Print ISSN: 0976-2876 Online ISSN: 2250-0138

Available online at: http://www.ijsr.in

INDIAN JOURNAL OF SCIENTIFIC RESEARCH

DOI:10.32606/IJSR.V17.I1.00018

Received: 05-04-2026 Accepted: 16-07-2026 Publication: 31-08-2026

Indian J.Sci.Res. 17 (1): 123-127, 2026 Review Article

GENETIC VARIABILITY, PHYTOCHEMICAL PROFILING AND BIOCHEMICAL CHARACTERIZATION OF GILOY (*Tinospora cordifolia*): A COMPREHENSIVE REVIEW

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ABSTRACT

***Tinospora cordifolia* (Willd.) Hook. f. & Thomson, commonly known as Guduchi or Giloy, is one of the most important medicinal plants used in traditional Ayurvedic medicine. The species is widely recognized for its immunomodulatory, antioxidant, antidiabetic, anti-inflammatory, antimicrobial, hepatoprotective, and anticancer properties. The therapeutic efficacy of *T. cordifolia* is attributed to the presence of diverse phytochemicals such as alkaloids, diterpenoid lactones, glycosides, steroids, sesquiterpenoids, and phenolic compounds. Genetic diversity plays an important role in determining phytochemical composition and biochemical variability among populations growing under different ecological conditions. Molecular markers and biochemical analyses have been extensively utilized to characterize germplasm diversity and identify elite medicinal genotypes. The present review summarizes the available literature on genetic diversity, biochemical constituents, phytochemical composition, medicinal significance, molecular characterization, and conservation strategies of *T. cordifolia*. The review highlights the importance of integrating molecular and biochemical approaches for the improvement, conservation, and sustainable utilization of this valuable medicinal species.**

KEYWORDS: Giloy, *Tinospora cordifolia*, Genetic Diversity, Phytochemicals, Biochemical Analysis, Medicinal Plants, Molecular Markers

Medicinal plants have served as an important source of therapeutic agents since ancient times and continue to contribute significantly to modern healthcare systems. According to the World Health Organization (WHO), nearly 80% of the world's population depends directly or indirectly on traditional herbal medicines for primary healthcare purposes. India is considered one of the richest countries in terms of medicinal plant diversity and traditional knowledge systems such as Ayurveda, Siddha, and Unani.

Among the medicinal plants used in Ayurveda, *Tinospora cordifolia* (Willd.) Hook. f. & Thomson, commonly known as Guruchi or Giloy, occupies a prominent position due to its wide range of pharmacological properties. The plant belongs to the family Menispermaceae and is distributed throughout tropical and subtropical regions of India. In Ayurveda, Guruchi is often referred to as "Amrita," meaning nectar of immortality, because of its rejuvenating and immunity-enhancing properties (Singh *et al.*, 2003).

Several reearchers have reported that *T. cordifolia* possesses antioxidant, antidiabetic, antimicrobial, anti-inflammatory, hepatoprotective, anticancer, and immunomodulatory activities (Upadhyay *et al.*, 2010). These medicinal properties are mainly attributed to the presence of important bioactive compounds such as alkaloids, diterpenoids, glycosides, steroids, polysaccharides, phenolics, and flavonoids (Sharma *et al.*, 2019). Different parts of the plant including stem, root, and leaves are widely used in the preparation of herbal formulations for the treatment of fever, diabetes, arthritis, jaundice, urinary disorders, and skin diseases.

Genetic diversity is an important biological attribute that determines the adaptability and survival of plant species under varying environmental conditions. In medicinal plants, genetic variability also influences the biosynthesis and accumulation of secondary metabolites responsible for therapeutic activities. Therefore, characterization of genetic diversity is essential for germplasm conservation, selection of elite chemotypes, and development of improved medicinal varieties. Molecular marker techniques such as RAPD, ISSR, AFLP, and SSR markers have been widely used for assessing genetic variation in medicinal plants including *Tinospora cordifolia* (Saha *et al.*, 2012).

Biochemical analysis is another important approach for evaluating the medicinal potential of plants. Estimation of proteins, carbohydrates, phenolics, flavonoids, chlorophyll, antioxidant activity, and other metabolites provides valuable information regarding plant physiology and pharmacological significance. Environmental conditions such as soil type, temperature, rainfall, and altitude also influence biochemical

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composition and phytochemical accumulation in medicinal plants (Gupta *et al.*, 2017).

Due to increasing commercial demand and overexploitation of natural populations, conservation of *T. cordifolia* genetic resources has become essential. Understanding the relationship between genetic diversity and biochemical variability can help in identifying superior genotypes with high medicinal value and improved adaptability. Therefore, the present review aims to compile and critically analyze available information regarding genetic diversity, phytochemical constituents, biochemical analysis, pharmacological importance, and conservation strategies of *Tinospora cordifolia*. (Fugure 1)

Taxonomy and Botanical Description

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Ranunculales
Family	Menispermaceae
Genus	*Tinospora*
Species	*cordifolia*

Morphological Characteristics

Plant Part	Characteristics
Stem	Succulent, green, climbing with warty surface
Leaves	Heart-shaped, simple, alternate
Roots	Long thread-like aerial roots
Flowers	Small, yellowish-green
Fruits	Red drupes

Figure 1: *Tinospora cordifolia*

Distribution and Habitat

Tinospora cordifolia is widely distributed in tropical and subtropical regions of India. It commonly grows in dry deciduous forests and prefers warm climatic conditions. The plant often climbs on large trees such as neem (*Azadirachta indica*) and mango (*Mangifera indica*).

Region	Distribution
Northern India	Uttar Pradesh, Uttarakhand, Punjab
Central India	Madhya Pradesh, Chhattisgarh
Southern India	Tamil Nadu, Karnataka, Kerala
Eastern India	West Bengal, Odisha
Western India	Rajasthan, Gujarat

GENETIC DIVERSITY IN *Tinospora cordifolia*

Genetic diversity refers to the variation in genetic makeup among individuals within a species. Assessment of genetic variability is important for conservation, breeding, and pharmaceutical utilization.

Molecular Marker Techniques

Several molecular markers have been employed for evaluating genetic diversity in *T. cordifolia*. (Table1)

Table 1: Molecular Marker Techniques

Marker Technique	Principle	Advantages	Applications
RAPD	Random amplification of DNA	Simple and inexpensive	Diversity analysis
ISSR	Amplification between microsatellites	High reproducibility	Population studies
AFLP	Selective DNA amplification	High polymorphism	Germplasm evaluation
SSR	Microsatellite analysis	Co-dominant markers	Genetic mapping
DNA Barcoding	Sequence-based identification	Accurate species identification	Authentication

Genetic Variability Studies

Studies using RAPD and ISSR markers have demonstrated significant genetic variation among geographically distinct populations of *T. cordifolia*. Genetic polymorphism is associated with ecological adaptation and biochemical diversity. Populations growing in different climatic conditions exhibit variation in medicinally important metabolites. (Table 2)

Table 2: Major Findings from Genetic Diversity Studies

Study	Marker Used	Key Findings
RAPD analysis	RAPD	Moderate to high polymorphism
ISSR profiling	ISSR	Geographic variation detected
DNA barcoding	ITS and matK	Species authentication successful
AFLP studies	AFLP	High genetic similarity among populations

Phytochemical Composition

The medicinal importance of *T. cordifolia* is attributed to its rich phytochemical profile. (Table 3)

Table 3: Major Phytochemical Constituents

Compound Group	Important Constituents	Biological Activity
Alkaloids	Berberine, magnoflorine	Antimicrobial
Glycosides	Tinocordiside	Immunomodulatory
Diterpenoids	Tinosporin, cordifolide	Anti-inflammatory
Steroids	β-sitosterol	Antioxidant
Phenolics	Gallic acid	Free radical scavenging
Flavonoids	Quercetin	Anticancer
Polysaccharides	Arabinogalactan	Immune enhancement

Biochemical Analysis

Biochemical characterization is important for understanding medicinal properties and evaluating elite germplasm.

Estimation of Primary Metabolites

Protein Content

Proteins are important biochemical constituents involved in metabolic activities. Protein estimation in *T. cordifolia* is generally carried out using the Lowry method.

Carbohydrate Content

Total carbohydrates are estimated using the Anthrone method. Carbohydrates contribute to energy metabolism and medicinal value.

Chlorophyll Content

Chlorophyll estimation provides information regarding photosynthetic efficiency and physiological status. (Table 4)

Table 4: Chlorophyll Content

Biochemical Parameter	Method Used	Importance
Total proteins	Lowry method	Metabolic activity
Carbohydrates	Anthrone method	Energy reserve
Chlorophyll	Arnon method	Photosynthetic efficiency
Phenolics	Folin-Ciocalteu method	Antioxidant activity
Flavonoids	Aluminium chloride assay	Anticancer properties

Secondary Metabolites

Secondary metabolites are biologically active compounds responsible for therapeutic effects.

Total Phenolic Content

Phenolic compounds exhibit strong antioxidant properties and protect against oxidative stress.

Total Flavonoid Content

Flavonoids contribute to antimicrobial, anti-inflammatory, and anticancer activities.

Antioxidant Activity

Antioxidant potential is commonly evaluated using DPPH radical scavenging assay and FRAP assay. (Table 5)

Table 5: Antioxidant activity

Assay	Principle	Significance
DPPH assay	Radical scavenging	Antioxidant evaluation
FRAP assay	Ferric reducing ability	Reducing power
ABTS assay	Radical cation decolorization	Antioxidant capacity

PHARMACOLOGICAL IMPORTANCE

Tinospora cordifolia possesses remarkable pharmacological properties due to the presence of diverse bioactive compounds including alkaloids, glycosides, diterpenoids, flavonoids, steroids, and phenolic compounds. The plant has been extensively used in traditional Ayurvedic medicine for the treatment of various diseases and disorders. Scientific investigations have also validated many of its traditional therapeutic applications.

The antidiabetic activity of *Tinospora cordifolia* has been widely reported in several experimental studies. Plant extracts help in lowering blood glucose levels by improving insulin secretion and enhancing glucose metabolism. Active phytochemicals present in the stem and leaves contribute to the regulation of carbohydrate metabolism and reduction of oxidative stress associated with diabetes.

The immunomodulatory potential of Guduchi is considered one of its most important medicinal properties. Polysaccharides and alkaloids present in the plant stimulate macrophage activation, increase phagocytic activity, and enhance the body's immune response. Due to these properties, the plant is commonly used for improving immunity and resistance against infections.

The antioxidant activity of *Tinospora cordifolia* is mainly attributed to the presence of phenolic compounds and flavonoids. These compounds neutralize free radicals and reduce oxidative damage to cells and tissues. Antioxidant activity plays an important role in preventing various chronic diseases including cardiovascular disorders, cancer, diabetes, and neurodegenerative diseases.

The plant also exhibits significant anti-inflammatory activity. Bioactive compounds such as diterpenoid lactones inhibit inflammatory mediators and reduce swelling, pain, and tissue damage. Because of these properties, Guduchi has traditionally been used in the treatment of arthritis, gout, and inflammatory disorders.

Antimicrobial studies have demonstrated that extracts of *Tinospora cordifolia* possess inhibitory effects against several bacterial and fungal pathogens. The antimicrobial activity is associated with alkaloids, glycosides, and phenolic constituents present in the plant. These properties support its traditional use in treating skin infections, fever, and microbial diseases.

The hepatoprotective effect of Guduchi has also been extensively studied. Plant extracts protect liver tissues against toxic chemicals, alcohol-induced damage, and oxidative stress. The hepatoprotective activity is mainly associated with antioxidant compounds that stabilize liver enzymes and improve hepatic function.

Several investigations have reported anticancer potential in *Tinospora cordifolia*. The plant extracts exhibit cytotoxic activity against certain cancer cell lines and may help in inhibiting tumor growth through antioxidant and immunomodulatory mechanisms. Flavonoids and diterpenoid compounds are believed to play an important role in these activities.

In addition to these medicinal properties, *Tinospora cordifolia* also shows antipyretic, anti-allergic, anti-stress, neuroprotective, and cardioprotective activities. Due to its broad spectrum of pharmacological actions and comparatively low toxicity, the plant is considered an important source for the development of herbal medicines and pharmaceutical formulations.

ROLE OF ENVIRONMENTAL FACTORS ON BIOCHEMICAL VARIABILITY

Environmental conditions significantly influence phytochemical accumulation. (Table 6)

Table 6: Environmental factors on biochemical variability

Environmental Factor	Effect on Plant
Temperature	Alters metabolite synthesis
Soil nutrients	Affects alkaloid production
Rainfall	Influences growth and biomass
Altitude	Changes antioxidant activity
Seasonal variation	Modifies phytochemical concentration

CONSERVATION AND SUSTAINABLE UTILIZATION

Overexploitation and habitat destruction threaten natural populations of *T. cordifolia*. Conservation strategies include:

- In situ conservation
- Ex situ germplasm preservation
- Tissue culture propagation
- Molecular characterization of elite genotypes
- Sustainable harvesting practices

Micropropagation techniques provide rapid multiplication of disease-free planting material.

CONCLUSION

Tinospora cordifolia is an important medicinal plant possessing enormous therapeutic potential due to its diverse phytochemical and biochemical constituents. Significant genetic diversity exists among different populations, which influences the accumulation of medicinally important metabolites. Molecular markers and biochemical analyses have proven effective in characterizing genetic variability and identifying elite genotypes. Conservation of genetic resources and sustainable utilization strategies are essential for maintaining biodiversity and ensuring long-term medicinal value. Future studies integrating genomics, metabolomics, and biotechnology will facilitate the development of improved medicinal varieties and standardized pharmaceutical products.

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