Tinospora cordifolia: a multipurpose medicinal plant- A review

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Traditional systems of medicine such as Ayurvedic, Uninai, Siddha and Homeopathy (AYUSH) have been in practice in a great account. Owing to population rise, inadequate supply of drugs, prohibitive cost of treatments, side effects of several allopathic drugs and development of resistance to currently used drugs for diseases have led to increased emphasis on the use of plant materials as a source of medicines for a wide variety of human ailments as witnessed by the use of folk medicines in the present scenario.

This review article describes the prominence of a medicinal plant Tinospora cordifolia in therapeutics such as use of crude extract of plant for the amelioration of various diseases, morphology, growth constraints, biochemical composition, biological activities, research work done, projects sanctioned to this plant species and the future prospects of this important neglected plant species for research in the field of plant tissue culture, natural products and nano-biotechnology.

Keyword: Medicinal Plants, Plant Extract, Tissue Culture, Natural Products, Biodiversity.

1. Introduction:
India is bestowed with enormous biodiversity of medicinal plants. Among them Tinospora cordifolia has a wide array of bioactive principles as well as it has been proven medicinally important plant, have not received considerable scientific attention.
Medicinal plants have been used as natural medicines. This practice has been in existence since prehistoric times. There are different ways in which plants have been found useful in medicines such as crude extract of plants has been used directly because of the presence of natural chemical constituents such as berberine, morphine, psilocin, vincristine etc. [1] and natural compounds for the synthesis of drugs such as tubocurarine, colchicine, nicotine, quinine etc. for therapeutic purpose by folk people. Many modern medicines such as digitalis, vinblastine, aspirin, quinine and paracetamol had their origin from the natural compounds of medicinal plants viz., foxglove (Digitalis purpurea), madagascar periwinkle (Vinca rosea), willow bark (Salix spp.), quinine bark (Cinchona officinalis), respectively [2].

A large number of plants are being used in medicine for therapeutic or prophylactic purposes. The therapeutic properties of medicinal plants are attributed owing to the presence of active substances such as alkaloids, flavonoids, glycosides, vitamins, tannins, and coumarins [3]. These natural compounds physiologically affect the body of human beings, interact with the pathogens and interrupt their growth at different stages of development and make the body disease free.
Tinospora cordifolia (Willd.) Miers ex Hook. F. and Thoms belonging to the family Menispermaceae, is a large, deciduous, climbing shrub found throughout India, especially in the tropical parts ascending to an altitude of 300 m. and also in certain parts of China \[4\]. It is known as heart leaved Moonseed plant in English, Guduchi in Sanskrit and Giloy in Hindi.

2. Growth Requirement
The plant is very rigid and it can be grown in almost all climates but prefers warm climate. Planting is usually done during rainy season (July to August). As it is climber so it requires support for its growth. Fast growing species such as Neem (Azadirachta indica), Jatropha (Jatropha curcas) and Moringa (Moringa oleifera) have been planted to provide support for its growth. Tinospora cordifolia growing with Neem (Azadirachta indica) is called as NEEM GILOY has chemical composition as similar as neem as well as giloy and show better therapeutic properties \[5\].

T. cordifolia prefers medium black or red soil for its cultivation. Giloy can also be successfully grown in large variety of soils, ranging from sandy to clay loam. However, the soil should be well drained with sufficient moisture and rich with organic matter for its growth.

3. Growth Constraints
T. cordifolia can be propagated by seeds and vegetative cuttings. However, both the ways are not suitable for large scale production and having problems in traditional methods of propagation. Viability of seeds is very less, poor seed set and germination of seeds are the main problems associated with its clonal propagation. Vegetative cuttings are also not suitable due to less productivity and also dependent upon weather conditions for its further growth. Keeping in view the Growth constraints, plant tissue culture techniques may be suitable methods for its large scale production in a lesser time and space.

4. Threats to This Plant
Due to the presence of immense medicinal properties, this plant has been overexploited by pharmaceutical companies and folk people for traditional remedies have led to the acute scarcity of this plant to meet the present-day demand. Due to its high demand, T. cordifolia has been listed amongst 29 highly prioritized medicinal plants of agro climatic zone 8 (Rajasthan, U.P. and M.P.) of India as identified by National Medicinal Plant Board, New Delhi, Government of India. This plant has also been listed in 178 medicinal plant species in high Volume Trade by NMPB, New Delhi, India \[6\]. Hence, this plant has been selected for the review article to make public or scientific community very well aware and update them about morphology, growth constraints, an array of its chemical compounds, medicinal properties, pharmaceutical products, research work done till date in different aspects, various research projects sanctioned by different funding agencies etc.

5. Morphological Description
Tinospora cordifolia is a large deciduous, extensively spreading climbing shrub with a number of coiling branches. Different parts of Tinospora have following type of morphology.

6. Stem
Stem of this plant is rather succulent with long, filiform, fleshy and climbing in nature. Aerial roots arise from the branches. The bark is creamy white to grey in colour and deeply left spirally \[7\] (Figure 1A).

7. Aerial Root:
Aerial roots are present, these aerial roots are characterized by tetra to penta-arch primary structure. However, cortex of root is divided in to outer thick walled and inner parenchymatous zone \[8\] (Figure 1F).

8. Leaves
Leaves of this plant are simple, alternate, ex-stipulate, long petioled approximately 15 cm,
round, pulvinate, heart shaped, twisted partially and half way round. Lamina is ovate, 10-20 cm long, 7 nerved and deeply cordate at the base and membranous [9] (Figure 1B).

9. Flowers
Flowers are unisexual, recemes, greenish yellow in colour, appears when plant is leaf less. Male flowers are clustered and female flowers exist in solitary inflorescence. Sepals are 6 in 2 series of 3 each. Outer ones are smaller than the inner sepals. Petals are also 6, smaller than sepals, free and membranous. Flowering occurs during March to June [10] (Figure 1D AND 1E).

10. Fruit
They are orange-red in colour, fleshy, aggregate of 1-3 and ovoid, smooth, drupelets on thick stalk with a sub terminal style scars. Fruits develop during winter [11] (Figure 1C).

11. Seed
Curved seed have been reported in this species. Hence this family is named as moonseed family also. As seeds are curved in shape, embryo also turned in to curve shape automatically. Moreover, the endocarp is variously ornamented and provides important taxonomic characters.

12. Natural Products
A variety of chemical constituents such as alkaloids, diterpenoid lactones, steroids, glycosides aliphatic compounds, polysaccharides have been reported from different parts of Tinospora cordifolia. Various natural products (active compounds) isolated from different plant parts along with their biological activities have been given here for readers reference (Table-1).

13. Biological Activities
The major biological activities of Tinospora cordifolia summarized in the following manner
### Table 1: Major and sub groups of natural products present in different parts of Tinospora cordifolia and their biological activities

<table>
<thead>
<tr>
<th>Active Component</th>
<th>Compound</th>
<th>Plant Part</th>
<th>Biological Activity (In Human being)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alkaloids</strong></td>
<td>Berberine, Choline, Tembestarine, Magnoflorine, Tinosporin, Palmetine, Isocolumbin, Aporphine alkaloids, Jatrotrrhizine, Tetrahydropalmatine,</td>
<td>Stem, Root</td>
<td>Anti-viral infections, Anti-cancer, anti-diabetes, inflammation, Neurological, immunomodulatory, psychiatric conditions</td>
<td>(12-17)</td>
</tr>
<tr>
<td><strong>Diterpenoid Lactones</strong></td>
<td>Furanolactone, Clerodane derivatives [(5R,10R)-4R-8R-dihydroxy-2S-3R:15,16-diepoxy-cleroda-13 (16), 14-dieno-17,12S:18,1S-dilactone], Tinosporon, Tinosporides, Jateorine, Columbin</td>
<td>Whole Plant</td>
<td>Vasorelaxant: relaxes norepinephrine induced contractions, inhibits Ca+2 influx, anti-inflammatory, anti-microbial, anti-hypertensive, anti-viral. Induce apoptosis in leukemia by activating caspase-3 and bax, inhibits bcl-2.</td>
<td>(18-22)</td>
</tr>
<tr>
<td><strong>Glycosides</strong></td>
<td>18-norlerodane glucoside, Furanoid diterpene glucoside, Tincordiside, Tincordifoliocide, Cordioside, Cordifoliocide Syringin, Syringin-apiosylglycoside, Pregnane glycoside, Palmatosides, Cordifoliocide A, B, C, D and E</td>
<td>Stem</td>
<td>Treats neurological disorders like ALS, Parkinsons, Dementia, motor and cognitive deficits and neuron loss in spine and hypothalamus, Immunomodulation, Inhibits NF-kBand act as nitric oxide scavenger to show anticancer activities.</td>
<td>(23-29)</td>
</tr>
<tr>
<td><strong>Steroids</strong></td>
<td>β–sitosterol, δ-sitosterol, 20 β-hydroxyeclaysone, Ecdysterone, Makisterone A, Giloinsterol</td>
<td>Shoot</td>
<td>IgA neuropathy, glucocorticoid induced osteoporosis in early inflammatory arthritis, induce cell cycle arrest in G2/M phase and apoptosis through c-Myc suppression. Inhibits TNF-α, IL-1 β, IL-6 and COX-2.</td>
<td>(30-32)</td>
</tr>
<tr>
<td><strong>Sesquiterpenoid</strong></td>
<td>Tinocordifolin</td>
<td>Stem</td>
<td>Antiseptic</td>
<td>(33)</td>
</tr>
<tr>
<td><strong>Aliphatic</strong></td>
<td>Octacosanol,</td>
<td>Whole</td>
<td>Anti-nociceptive and anti-</td>
<td>(34-36)</td>
</tr>
<tr>
<td>compound</td>
<td>Heptacosanol Nonacosen-15-one dichloromethane</td>
<td>plant inflammatory. Protection against 6-hydroxydopamine induced parkinsonisms in rats. Down regulate VEGF and inhibits TFN-α from binding to the DNA.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>3,(a,4-di hydroxy-3-methoxy-benzyl)-4-(4-compounds hydroxy-3-methoxy-benzyl)-tetrahydrofuran, Jatrorrhizine, Tinosporidine, Cordifol, Cordifelone, Giloinin, Giloin, N-trans-feruloyltyramine as diacetate, Tinosporic acid.</td>
<td>Root, Whole Plant Protease inhibitors for HIV and drug resistant HIV. (37-38)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The chemical structures of medicinally potent chemical compounds reported in this plant are being depicted here, which would help researchers to identify these chemicals from the same or different plant resources. The structures of important natural products are as follows:

![Berberine](image1.png)
![Plamatine](image2.png)
![Choline](image3.png)
![Furanolactone](image4.png)
![Magnochlorine](image5.png)
![Tinocordifolin](image6.png)
![Isocolumbin](image7.png)
![β-sitosterol](image8.png)
Using the above mentioned potent chemical compounds from this plant species, various pharmaceutical market products have been produced by the different companies (Table 2)

<table>
<thead>
<tr>
<th><strong>Name of Market Product</strong></th>
<th><strong>Biological Roles</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinospora Cordifolia Pellets</td>
<td>A number of diseases</td>
</tr>
<tr>
<td>Guduchi</td>
<td>The immune system and the body's resistance to infections</td>
</tr>
<tr>
<td>Abhaibhubejhr</td>
<td>Anti-stress</td>
</tr>
<tr>
<td>Safe herb</td>
<td>Cure by Anemia and sexual disabilities.</td>
</tr>
<tr>
<td>Brave Heart Capsule</td>
<td>It lowers the lipid levels especially cholesterol and LDL-cholesterol in body, diuretic</td>
</tr>
<tr>
<td>Cirrholv capsules</td>
<td>Hepatoprotective</td>
</tr>
<tr>
<td>Cirrholv-ds syrup</td>
<td>Hepatoprotective</td>
</tr>
<tr>
<td>Mussaffen</td>
<td>Blood purifier and anti-allergic</td>
</tr>
<tr>
<td>MadhuMehari</td>
<td>Cure by urinary problems, maintain blood sugar, fatigue</td>
</tr>
<tr>
<td>Tonplex</td>
<td>Increase immunity</td>
</tr>
<tr>
<td>Rebuild</td>
<td>Anti-stress and anti-oxidant</td>
</tr>
</tbody>
</table>

**14. Anti-Diabetic Activities**

The stem of this plant is generally used to cure diabetes by regulating level of blood glucose [39]. It has been reported to act as anti-diabetic drug through explanatory oxidative stress, promoting insulin secretion by inhibiting gluconeogenesis and glycogenolysis. The anti-diabetic properties exhibited by this plant species are attributed due to the presence of alkaloids (Magnoflorine, Palmetine, Jatrorrhizine) [17], tannins, cardiac glycosides, flavonoids, saponins, steroids etc. [40]. The crude extract of stem in ethyl acetate, dichloromethane, chloroform and hexane inhibits the enzymes like salivary, amylase and glucosidase resulting increase in post-prandial
glucose level and shows potential activities against Diabetes mellitus disease [41]. The root extract of this plant has also been reported to have anti-diabetic properties which decrease the level of glycosylated haemoglobin, hydroperoxidase and vitamin E [42].

15. Immunomodulatory Activities: 
*T. cordifolia* is well known for its immunomodulatory response. This property has been well documented by scientists [43-45]. A large variety of compounds which are responsible for immunomodulatory and cytotoxic effects are 11-hydroxymuskatone, N-methyle-2-pyrrolidone, N-formylammonain, cordifolioside A, magnoflorine, tinocordioside and syringin [46]. These natural compounds have been reported to improve the phagocytic activity of macrophages, enhancement in nitric acid production by stimulation of splenocyte, [47] and production of reactive oxygen species (ROS) in human neutrophil cells [48].

16. Anti-toxic Activities 
Aqueous extract of this plant has already been reported to show scavenge activity due to the presence of antioxidant against free radicals generated during aflatoxicosis [18]. Further alkaloids such as choline, tinosporine, isocolumbin, palmetine, tetrahydropalmatine and magnoflorine from *T. cordifolia* showed protection against aflatoxin induced nephrotoxicity [18]. Furthermore *T. cordifolia* shows protective effect by lowering the concentration of thiobarbituric acid reactive substance (TBARS) and enhancing the glutathione (GSH), ascorbic acid, protein and the activities of antioxidant enzymes viz., superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase, glutathione S-transferase (GST) and glutathione reductase (GR) in kidney [15]. However, leaf and stem extract of *T. cordifolia* has been reported to show hepatoprotective effect in male albino mice against lead nitrate induced toxicity. Similarly, oral dose of plant extract prohibited the lead nitrate induced liver damage [49-50].

17. Anti-HIV Activities 
Root extract of this plant has been shown a decrease in the regular resistance against HIV [51]. This anti HIV effect was exposed by reduction in eosinophil count, stimulation of B lymphocytes, macrophages, level of hemoglobin and polymorphonuclear leucocytes [51-52].

18. Anti-Cancer Activities: 
*T. cordifolia* shows anti-cancer activity, this activity is mostly shown in animal models. Root extract of *T. cordifolia* has been shown radio protective role due to extensively increase in body weight, tissue weight, tubular diameter. Dichloromethane extracts of TC shows cytotoxic effects owing to lipid peroxidation and release of LDH and decline in GST [16]. In pre-irradiating mice, root extract has widely affected radiation, induced rise in lipid peroxidation and resulted in the decline of GSH in testes [47]. Most of the synthetic chemotherapeutic agents laid toxic side effects on the living organisms [53]. The effect of Giloy has been reported better than doxorubicin treatment [54].

19. Anti-Microbial Activities 
Methanolic extract of *T. cordifolia* has been reported against microbial infection [55]. Antibacterial activity of *T. cordifolia* extract has been bio assayed against *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumonia*, *Proteus vulgaris*, *Salmonella typhi*, *Shigella flexneri*, *Salmonella paratyphi*, *Salmonella typhimurium*, *Pseudomonas aeruginosa*, *Enterobacter aerogen* and *Enterobacter aerogen* [55-57]. Further, *T. cordifolia* extract has been reported against bacterial growth and improved phagocytic and intracellular bacterial capacities of neutrophils in mice [58].

20. Anti-Oxidant Activities 
Methanolic extract of stem of *T. cordifolia* has been reported to anti-oxidant activity, by increasing the erythrocytes membrane lipid peroxide and catalase activity. It also decreases the activity of SOD, GPx in alloxa induced diabetic rats [59-60]. Extract of *T. cordifolia* has
been reported its free radical scavenging properties \[61\]. Leaf extract of *T. cordifolia* reported to have an alpha-glucosidase inhibitor, characterized as saponarin was found to be also significant antioxidant and hydroxyl radical scavenging activity \[53\]. Due to the presence of alkaloids it shows protection against aflatoxin-induced nephrotoxicity \[15\]. *T. cordifolia* aqueous extract has a radio protective activity, enhancing the survival of mice against a sub-lethal dose of gamma radiation \[50, 62\].

Keeping in view the above mentioned medicinal properties, this plant has been listed an important plant amongst the 32 prioritized plants by NMPB, New Delhi, Government of India. Various funding agencies have been sanctioned the large amount to research on this important ignored plant species in the form of major research projects to different organizations/ institutions, are also being represented here for the help of scientists (Table 3). At the same time, type of research work done on this potent medicinal plant species are also being given here (Table 4).

**Table 3**: Various research projects sanctioned on *Tinospora cordifolia* by different funding agencies

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Title</th>
<th>Area</th>
<th>Funding Agencies</th>
<th>Year</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Studies on Reproductive biology and genetic diversity of <em>Rauwolfia serpentina</em>, <em>Tinospora cordifolia</em> and <em>Asparagus racemosus</em></td>
<td>Reproductive Biology</td>
<td>Department of Science and Technology, Govt. of India, New Delhi</td>
<td>2006-2009</td>
<td>9,30,000.00</td>
</tr>
<tr>
<td>2.</td>
<td>Prevention of Radiation induced reproductive dysfunctions by <em>Tinospora cordifolia</em> (an Indian medicinal plant) extract.</td>
<td>Biochemistry and Pharmacology</td>
<td>Indian Council of Medical Research, Govt. of India, New Delhi</td>
<td>2007-2010</td>
<td>NA</td>
</tr>
<tr>
<td>3.</td>
<td>Studies on Modulation of Redox Status and Anti-Inflammatory Effects of <em>Fagonia cretica Linn</em>, <em>Tinospora cordifolia</em> and <em>Rubia cordifolia</em></td>
<td>Pharmacology</td>
<td>Department of Science and Technology, Govt. of India, New Delhi</td>
<td>2009-2012</td>
<td>NA</td>
</tr>
<tr>
<td>4.</td>
<td>In vitro studies on inhibition of eicosanoid metabolism for control of arthritis by extracts of stem of <em>Tinospora cordifolia</em></td>
<td>Biochemistry and Pharmacology</td>
<td>Department of Science and Technology, Govt. of India, New Delhi</td>
<td>2011-2012</td>
<td>21,17,008.00</td>
</tr>
<tr>
<td>5.</td>
<td>Yield Enhancement Strategies for Production of Therapeutic Compounds by Cell and Tissue Cultures of <em>Tinospora cordifolia</em></td>
<td>Plant Tissue Culture and Pharmacology</td>
<td>Department of Biotechnology, Govt. of India, New Delhi</td>
<td>2011-2014</td>
<td>21,15,000.00</td>
</tr>
</tbody>
</table>

**NA- Not Available**
### Table 4: Recent Update of Research work done on *Tinospora cordifolia* by various researchers

<table>
<thead>
<tr>
<th>Types of research work done on <em>Tinospora cordifolia</em></th>
<th>Explant</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biochemical Research</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alkaloids From <em>Tinospora cordifolia</em> Miers</td>
<td>Root</td>
<td>[63]</td>
</tr>
<tr>
<td>Antifungal and HPLC analysis of the crude extracts of <em>Acorus calamus</em>, <em>Tinospora cordifolia</em> and <em>Celastrus paniculatus</em></td>
<td>Whole plant</td>
<td>[73]</td>
</tr>
<tr>
<td><em>Tinospora cordifolia</em> induces enzymes of carcinogen/drug metabolism and antioxidant system, and inhibits lipid peroxidation in mice</td>
<td>Whole plant</td>
<td>[76]</td>
</tr>
<tr>
<td>Purification and characterization of a thiol amylase over produced by a non-cereal non-leguminous plant, <em>Tinospora cordifolia</em></td>
<td>Whole plant</td>
<td>[77]</td>
</tr>
<tr>
<td>Amritosides A, B, C and D: clerodane furano diterpene glucosides from <em>Tinospora cordifolia</em></td>
<td>Whole plant</td>
<td>[78]</td>
</tr>
<tr>
<td>Adenosyl-L-methionine(s)-cochlaurine-n-methyl transferase From <em>Tinospora cordifolia</em></td>
<td>Whole plant</td>
<td>[82]</td>
</tr>
<tr>
<td>Magnoflorine from <em>Tinospora cordifolia</em> stem inhibits a-glucosidase and is antiglycemic in rats</td>
<td>Root</td>
<td>[85]</td>
</tr>
<tr>
<td><strong>Plant Tissue Culture Research</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effect of growth regulators, carbon source and cell aggregate size on berberine production from cell cultures of <em>Tinospora cordifolia</em> Miers</td>
<td>Leaf</td>
<td>[64]</td>
</tr>
<tr>
<td>Micropropagation of <em>Tinospora cordifolia</em> (Wild.) Miers ex Hook. F and Thoms– a multipurpose medicinal plant</td>
<td>Shoot</td>
<td>[65]</td>
</tr>
<tr>
<td>In vitro propagation of <em>Tinospora cordifolia</em> (wild.) Miers ex hook. F. Thoms</td>
<td>Stem and leaf</td>
<td>[66]</td>
</tr>
<tr>
<td>In vitro clonal propagation through mature nodes of <em>Tinospora cordifolia</em> (wild.)Hook. F. and Thoms.: an important ayurvedic medicinal plant</td>
<td>Nodal segment</td>
<td>[67]</td>
</tr>
<tr>
<td>In vitro regeneration of <em>Tinospora cordifolia</em> (wild.) Hook. f. and thoms: an important diabetic plant</td>
<td>Petiole, leaf and nodal segment</td>
<td>[75]</td>
</tr>
<tr>
<td>Conservation of biodiversity of highly important medicinal plants of India through tissue culture technology- a review</td>
<td>Shoot tip and Nodal Segment</td>
<td>[79]</td>
</tr>
<tr>
<td>Identification of <em>Tinospora cordifolia</em> (Wild.) Miers ex Hook F. and Thomas Using RAPD Markers</td>
<td>Stem Nodal cutting</td>
<td>[80]</td>
</tr>
<tr>
<td><strong>Activity Against Various Diseases (Biological Activity)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hepatoprotective and Immunomodulatory Properties of T. cordifolia In CCl4 Intoxicated mature albino rates</td>
<td>Whole plant</td>
<td>[44]</td>
</tr>
<tr>
<td>Evaluation of the antineoplastic activity of guduchi (<em>Tinospora cordifolia</em>) in cultured HeLa cells</td>
<td>Stem</td>
<td>[56]</td>
</tr>
<tr>
<td>An immunomodulator from <em>Tinospora cordifolia</em> with antioxidant activity in cell-free systems</td>
<td>Dry Stem extract</td>
<td>[72]</td>
</tr>
<tr>
<td>Evaluation of antileishmanial potential of <em>Tinospora sinensis</em> against experimental visceral leishmaniasis</td>
<td>Whole Plant</td>
<td>[74]</td>
</tr>
</tbody>
</table>
### In vitro antibacterial activity of methanolic root extract of *Tinospora cordifolia* (wild)

<table>
<thead>
<tr>
<th>Description</th>
<th>Plant Part</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-diabetic property of <em>Tinospora cordifolia</em> and its active compound is mediated through the expression of Glut-4 in L6 Myotubes</td>
<td>Stem</td>
<td>[86]</td>
</tr>
<tr>
<td>Androgenic action of <em>Tinospora cordifolia</em> ethanolic extract in prostate cancer cell line LNCaP</td>
<td>Stem</td>
<td>[87]</td>
</tr>
<tr>
<td>Effects of supplementation of <em>Tinospora cordifolia</em> to crossbred cows peripartum</td>
<td>Stem</td>
<td>[88]</td>
</tr>
<tr>
<td>Effects of <em>Tinospora cordifolia</em> supplementation on semen quality and hormonal profile in rams</td>
<td>Whole Plant</td>
<td>[89]</td>
</tr>
<tr>
<td>Comparative Hepatoprotective Potential of <em>Tinospora cordifolia</em>, <em>Tinospora sinensis</em> and Neem-guduchi</td>
<td>Stem</td>
<td>[90]</td>
</tr>
<tr>
<td>The anti-mycobacterial activity of <em>Tinospora Cordifolia</em> medicinal plant used for the treatment of leprosy and Tuberculosis</td>
<td>Stem</td>
<td>[91]</td>
</tr>
<tr>
<td>Glucose uptake-stimulatory activity of <em>Tinospora cordifolia</em> stem extracts in Ehrlich ascites tumor cell model system</td>
<td>Stem</td>
<td>[101]</td>
</tr>
</tbody>
</table>

### Molecular Analysis

<table>
<thead>
<tr>
<th>Description</th>
<th>Plant Part</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic diversity analysis of <em>Tinospora cordifolia</em> germplasm collected</td>
<td>Petiole, Lenticel, Stomatal Trichome, Stem</td>
<td>[68]</td>
</tr>
<tr>
<td>Assessment of Genetic Diversity in Medicinal climber of <em>Tinospora cordifolia</em> (willd.) Miers (Menispermaceae) from Gujrat, India</td>
<td>Stem</td>
<td>[69]</td>
</tr>
<tr>
<td>Molecular phylogeny in Indian <em>Tinospora</em> species by DNA based molecular markers</td>
<td>Leaf</td>
<td>[70]</td>
</tr>
</tbody>
</table>

### Green Synthesis/ Nano Biotechnology Research

<table>
<thead>
<tr>
<th>Description</th>
<th>Plant Part</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green synthesis, characterization and in vitro antibacterial activity of silver nanoparticles by using <em>Tinospora cordifolia</em> leaf extract</td>
<td>Leaf</td>
<td>[71]</td>
</tr>
<tr>
<td>Synthesis of pediculocidal and larvicidal silver nanoparticles by leaf extract from heartleaf moonseed plant, <em>Tinospora cordifolia</em> Miers.</td>
<td>Leaf</td>
<td>[92]</td>
</tr>
</tbody>
</table>

### Endophytic Research

<table>
<thead>
<tr>
<th>Description</th>
<th>Plant Part</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxol producing endophytic fungus Fusarium culmorum SVJM072 from medicinal plant of <em>Tinospora cordifolia</em> - a first Report</td>
<td>Whole Plant</td>
<td>[84]</td>
</tr>
</tbody>
</table>

## 21. Future Prospects

Traditions of plant-collection and plant based medications have been handed over from generation to generation. Plants collected from different sources show wide disparity in therapeutic values. In the recent years there has been greater expansion of indigenous drug industry in India. Consequently the demand for the medicinal plants has enormously increased. According to latest estimate, there are about eight thousand licensed pharmacies of Indian Systems of Medicine in the country, engaged in the...
manufacture of drugs to meet the requirement of people \[83\]. The total annual requirement of the raw materials of these pharmacies was estimated in tonnes. Presently, the increasing demand is fulfilled by cutting trees from their natural habitat and/or uprooting there trees/shoots/leaves on nominal charges or by illegal cuttings. This plant species has huge therapeutic potential, it has been over exploited by human activities. So there is an urgent need to conserve it. Plant tissue culture techniques are the alternative method to rapid propagation of this plant for its conservation and for the enhancement of secondary products.

Fungal endophytes are extremely common and highly diverse microorganisms that live within plant tissues, but usually remain asymptomatic. These organisms reside in the living tissues of host plant and do so in a variety of relationships, ranging from symbiotic to slightly pathogenic \[93-94\]. They occupy a wide range of different habitats due to their vast nutritional diversity as heterotrophs and symbionts. Exploitation of endophytes in production of several metabolites (primary and secondary) is now at the front of Biotechnology along with other groups of organisms. Endophytic fungi were found associated with T. cordifolia \[84\]. The major factors associated with the biological success of these organisms in nature are their metabolic and biochemical diversity. This has allowed adaptation and exploitation of unique environments with other organisms. The endophytic fungi may produce a plethora of substances of potential use to modern medicine, agriculture and industry \[85\].

Recently, the phytodiversity is also being used by the scientists to produce nanoparticles. Green synthesis technology has been introduced for the synthesis of noble metallic nanoparticles using plant extract. This method for the synthesis of nanoparticles is environmental friendly, cheap and easy \[96-100\]. These nanoparticles play an indispensable role in drug delivery, diagnostic, imaging, sensing, gene delivery, artificial implant, tissue engineering and now days in medicinal textiles for their antimicrobial activities. In such a way, we will have opportunity to get benefited by the plants. Hence, further studies are required in the field of tissue culture to raise the success rate, molecular analysis of any genetic changes if comes through indirect regeneration process, exploration of a variety of fungal endophytes to reveal the exact pathway of natural product synthesis in the plant cells, and in the field of nano biotechnology to solve the emerging problems of various incurable diseases through drug delivery system by nanoparticles.

22. References

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