronic and chronic toxicity, mutagenicity, genotoxicity, teratogenicity, and pharmacokinetic studies, should be conducted according to standardized OECD guidelines to establish the long-term safety of the plant. Traditional use of *T. fragrans* for the treatment of wounds, fever, and gastrointestinal disorders has not reported significant adverse effects; however, such empirical evidence cannot substitute for systematic scientific evaluation. Therefore, detailed toxicological assessments, including repeated-dose toxicity and reproductive toxicity studies, are required to better define the long-term safety profile, potential risks, dosage parameters, and therapeutic window of *T. fragrans* preparations [2].

### Future perspectives

Future research on *T. fragrans* should focus on identifying and characterizing its bioactive constituents through bioassay-guided fractionation and structural elucidation. Standardization of plant extracts and evaluation of their dose-response relationships are also necessary to ensure reproducibility and therapeutic reliability.

Further investigations should explore the molecular mechanisms underlying the reported pharmacological activities, including studies on



relevant cell signaling pathways, enzyme inhibition, and gene expression. Comprehensive toxicological evaluations, including chronic toxicity, reproductive toxicity, and pharmacokinetic studies, are required to establish long-term safety.

In addition, well-designed preclinical and clinical studies are needed to confirm the therapeutic efficacy of *T. fragrans* preparations in humans. The application of modern research approaches such as metabolomics, proteomics, and advanced drug-delivery systems may further support the development of standardized and evidence-based herbal formulations derived from this plant. Such investigations could strengthen the scientific validation and potential therapeutic utilization of *T. fragrans*.

## Conclusion

*T. fragrans* is a medicinal plant that has attracted scientific interest due to the presence of diverse phytochemical constituents and its long-standing use in traditional medicine. Available studies indicate that the plant possesses several biological properties, including antioxidant, antimicrobial, anti-inflammatory, antidiarrhoeal, and antidiabetic activities. However, most of the current evidence is based on preliminary experimental studies. Further research is required to isolate and characterize the active constituents, clarify their mechanisms of action, and evaluate long-term safety through comprehensive toxicological studies. In addition, well-designed clinical investigations are necessary to confirm the therapeutic potential of *T. fragrans*. Such systematic studies will be essential to support the development of scientifically validated and standardized herbal preparations derived from this plant.

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