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Integrated analysis of *Tinospora cordifolia* germplasm: Nutritional, qualitative, quantitative, and phytochemical traits

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Abstract

Tinospora cordifolia, often known as "*Guduchi*" is a deciduous climber and is considered valuable in terms of its immense medicinal properties. This study evaluated 48 *Tinospora cordifolia* germplasm accessions collected from Tamil Nadu for their nutritional, qualitative, quantitative, and phytochemical properties. Significant variations were observed among the accessions. TC-22 exhibited the highest phenol (122.73 mg/g) and flavonoid content (18.84 mg/g), while TC-30 recorded the highest tannin content (234.56 mg/g). TC-20 demonstrated superior protein (13.85%), carbohydrate (86.92 mg/g), and antioxidant activity (261.74%) levels. Additionally, TC-20 displayed elevated potassium (1.45%), calcium (0.35%), and iron (48.74%) levels, with the highest zinc content (15.67 µg/g) among accessions. TC-30 had the highest fat content (8.81%), while TC-22 recorded the maximum cardiac glycosides (2.27%). The study identified TC-35 as having the highest fiber content (13.22%) and energy value (99.66 Kcal/100g). Vitamin C (68.96 mg/100g) and vitamin A (0.44 mg/100g) were most abundant in TC-33. These findings provide valuable insights into the biochemical diversity of *T. cordifolia* germplasm, highlighting its potential for nutritional and therapeutic applications. Findings unmistakably demonstrated the significance of ecological condition variables in determining the quantitative and qualitative parameters of diverse accessions from the different places of Tamil Nadu.

Keywords: Germplasm, *Tinospora cordifolia*, Tamil Nadu, qualitative, quantitative

Introduction

The recent surge in the use of herbal medicines has led to a significant rise in Herbal drugs production facilities, driven by the growing demand for herbal raw materials. India's herbal product exports have risen in recent years, with $ 628.25 million exported in 2022-23 and $ 612.1 million in 2021-22. Top exports include ashwagandha, turmeric, and ginger, reflecting growing global demand for Ayurvedic and herbal products (Basai, 2023). *Tinospora cordifolia* Willd Miers ex HooK. F. and Thoms, often known as "*Guduchi*" is a diploid (2n = 22), deciduous climber in the family Menispermaceae. It spreads over the tropical and subtropical Indian subcontinent as well as China reaching heights of upto an altitude of about 300 m. Ancient Ayurveda writings describe *T. cordifolia* as an useful herb to cure general senility, dyspepsia, and urinary disorders (Ahmad *et al*., 2009).

Talbot *et al*. (2006) reported that it is pertinent to note that people's faith on natural products is on surge but at the same time, the need to safeguard the value chain to ensure quality of the raw material produced is to be realized which requires focus on research in identifying genotypes rich in bioactive constituents. India holds advantage of its rich plant biodiversity which is distributed in various habitats. Among the various medicinal plants used in AYUSH, *Tinospora cordifolia* is considered valuable in terms of its immense medicinal properties. Plant extracts of *T. cordifolia* are used for the rehabilitation of fever, diabetes, allergies, immune system, gout, skin inflammation, snake and scorpion bites, respiratory tract infections, tuberculosis, rheumatoid arthritis, cancer, *etc.*

The stem and root of plant play an important role in water purification by sedimentation, flocculation or antibiosis. In addition, the leaves of the plant also contribute significantly to the treatment of respiratory ailments and serve as a source of vitamins A and C. Stem juice also shows strong antimicrobial, antimalarial and antiviral properties. Fruits of the plant are edible and are rich in ascorbic acid. Its kernel are rich source of carotenoids, lecithin and steroids. The plant alkaloids closely resemble like action to the antibiotics which are useful to treat asthma (Ahmed *et al*., 2006; Puratchimani and Jha, 2007; Srinivasan *et al.,* 2008; Gahlaut *et al*., 2012; Tanwar *et al*., 2012 and Choudhary *et al*., 2014). *Tinospora* is cultivated commercially in India due to its significant demand in the Ayurvedic, pharmaceutical, and herbal product industries. Its cultivation is particularly prominent in states like Rajasthan, Madhya Pradesh, Uttar Pradesh, and Maharashtra. Farmers often grow *Tinospora* in agroforestry systems or as an intercrop with other species (Basai, 2023). In the current study, biochemical properties of *T. cordifolia* accessions that were gathered from various parts of Tamil Nadu were studied.

Materials and methods

Sample collection

Healthy and younger stem samples of 48 *Tinospora* wild populations were collected from different parts of Tamil Nadu during

2021-23 (Table 1). The collection was based on phenotypic evaluation of various traits, including leaf arrangement, color, size, length, and breadth; stem color, size, and internodal distance; as well as flower count, color, and size. The collected populations were established in the medicinal garden of the Horticultural College and Research Institute, Tamil Nadu Agricultural University, following a RCBD (Randomized Complete Block Design) layout with three replications. The plants were propagated through stem cuttings and field planted, with a spacing of 2 m × 3 m, and cultural practices were carried out as per the scheduled guidelines (NMPB).

Table 1. Accessions of *T. cordifolia* collected from several sites in Tamil Nadu

Accession	Place	District	Latitude	Longitude	Altitude (MSL)
TC-01	Dharmathupatti	Theni	9°59′38″N	77°20′56″E	351 m
TC-02	Narasingapuram	Theni	9°56′18″N	77°36′01″E	341 m
TC-03	Palani	Dindigul	10°26′57″N	77°30′58″E	378 m
TC-04	Villacheri	Madurai	9°53′45″N	78°03′39″E	143 m
TC-05	Srivilliputhur	Virudhunagar	9°30′25″N	77°38′02″E	150 m
TC-06	Thalaivasal	Salem	11°35′10″N	78°45′30″E	162 m
TC-07	Thantheeni	Karur	10°55′50″N	78°05′49″E	131 m
TC-08	Samathuvapuram	Salem	11°49′32″N	77°55′09″E	360 m
TC-09	Kaveripattinam	Krishnagiri	12°25′05″N	78°13′05″E	464 m
TC-10	Nallampalli	Dharmapuri	12°03′33″N	78°06′49″E	485 m
TC-11	Papparapatti	Dharmapuri	12°12′25″N	78°03′26″E	494 m
TC-12	Perundurai	Erode	11°16′15″N	77°34′57″E	278 m
TC-13	Natrampalli	Thirupathur	12°35′07″N	78°30′29″E	443 m
TC-14	Kalavai	Ranipet	12°46′01″N	79°25′01″E	132 m
TC-15	Sendamangalam	Namakkal	11°16′51″N	78°14′15″E	180 m
TC-16	Somandargudi	Kallakurichi	11°45′36″N	78°55′56″E	135 m
TC-17	Cheyyar	Thiruvannamalai	12°39′12″N	79°32′39″E	90 m
TC-18	Thiruvetriyur	Ramanathapuram	9°42′29″N	78°57′02″E	11 m
TC-19	Gopalasamudram	Thirunelveli	8°40′22″N	77°37′49″E	55 m
TC-20	Thovalai	Kanyakumari	8°13′47″N	77°30′02″E	49 m
TC-21	Thally	Krishnagiri	12°35′09″N	77°39′09″E	910 m
TC-22	Nemili	Ranipet	12°36′07″N	78°31′00″E	435 m
TC-23	Gudiyatham	Vellore	12°56′12″N	78°52′46″E	268 m
TC-24	Pallikonda	Vellore	12°54′22″N	78°56′17″E	251 m
TC-25	Ashok Nagar	Chennai	13°02′09″N	80°12′43″E	10 m
TC-26	Virudhachalam	Cuddalore	11°30′52″N	79°19′31″E	33 m
TC-27	Neyveli	Cuddalore	11°32′07″N	79°28′46″E	35 m

TC-28	Kalpakkam	Kanchipuram	12⁰31′19″N	80⁰09′26″E	2 m
TC-29	Padappai	Kanchipuram	12⁰52′43″N	80⁰01′50″E	28 m
TC-30	Acharavakkam	Chengalpattu	12⁰41′44″N	79⁰58′41″E	32 m
TC-31	Pallipattu	Thiruvallur	13⁰19′59″N	79⁰26′34″E	158 m
TC-32	Vanthavasi	Thiruvannamalai	12⁰29′58″N	79⁰35′56″E	71 m
TC-33	Tindivanam	Villupuram	12⁰13′21″N	79⁰38′44″E	37 m
TC-34	Palaiyur	Mayiladuthurai	10⁰46′28″N	79⁰49′01″E	4 m
TC-35	Courtallam	Tenkasi	8⁰55′27″N	77⁰16′40″E	194 m
TC-36	Thirupuvanam	Sivagangai	9⁰49′25″N	78⁰15′15″E	106 m
TC-37	Thirukalukundram	Chengalpattu	12⁰36′18″N	80⁰03′50″E	33 m
TC-38	Mathampatti	Coimbatore	10⁰58′11″N	76⁰51′33″E	428 m
TC-39	Saravanampatti	Coimbatore	11⁰04′36″N	77⁰00′02″E	418 m
TC-40	Kinethukadavu	Coimbatore	10⁰48′39″N	77⁰01′20″E	308 m
TC-41	Kunnathur	Thirupur	11⁰15′43″N	77⁰25′01″E	313 m
TC-42	Kannaivadi	Thirupur	10⁰48′40″N	77⁰47′04″E	201 m
TC-43	Bhavanisagar	Erode	11⁰28′37″N	77⁰08′13″E	257 m
TC-44	Nilakottai	Dindigul	10⁰09′51″N	77⁰51′08″E	226 m
TC-45	Vedasandur	Dindigul	10⁰31′50″N	77⁰56′54″E	212 m
TC-46	Kallupatti	Madurai	9⁰43′04″N	77⁰51′13″E	142 m
TC-47	Karaiyipatti	Madurai	10⁰06′52″N	78⁰26′21″E	129 m
TC-48	Mohanur	Namakkal	11⁰03′18″N	78⁰08′39″E	117 m

Table 2 presents the methods used for qualitative phytochemical analysis, detailing the specific techniques employed to evaluate various biochemical compounds and nutrients in plant samples.

Results and discussion

Biochemical studies were conducted in the leaf samples of 48 *Tinospora* accessions, which revealed statistically significant differences among them for various parameters. The results are presented in Tables 3 and 4. Accession TC-22 exhibited the highest phenol content (122.73 mg/g), while TC-01 had the lowest content (46.56 mg/g). Previous studies have reported total phenolic contents in various plant species, such as *Bryophyllum pinnatum* (18.4 mg/g - leaves), *Ipomea aquatica* (18.8 mg/g - leaves), *Oldenlandia corymbosa* (11.6 mg/g - whole plant), *Ricinus communis* (29.2 mg/g - roots), *Terminalia bellerica* (29.6 mg/g - leaves), *Tinospora cordifolia* (40.8 mg/g - leaves), *Tinospora cordifolia* (12.8 mg/g - stem), and *Xanthium strumarium* (71.6 mg/g - leaves) as reported by Yadav and Agarwala (2011). Additionally, Kumar *et al.* (2013) observed a total phenol content of 17.3 ± 0.4 mg/g in *Tinospora* leaves.

Table 2. Methods of qualitative phytochemical analysis

Parameter	Methodology	Reference
Phenol	Bromination method	Ingberman (1958)
Flavonoids content (mg/g)	Aluminium chloride spectrometric technique	Chang *et al.*, (2002)
Antioxidant activity (%)	Stabilized DPPH radicals to measure free radical scavenging capacity	Koleva *et al.*, (2002)
Saponin	Determined using Obadoni and Ochuko technique	Obadoni and Ochuko (2001)
Cardiac glycosides	Quantitatively measured with minor adjustments to the described method	Solich *et al.*, (1992)
Protein (Bradford Method)	Bradford test procedure	Bradford (1976)
Carbohydrate content (mg/g)	Extractable carbohydrates measured using Anthrone method	Yemm and Willis (1954)
Tannin content	Modified AOAC procedure	AOAC (1980)
Nitrogen (%)	Determined using Kjeldahl technique	Kirk (1950)
Phosphorus (%)	Colorimetric technique with malachite green	Majed *et al.*, (2012)
Potassium (%)	Flame photometry	Bhandal and Malik (1988)
Calcium (%)	Titration with standardised EDTA solutions	Armstrong and Kirkby (1979)
Iron (ppm)	Spectroscopy	Jones (1991)
Magnesium (%)	Complexometric approach	Sahrawat, K. L. (1987)
Zinc (ppm)	Quantification via atomic-absorption spectroscopy	David (1958)
Manganese (ppm)	Determined using atomic absorption spectrometry	Tinggi *et al.*, (1997)
Copper (ppm)	Measured calorimetrically	Middleton (1965)
Fat content (%)	Recovery using a lipophilic solvent	Stien *et al.*, (2007)
Reducing sugar (%)	Quantified using Benedict's reagent	Thomas and Dutcher (1924)
Fibre (%)	Measured gravimetrically	Van Soest and McQueen (1973)
Energy	Total energy content estimated using FAO method	FAO (2003)
Vitamin C	Spectrometry for ascorbic acid quantification	Hassan and Hassan (2008)
Vitamin A	Measured using spectrophotometric techniques	Lopez-Teros *et al.*, (2017)

The present study recorded significantly higher protein content (13.85%) in TC-20. Tyagi and Chauhan (2020) reported a protein content of 6.26% in *Tinospora cordifolia* stem powder. Aranha *et al.* (2012) isolated Guduchi protein with a yield of 29 mg/100 g fresh stem or 7.0% in dried leaf powder. Among the accessions, TC-20 exhibited the highest carbohydrate content (86.92 mg/g) in our research. The presence of carbohydrates in *Tinospora* plants has been reported by Yadav and Agarwala (2011). Kumar *et al.* (2013) observed the presence of carbohydrates at a level of 84.1 ± 5.2 mg/g. Its high protein and carbohydrate content contributes to the provision of vital energy. In our current study, TC-22 showed the highest total flavonoid content (18.84 mg/g). Similarly, Yadav and Agarwal (2011) reported the presence of flavonoids in extract of various plants, including *Bryophyllum pinnatum* (8.4 mg/g - leaves), *Ipomea aquatica* (37.6 mg/g - leaves), *Oldenlandia corymbosa* (4.4 mg/g - whole plant), *Ricinus communis* (6 mg/g - roots), *Terminalia bellerica* (42.8 mg/g - leaves), *Tinospora cordifolia* (18 mg/g – leaves, 6 mg/g - stem), and *Xanthium strumarium* (28.8 mg/g - leaves). In another study, Kumar *et al.* (2013) identified flavonoid contents of 6.5 ± 0.2 mg/g in *Tinospora* leaves.

In our study, the highest tannin content of 234.56 mg/g was observed in accession TC-30, while the lowest content of 142.74 mg/g was recorded in TC-35. Choudhry *et al.* (2014) in a similar study reported tannin content of 154.1 mg/g in male and 162.5 mg/g in female *Tinospora* plants. Kumar *et al.* (2013) reported a tannin content of 133.8 ± 0.5 mg/g. Khan *et al.,* (2020) discovered a substantial quantity of tannin (204.39 ± 19.66 mg) in the methanol extract of *Tinospora.* According to Uadia *et al.,* (2017), tannins are present in the leaf, stem, and root of *Vernonia amygdalina* and the tannin content in the root (33.90 mg) was lower compared to the leaf (69.33 mg) and the stem (50.70 mg).

The DPPH technique, commonly used to assess antioxidant activity, was employed to evaluate the extracts' ability to scavenge free radicals. In our study, the highest antioxidant activity was observed in TC-20 at 261.74%, while the lowest activity was found in TC-1 at 48.56%. Contrary to the findings of our study, Upadhyay *et al*. (2014) reported the best antioxidant activity of 84.62 mg/g in *Tinospora* ethanolic extract. According to Premanath and Lakshmidevi (2010), ethanolic and methanolic leaf extracts of *T. cordifolia* demonstrated higher efficacy in scavenging DPPH radicals compared to the aqueous stem extract, with an EC50 value of 0.5 mg/mL for ethanol and 0.9 mg/mL for methanol. Accession TC-22 exhibited the highest levels of nitrogen (1.06%), phosphorus (1.17%), and magnesium (7.55%) in our study. However, Shivraj and Khobragade (2009) reported nitrogen content of 0.45%, phosphorus content of 0.57%, and magnesium content of 6.41% in *Tinospora* leaves.

In the present study, TC-20 exhibited the highest levels of potassium (1.45%), calcium (0.35%), and iron (48.74%). Consistent with these findings, Shivraj and Khobragade (2009) reported potassium content of 0.845%, calcium content of 0.13%, and iron content of 28.00% in *Tinospora* herbage. Our

research recorded significantly higher zinc content of 15.67 µg/g in TC-20. Similarly, Tyagi and Chauhan (2020) reported a good quantity of zinc (10.35 µg/g) in *Tinospora* leaf powder, and Shivraj and Khobragade (2009) also reported 12.00 µg/g of zinc in the same crop. TC-22 exhibited the highest manganese content of 17.76 ppm in our study, while Garg *et al.* (2022) reported manganese content of 56.7 ± 1.5 µg/g in the same plant. TC-30 recorded the highest copper content of 6.19 µg/g. Tyagi and Chauhan (2020) reported copper content of 10.01 µg/g, and Shivraj and Khobragade (2009) found 3.10 µg/g of copper in *Tinospora* leaf samples.

TC-30 showed the highest fat content of 8.81%. Modi *et al.* (2020) observed a fat content of 3.1% in *Tinospora* leaves. TC-20 exhibited the highest saponin content of 3.88% in our study, while Shervani and Mishra (2019) reported saponin content of 2.59% (Sample I), 2.34% (Sample II), and 2.10% (Sample III) in *Tinospora* cultivated in different soil conditions. TC-22 had the highest cardiac glycoside content of 2.27% in our study, whereas Pradhan *et al.* (2013) reported cardiac glycoside content of 1.52 ± 0.03 (Chhindwara), 0.56 ± 0.02 (Jabalpur), and 0.72 ± 0.02 (Seoni) in different districts of Madhya Pradesh.

TC-14 exhibited the highest reducing sugar content of 0.26% in our study. Similarly, Khan *et al.* (2011) observed reducing sugar content of 55 mg/g in freshly ripened *Tinospora* fruits. TC-35 showed significantly higher fiber content of 13.22% in our study, while Tyagi and Chauhan (2020) reported crude fiber content of 4.69% in *Tinospora* leaf powder. TC-35 had the highest energy content of 99.66 Kcal/100g in our study, whereas Shivraj and Khobragade (2009) reported an energy content of 292.54 Cal/100g in the same crop. TC-33 exhibited the highest vitamin C content of 68.96 mg/100g and vitamin A content of 0.44 mg/100g in our study. Gupta and Sharma (2011) reported vitamin C content of 41.36 mg/100g in *T. cordifolia* leaves. The conservation and utilization strategy involves establishing a field gene bank at the Medicinal Department of HC&RI, TNAU, where all 48 accessions will be cultivated and maintained under controlled conditions.

Table 3. Biochemical characterization of *Tinospora cordifolia* from diverse accessions

Accession	Phe. (mg/g)	Pro. (%)	Car. (mg/g)	Fla. (mg/g)	Tan. (mg/g)	AO (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe(ppm)
TC-01	48.56	7.62	63.98	10.53	177.45	191.51	0.48	0.79	0.53	0.20	5.15	25.61
TC-02	67.34	5.98	49.94	9.86	201.75	209.43	0.72	0.91	1.01	0.14	4.83	29.48
TC-03	71.85	8.51	56.77	11.47	164.41	215.67	0.69	0.80	0.64	0.14	6.24	30.06
TC-04	86.76	6.88	72.58	8.66	210.94	187.56	0.57	0.58	0.98	0.10	3.95	27.91
TC-05	64.64	7.98	54.56	11.48	212.58	175.98	0.71	0.82	0.52	0.22	4.37	24.42
TC-06	98.12	10.76	73.01	10.56	192.56	210.56	0.82	0.69	0.56	0.16	5.02	22.57
TC-07	71.67	6.42	71.22	9.08	208.71	162.77	0.75	0.98	0.76	0.18	4.86	30.56
TC-08	95.61	9.23	63.47	10.77	149.74	181.05	0.62	0.58	1.01	0.17	4.98	27.41
TC-09	94.86	8.43	54.67	8.94	195.86	197.18	0.80	0.61	0.76	0.13	6.41	27.64
TC-10	86.74	9.76	50.51	12.56	165.71	179.86	0.75	0.82	0.93	0.25	6.24	23.87
TC-11	68.18	7.99	63.81	9.81	209.59	192.56	0.68	0.78	0.83	0.14	4.84	26.41
TC-12	91.76	5.71	74.47	8.56	193.56	174.86	0.74	0.75	0.79	0.19	5.39	29.56
TC-13	74.86	8.92	53.81	8.41	184.76	201.56	0.64	0.96	0.79	0.16	5.83	25.64
TC-14	75.84	5.57	69.78	10.66	180.62	210.56	0.74	0.64	0.82	0.17	5.92	28.42
TC-15	100.07	9.16	71.48	11.91	156.67	221.87	0.76	1.00	0.68	0.18	5.63	26.92
TC-16	89.78	7.85	63.54	10.64	200.56	200.02	0.61	0.71	1.11	0.13	4.16	21.57
TC-17	103.77	9.78	79.43	12.95	215.57	240.86	0.83	0.59	0.64	0.19	5.76	31.87
TC-18	79.56	5.47	76.09	8.25	173.85	209.14	0.58	0.69	1.02	0.16	5.63	28.37
TC-19	63.51	7.81	64.85	10.41	192.56	173.56	0.71	0.89	0.79	0.18	3.67	27.86
TC-20	116.84	13.85	86.92	15.58	213.58	261.74	0.85	1.06	1.45	0.35	6.39	38.74
TC-21	84.86	5.90	71.56	8.76	192.51	206.61	0.59	0.69	0.90	0.13	6.46	31.86
TC-22	122.73	12.93	85.66	18.84	227.51	256.47	1.06	1.17	1.29	0.29	7.55	35.55
TC-23	109.76	7.39	81.66	13.56	204.47	225.61	0.56	0.74	0.65	0.15	4.57	28.16
TC-24	92.54	6.50	73.59	12.41	187.34	214.76	0.66	0.63	0.77	0.26	5.69	29.13
TC-25	88.81	9.81	59.64	9.65	212.58	217.86	0.52	0.78	0.73	0.21	5.92	28.57
TC-26	110.49	12.68	81.54	17.78	221.58	234.56	0.90	1.04	0.95	0.22	7.12	34.75

TC-27	101.55	7.35	73.54	9.12	167.55	169.45	0.64	0.98	0.65	0.13	5.76	32.49
TC-28	83.97	10.85	50.85	10.76	156.48	174.76	0.53	0.89	0.62	0.16	4.47	29.47
TC-29	99.12	5.78	79.56	8.56	181.84	171.98	0.78	0.64	0.64	0.19	4.86	30.56
TC-30	107.53	8.22	78.63	16.71	234.56	260.57	0.75	0.88	0.59	0.18	6.94	31.86
TC-31	95.97	7.05	67.71	13.41	160.38	198.03	0.69	0.56	0.96	0.09	5.81	28.56
TC-32	113.46	11.43	75.76	16.08	219.76	255.61	0.86	1.12	1.44	0.27	6.41	33.60
TC-33	85.67	5.82	62.51	10.38	168.35	185.76	0.69	0.86	0.72	0.17	5.28	25.54
TC-34	92.86	7.92	74.48	9.78	196.67	177.56	0.63	0.93	0.74	0.16	5.62	23.89
TC-35	76.84	9.46	63.86	12.01	142.74	204.67	0.77	0.86	1.24	0.19	3.85	21.41
TC-36	82.78	6.76	54.48	11.09	176.48	186.76	0.84	0.75	0.65	0.15	5.42	30.86
TC-37	85.67	8.56	64.88	8.32	154.75	194.86	0.71	0.94	0.82	0.19	6.09	26.86
TC-38	75.67	7.12	53.85	10.05	177.71	197.67	0.79	0.85	0.86	0.17	4.28	30.56
TC-39	78.09	6.55	66.44	13.55	185.56	201.34	0.65	0.67	0.83	0.18	5.08	31.41
TC-40	105.67	9.98	84.85	16.64	220.94	235.67	0.91	1.13	1.39	0.25	6.05	33.84
TC-41	94.56	6.85	69.42	10.98	156.75	183.82	0.74	0.95	0.69	0.15	3.63	29.13
TC-42	77.98	10.42	66.67	10.74	192.84	182.86	0.67	0.86	1.01	0.17	4.92	25.80
TC-43	98.57	8.82	59.84	8.47	214.47	212.18	0.82	0.76	0.76	0.20	5.76	31.95
TC-44	64.89	6.07	56.67	11.54	163.47	176.12	0.68	0.67	1.22	0.18	5.43	26.49
TC-45	91.81	8.05	52.01	8.85	174.71	183.56	0.56	0.78	0.73	0.23	5.21	29.47
TC-46	79.56	9.28	71.08	9.18	185.67	226.46	0.73	0.87	0.87	0.18	4.26	28.62
TC-47	76.78	7.98	52.67	12.61	148.56	185.67	0.49	0.92	1.12	0.19	5.19	31.96
TC-48	99.10	9.58	69.91	8.79	169.08	163.56	0.68	0.83	0.75	0.19	6.19	24.47
C.D.	3.841	0.352	2.637	0.469	8.546	8.049	0.029	0.035	0.039	0.008	0.24	1.284
SE(m)	1.366	0.125	0.938	0.167	3.039	2.862	0.010	0.013	0.014	0.003	0.08	0.456

Phe.- Phenol (mg/g), Pro.- Protein content (%), Car.- Carbohydrate content (mg/g), Fla.- Flavonoids content (mg/g), Tan.- Tannin content (mg/g), AO- Anti- oxidant content (%), N-Nitrogen (%), P-Phosphorus (%), K-Potassium (%),Ca-Calcium (%), Mg-Magnesium (%), Fe-Iron (ppm)

Table 4. Biochemical characterization of *Tinospora cordifolia* from diverse accessions

Accession	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fat (%)	Sap. (%)	Ca. Gl. (%)	Re. Su. (%)	Fib. (%)	Ene. (Kcal/100g)	Vit. C (mg/100g)	Vit. A (mg/100g)
TC-01	9.48	10.57	5.11	4.98	2.34	1.42	0.13	11.32	88.60	56.03	0.30
TC-02	8.72	9.32	3.84	6.73	2.59	0.58	0.15	10.91	86.44	61.25	0.23
TC-03	10.54	8.52	4.99	5.49	2.10	0.26	0.19	11.18	81.39	49.69	0.28
TC-04	6.26	12.99	5.52	6.56	2.63	1.86	0.20	11.86	82.68	52.89	0.36
TC-05	8.13	14.82	5.87	7.17	2.32	1.57	0.10	10.36	85.27	65.64	0.41
TC-06	7.67	12.59	4.51	5.72	2.28	0.30	0.09	12.11	79.66	57.57	0.22
TC-07	12.22	9.62	3.99	7.51	2.05	0.87	0.12	10.76	94.34	59.56	0.25
TC-08	9.88	9.66	4.62	4.49	2.95	1.02	0.17	11.59	84.58	50.76	0.43
TC-09	7.56	12.92	4.86	7.79	2.46	1.98	0.11	12.02	95.65	66.18	0.32
TC-10	7.06	9.82	3.76	2.62	2.60	2.05	0.18	11.00	93.47	55.89	0.19
TC-11	8.92	9.88	4.62	4.49	2.30	0.85	0.15	12.93	96.55	53.60	0.36
TC-12	9.56	13.56	4.26	4.83	2.20	0.23	0.19	10.21	90.73	64.58	0.30
TC-13	7.98	14.86	3.28	3.97	2.00	1.34	0.22	11.25	89.60	55.32	0.31
TC-14	8.57	10.56	3.82	6.47	3.19	2.00	0.26	10.83	87.22	61.16	0.23
TC-15	11.54	9.97	4.39	6.49	1.99	1.44	0.21	11.25	80.45	48.75	0.28
TC-16	7.42	14.91	3.82	6.36	3.65	1.35	0.17	11.94	83.18	54.32	0.37
TC-17	12.85	15.67	4.86	4.42	2.45	1.76	0.14	10.29	84.67	64.66	0.41
TC-18	8.88	10.56	3.69	8.36	2.90	1.19	0.20	12.10	79.70	56.32	0.22
TC-19	10.56	12.48	3.22	8.40	3.05	0.34	0.13	10.52	92.64	59.26	0.25
TC-20	15.67	16.49	5.76	3.46	3.88	1.30	0.15	11.54	83.73	53.09	0.41
TC-21	10.85	15.52	5.63	7.44	3.13	0.98	0.19	11.80	92.13	65.49	0.32
TC-22	13.67	17.76	4.96	4.54	2.22	2.27	0.20	12.92	94.87	56.31	0.19
TC-23	9.32	15.50	5.17	7.68	0.98	1.41	0.10	12.54	97.59	54.48	0.37
TC-24	11.84	16.06	3.49	5.96	2.27	0.57	0.09	10.32	89.37	64.21	0.29
TC-25	11.56	14.31	4.09	1.92	2.64	0.25	0.12	11.11	88.93	55.79	0.29

TC-26	13.38	16.91	4.42	3.97	2.08	1.85	0.18	10.66	86.25	61.62	0.22
TC-27	8.42	14.82	5.03	7.74	2.66	1.53	0.11	11.40	85.13	50.40	0.28
TC-28	9.86	11.56	4.63	6.56	2.31	1.43	0.19	11.89	84.17	52.53	0.34
TC-29	8.74	13.34	3.82	8.17	2.28	0.59	0.15	10.45	85.42	66.95	0.43
TC-30	13.30	16.59	6.19	8.81	2.15	0.26	0.19	12.09	79.50	57.15	0.22
TC-31	12.02	9.49	5.62	7.47	2.92	1.90	0.13	10.94	93.77	60.75	0.25
TC-32	14.47	8.57	4.96	7.21	2.47	1.58	0.14	11.80	85.21	49.01	0.43
TC-33	11.57	13.52	3.98	6.36	2.62	1.42	0.19	12.31	92.34	68.96	0.44
TC-34	10.42	9.99	5.62	6.28	2.25	0.58	0.20	10.90	91.60	54.21	0.19
TC-35	6.75	8.98	5.06	8.44	2.19	0.27	0.10	13.22	99.66	53.89	0.34
TC-36	8.63	10.46	5.36	7.80	2.39	1.83	0.09	10.55	90.28	66.07	0.30
TC-37	6.92	14.96	3.86	2.18	2.61	1.60	0.12	11.60	87.27	56.98	0.30
TC-38	8.56	11.84	5.09	3.39	2.11	1.41	0.17	11.24	85.86	60.97	0.24
TC-39	8.56	13.56	3.43	8.56	2.64	2.00	0.11	10.89	78.58	49.93	0.28
TC-40	13.37	16.36	5.43	5.64	2.36	1.49	0.17	11.75	80.70	51.82	0.36
TC-41	8.56	11.41	4.56	6.32	2.26	1.37	0.15	10.34	85.72	65.31	0.40
TC-42	11.86	13.86	3.85	4.49	1.98	1.75	0.19	12.13	79.78	59.24	0.22
TC-43	9.86	14.82	4.42	6.47	2.97	1.18	0.13	10.82	96.60	58.67	0.25
TC-44	8.48	13.86	3.62	7.37	2.45	1.99	0.15	11.43	84.79	50.18	0.32
TC-45	6.83	14.71	5.63	7.92	2.66	1.37	0.19	11.95	94.48	64.10	0.32
TC-46	7.67	12.56	4.82	6.37	2.31	1.33	0.20	11.07	93.94	57.15	0.18
TC-47	12.67	12.58	3.93	2.96	2.18	1.77	0.10	13.03	92.40	52.42	0.36
TC-48	9.74	11.47	5.42	8.56	2.36	1.19	0.09	9.75	92.54	63.47	0.31
C.D.	0.414	0.592	0.183	0.245	0.094	0.066	0.008	0.509	3.628	2.639	0.013
SE(m)	0.147	0.210	0.065	0.087	0.034	0.024	0.003	0.181	1.290	0.938	0.004

Zn- Zinc (ppm), Mn- Manganese (ppm), Cu- Copper (ppm), Fat content (%), Sap- Saponin (%), Ca. Gl.- Cardiac Glycosides (%), Re. Su.- Reducing sugar (%), Fib.- Fibre (%), Energy (Kcal/100g), Vit. C- Vitamin C (mg/100g), Vit. A- Vitamin A (mg/100g).

Conclusion

The current investigation reveals high degree of variability in biochemical constituents of *Tinospora* which varied among locations. Significant diversity was seen in terms of the qualitative indices. Collections with superior characters were identified viz. TC-22 (Nemili, Ranipet district) recorded the highest phenol (122.73 mg/g), flavonoid (18.84 mg/g), nitrogen (1.06%), phosphorus (1.17%), magnesium (7.55%) manganese (17.76 ppm) and cardiac glycosides (2.27%) contents. TC-20 (Thovalai, Kanyakumari district) showed significantly higher protein (13.85%), carbohydrate (86.92mg/g), antioxidant activity (261.74 %), potassium (1.45%), calcium (0.35%) and zinc (15.67 µg/g). TC-30 (Acharavakkam, Chengalpattu) recorded maximum tannin (234.56 mg/g), copper (6.19µg/g) and fat (8.81%) contents. TC-35 (Courtallam, Tenkasi district) was identified as higher fibre (13.22%) and energy rich (99.66 Kcal/100g). Maximum vit. C (68.96 mg/100g) and vit. A (0.44 mg/100g) were observed in TC 33 (Tindivanam, Villupuram). The findings indicates that ecological condition under which *Tinospora* is grown determines its biochemical and nutritional quality.

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