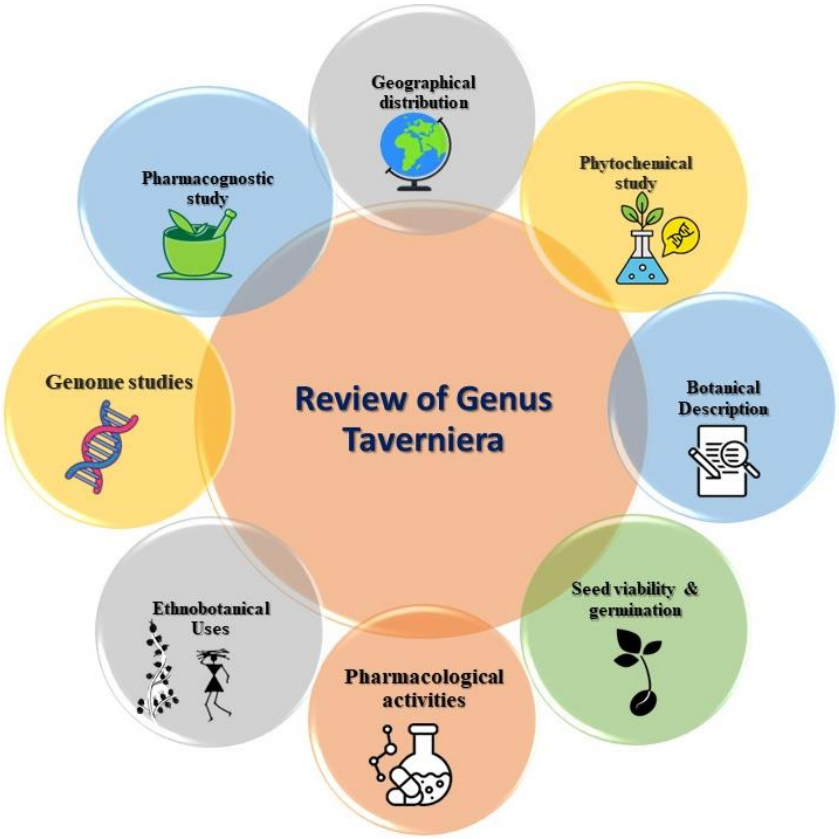
REVIEW OF LITERATURE

Chapter II



2.1 Distribution and Ecology

Taverniera DC. genus consists of 17 species distributed in African, Middle east and Asian countries, out of which two species occur in India (Mangalorkar, 2013). Several botanists—Roxburg (1832), Graham (1839), Dalzell (1850), Palin (1880), Hooker (1872-1897), Gray (1886), Boissier (1888), Narine (1894), Libosa (1896) and Woodrow (1897-1901) - reported the occurrence of *Taverniera cuneifolia* in India. Additionally, the Flora of Presidency of Madras (Gamble, 1901) and the Flora of Presidency of Bombay (1908) provided further information on the species' detailed description and range of occurrence respectively. In "Notes on vegetation at Dwarka" by Borgeson (1929) included a brief discussion of *T. cuneifolia*.

The plant's description and existence after independence have been documented in the Flora of Saurashtra (Santapau 1953, 1962). Later on, Ali provided a detailed description of *T. cuneifolia* in 1977, and the International Plant Name Index (IPNI) subsequently selected *T. cuneifolia* (Roth) Ali as the official name. The chromosomal count was published for the first time by

Jahan *et al* (1994). Sarwar (2002) revised the status of *T. cuneifolia* in the Flora of Pakistan. As per the International Plant Name Index (IPNI), details of *T. cuneifolia* as follows:

Genus: Taverniera DC.

Botanical name: Taverniera cuneifolia (Roth) Ali

Higher Taxon: Hedysareae

Synonyms: *Hedysarum cuneifolium* Roth, *Taverniera ephedroidea* Jaub. & Spach, *Taverniera glabra* Boiss, *Taverniera nummularia* sensu Baker :auct. non DC., *Hedysarum gibsonii* Grah., *Onobrychis cuneifolia* DC., *Onobrychis diffusa* Camb., *Taverniera stocksii* Boiss.

Vernacular names:

English: East Indian moneywort (ILDIS),

Gujarati: Desi jethimadh (Thaker, 1908), Jethimal, Jethimadh

2.2 Phlyogenetic status

Cladistically, *T. cuneifolia*, a member of the Fabaceae family, was first placed in the Rosales (Bentham & Hooker); however, newer classifications by Cronquist and APG III based on phytoconstituents and the matK gene have placed it in the Fabales. The following is the status of *T. cuneifolia* according to multiple classifications (Table 2.1):

Table 2.1: Taxonomical status of *Taverniera cuneifolia*

Bentham & Hooker (1862-1883)	**Cronquist (1988)**	**APG IV (2016)**
Division: Spermatophyta	**Kingdom:** Plantae	**Clade:** Eudicots
Sub Division: Angiospermae	**Phylum:** Magnoliophyta	**Clade:** Core eudicots
Class: Dicotyledonae	**Class:** Magnoliopsida	**Clade:** Eurosids
Sub Class: Polypetalae	**Sub class:** Rosidae	**Order:** Fabales
Series: Calyciflorae	**Superorder:** Fabanae	**Family:** Fabaceae
Order: Rosales	**Order:** Fabales	**Sub family:** Faboideae

Family: Fabaceae	**Family:** Fabaceae	**Tribe:** Hedysareae
Genus: Taverniera	**Genus:** Taverniera	**Genus:** Taverniera
Species: cuneifolia	**Species:** cuneifolia	**Species:** cuneifolia

2.3 Geographical Distribution

Taverniera genus belong to the family Fabaceae which has seventeen species: *T. abyssinica* A. Rich., *T. aegyptica* Boiss., *T. albida* Thulin, *T. brevialata* Thulin, *T. cuneifolia* (Roth) Arn., *T. diffusa* (Cambess.) Thulin, *T. echinate* Mozaff., *T. glabra* Boiss., *T. glauca* Edgew., *T. lappacea* (Forssk.) DC., *T. longisetosa* Thulin, *T. multinoda* Thulin, *T. nummularia* DC., *T. oligantha* (Franch.) Thulin, *T. schimperi* Jaub. & Spach, *T. sericophylla* Balf.f. and *T. spartea* DC. Geographically out of 17 species, 7 species are restricted to Africa (Djibouti, Egypt, Ethiopia, Somalia and Sudan) from which *T. abyssinica* and *T. schimperi* is endemic to Ethiopia, *T. longisetosa* is endemic to Somalia, *T. oligantha* is endemic to Djibouti and *T. sericophylla* is endemic to Socotra, which is an extinct species as per the International Legume Database and Information Service (Plant of the World online). Rest 11 species are found in Middle East country (Bahrain, Iran, Iraq, Oman, Qatar, Saudi Arabia, South Yemen, United Arb Emirates and Yemen), of which *T. albida* and *T. glauca* are endemic to Yemen, *T. brevialata* is restricted to Oman, *T. echinata* is endemic to Iran. South Asian countries (India and Pakistan) have just five species: *T. cuneifolia* and *T. diffusa*, *T. glabra*, *T. lappacea*, and *T. spartea*, the first two of which are exclusively found in India (Table 2.1) (Plant of the World online, The plant list and The Catalogue of Life) (Table 2.2) (Fig. 2.1).

Species Name	**Synonyms**	**Geographical Distribution**
Taverniera abyssinica A. Rich. (Thulin, 1985)	*Taverniera schimperi* Jaub. and Spach var. *oligantha* sensu Cufod	Africa: Ethiopia (Thulin, 1985)
Taverniera aegyptiaca Boiss. (Thulin, 1985)	NA*	Africa: Djibouti (Audru *et al*., 1987) Egypt, Ethiopia Sudan Middle East, Saudi Arabia (Thulin, 1985)
Taverniera albida Thulin. (Thulin, 1985)	NA*	Asia; Middle East: South Yemen (Thulin, 1985)
Taverniera brevialata Thulin (Thulin, 1985)	NA*	Asia; Middle East-Oman (Thulin, 1985)
Taverniera cuneifolia (Roth) Arn.	*Hedysarum cuneifolium* Roth *Taverniera stocksii* Boiss. *Taverniera nummularia* Baker (*Plant of the World online, powo.science.kew.org*).	India, Iran, Oman, Pakistan, Somalia, united Arb Emirates (*Plant of the World online, powo.science.kew.org*).
Taverniera diffusa (Cambess.) Thulin (Thulin, 1985)	*Onobrychis diffusa* Cambess (Thulin, 1985)	Asia- India: Punjab, Rajasthan; Pakistan (Thulin, 1985) United Arb Emirates, Somalia, Oman (Catalogue of Life)
Taverniera echinata Mozaff. (Mozaffarian, 1988)	NA*	Asia; Iran (Mozaffarian, 1988)
Taverniera glauca Edgew. (Thulin, 1985)	NA*	Asia; Middle East: South Yemen (Thulin, 1985); Yemen (Boulos, 1988)

Taverniera glabra Boiss.	*Taverniera ephedroidea* Jaub. & Spach (Plant of the World online, powo.science.kew.org).	Arabian Peninsula, S. Iran to Pakistan. (*Plant of the World online, powo.science.kew.org*).
Taverniera lappacea (Forssk.) DC. (Thulin, 1985; Ali, 1977)	*Hedysarum lappaceum* Forssk. (Ali, 1977) *Taverniera stefaninii* Chiov. (Thulin, 1985; Ali, 1977)	Africa: Ethiopia, Somalia, Sudan; Asia (Thulin, 1985) Pakistan (Thulin, 1985; Ali, 1977) Middle East: Oman, Saudi Arabia, South Yemen (Thulin, 1985)
Taverniera longisetosa Thulin	NA*	Africa: Somalia (Thulin, 1985)
Taverniera multinoda Thulin	NA*	Africa: Somalia; Middle East: Oman (Thulin, 1985)
Taverniera nummularia DC. (Townsend, 1974)	*Taverniera persica* Boiss. and Hausskn.	Asia: Iran (Thulin, 1985; Townsend, 1974; Parsa, 1948; Rechinger, 1984) Iraq (Thulin, 1985; Townsend, 1974; Rechinger, 1984)
Taverniera oligantha (Franch.) Thulin (Thulin, 1985)	*Taverniera schimperi* Jaub. and Spach var. *oligantha* Franch.	Africa: Djibouti (Thulin, 1985)
Taverniera schimperi Jaub. & Spach,	NA*	Africa: Ethiopia (Thulin, 1985)
Taverniera sericophylla Balf.f.	NA*	Africa: Socotra (Thulin, 1985)
Taverniera spartea DC. (Thulin, 1985; Ali, 1977)	*Hedysarum spartium* Burm. F., *Taverniera gonoclada* Jaub. & Spach (Ali, 1977) *Taverniera incana* Boiss. (Thulin, 1985)	Asia: Iran (Thulin, 1985; Townsend, 1974; Parsa, 1948; Rechinger, 1984) Pakistan (Ali, 1977) Middle East: Bahrain, Oman, Qatar, Saudi Arabia, United Arab Emirates (Thulin, 1985)

NA*: Not available

Table 2.2: Geographical distribution of different species of *Taverniera* genus

Internationally T. cuneifolia has been discovered throughout in coastal regions in Africa, Asia, and Eurasia. From Africa, Somalia (Thulin, 1985); from Asia, Iran (Thulin, 1985); Pakistan (Thulin, 1985; Ali, 1977); and from Eurasia (Middle East), Oman (Thulin, 1985); United Arab Emirates (Thulin, 1985); and Farasan Islands (Alfarhan, 2005).

Nationally, *T. cuneifolia* has been seen in **Gujarat** (Shah, 1978) - Shetrunjaya, Rozimata temple, Narara beyt, Rampara sanctuary, Hingolgadh sanctuary (Nagar, 2008), **Kutch** (Bhuj) Tapkeshwari Hill Range (Joshi et al., 2013), Gir forest, Ghumli, Dwarka, and Gir forest (Santapau, 1962) **Maharashtra** (Karthikeyan & Kumar, 1993) - Majalgaon (Khan *et al*., 2012), **Osmanabad** (Jamdhade and Surwase 2013), **Karnataka** - (Bijapur, Madhbhavi, Raichur and Bellary (Singh, 1988), **Madhya Pradesh** (Sanjappa, 1992); Orissa (Bairiganjan et al., 1985); **Punjab** (Bhandari, 1978) -Plains of Punjab (Khare, 2007); **Rajasthan** (Bhandari, 1978, Shetty & Singh, 1987); **West Bengal** (Sanjappa, 1992), **Andhra Pradesh** (Gamble, 1918; Rao et al., 2006) - Betam cherala, Kurnool district, **Jammu and Kashmir**: North West Himalaya (Chauhan *et al*., 2003; Fig. 2.1 and 2.2).

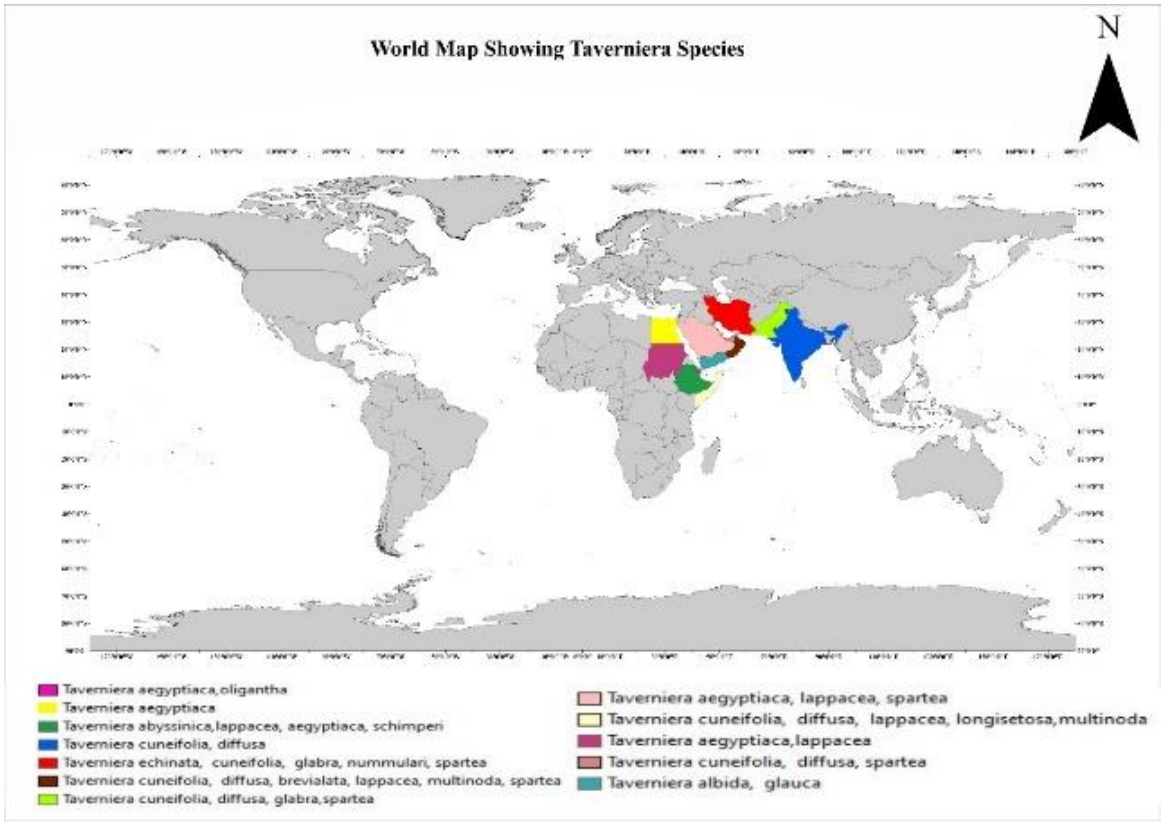


Figure 2.1: Distribution of *Taverniera* genus in world map

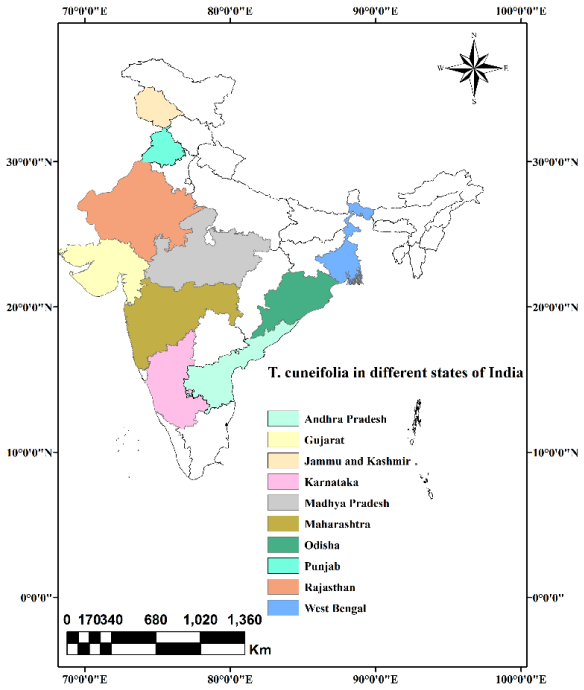


Figure 2.2: *T. cuneifolia* in different states of India

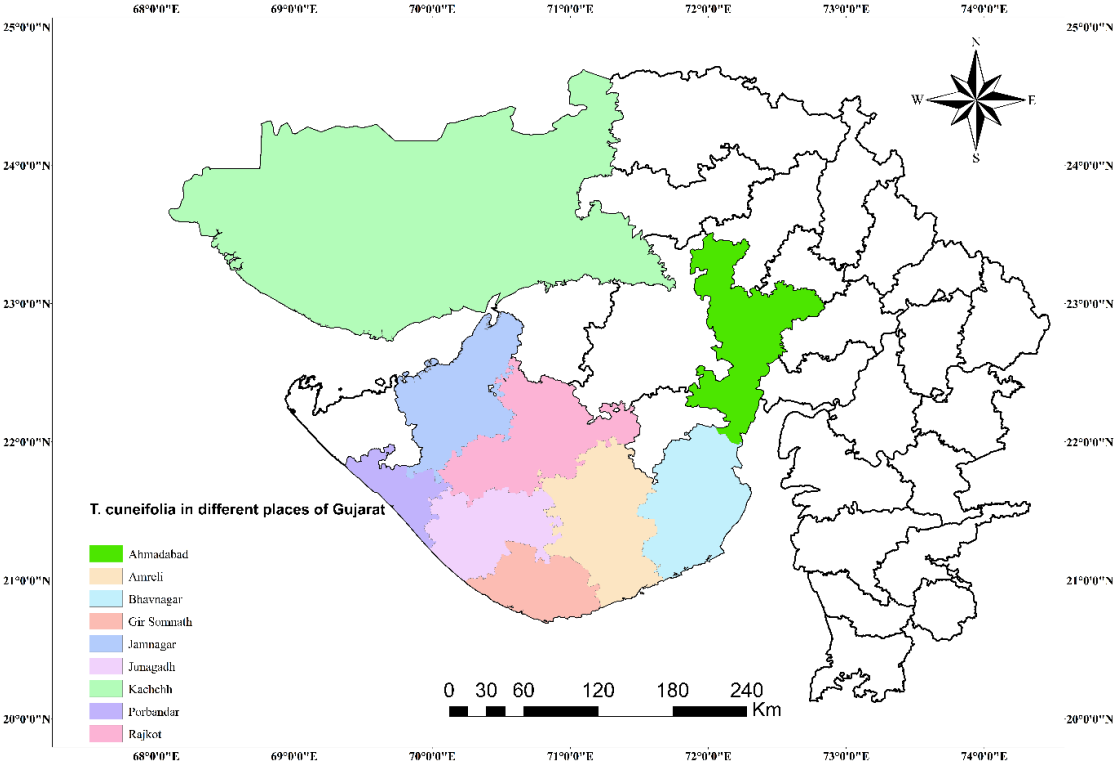


Figure 2.3: *T. cuneifolia* in different places of Gujarat

2.4 Botanical Description of *Taverniera* genus

All Taverniera species are either perennial shrubs or shrublets. The leaves are unifoliolate or digitate to ternate, with typically thick leaflets. Flowers are present in axillary racemes or are sometimes reduced to 1–few-flowered clusters; Calyx teeth are subequal or the two uppers are farther apart. Corolla purple, marcescent, standard widely obovate, constricted at the base, barely clawed; wings small; keel about equal to the standard, obliquely truncated at the apex; Stamen Monadelphous; anther uniform. Fruit Pod depressed, splitting transversely into 1–5 indehiscent 1-seeded segments (Plants of the World online, Cooke, 1908).

2.4.1 Ecology

The flowers of Taverniera cuneifolia are often beautiful to attract pollinators since the plant is predominantly insectivorous. This excess of seed production acts as a survival strategy. They are 2 mm in diameter and brown to golden in colour. The leaves are adapting to terrestrial and salty environments. In coastal locations, the leaves are rather fleshy (swollen), whereas in terrestrial places they are membranous. Another intriguing adaptation is the winter and summer shade of leaves, although photosynthesis continues in the green stem. This is likely the reason why even green twigs may be spotted throughout the off-season and sugar storage persists. *Aristida* sp., *Helandia latebrosa, Zizyphus nummularia, Alyscicarpus vaginalis, Bothriochloa pertusa, Indigofera cordifolia*, and *Pulicaria wightiana* coexist alongside *T. cuneifolia* in fallow areas.

2.4.2 Pharmacognostic study

Pharmacognostic investigation on the roots of *T.cuneifolia* was carried out from the perspective of anatomy, powder and histochemical studies by Mangalorkar *et al.*, (2013); Gohil and Daniel (2014) and Prajapati *et al*. (2013; 2014). Pericyclic fibres, bast fibre, prismatic crystals, cork cells, and starch grains were discovered in the roots of *T. cuneifolia* in this study. Prismatic crystals (calcium oxalate crystals), pericyclic fibres, single layered epidermis, and anisocytic stomata were observed in leaf pharmacognostics. The upper and lower epidermal stomatal indexes are 14 and 13 respectively. Histochemical investigations reported the presence of particular starch grains, tannin, and lignin. Study on stem revealed the presence of discontinued pericyclic fibres, prismatic crystal and oil-globules whereas roots showed the presence of barrel shaped lignified cork cell, simple, compound starch grain and pericyclic fibres.

2.4.3 Ethnobotanical uses

T. abyssinica has traditionally been used to treat headaches, colic, fever, and stomach-aches. It can also be smoked, chewed, or drunk as juice or as a root infusion (Helmut *et al*., 2014; Gulumian *et al*., 2018).

T.cuneifolia root decoction is used to cure cough and fever whereas the paste of root is applied on the swollen portion. Roots and seeds are preferred nutritional sources of food for poor people. In Porbandar area, ayurvedic physicians employ the whole plant in the preparation of bhasma (incinerator) Thaker, (1910).

2.5 Phytochemistry, Pharmacological and Bioactive compounds

In this section, the review of phyto-chemical aspect of *Taverniera* species has been done. So far, total 117 compounds were identified and isolated, which includes terpenoids, flavonoids, triterpenoid saponins, phenolic acids, saponins, organic acids, fatty acids, amino acids, sugars, vitamins, saikosaponins and sterols. Out of these, flavonoids and terpenoids were the most prominent. The detailed summary of the reported phytochemical and pharmacological studies on Taverniera genus is given in Table 2.3. 2.4, 2.5, respectively.

2.5.1 Primary metabolites

Primary metabolites are components that are specifically involved in plant development and metabolism and are essential in sustaining normal physiological functions. Primary metabolites reported form *Taverniera* spp. are amino acids, fatty acids, carbohydrates and vitamins which are mainly isolated from the roots and aerial parts of the plant. Among 20 amino acids, 19 were reported from *T. cuneifolia* and 17 from *T. lappacea.* Ornithine has been reported from *T. lappacea,* whereas threonine, glutamic acid and proline are exclusively reported from *T. cuneifolia*. Fatty acids which are reported only from *T.cuneifolia* are linolenic acid, oleic acid and behenic acid whereas undecylic aci, pentadecylic acid and margaric acid are reported exclusively from *T. lappacea*. Sugars such as arabinose, furfuryl alcohol and β-d-glucopyranos are reported from *T.cuneifolia* whereas Xylose, inuli, sorbitol, ribose, glucuroni, glacturonic and stachyose are extracted from the *T. lappacea*. Information regarding vitamins is only available for *T. cuneifolia* (Mangalorkar, 2013; Mangalorkar *et al.*, 2016; Heba Ibrahim Abd EI-Moaty, 2015) (Table 2.3).

Table 2.3: Naturally occurring primary metabolites, reported from genus *Taverniera*

Group of natural compounds	**Compound**	**Plant source**	**Plant part**	**References**
Amino Acids	Arginine, Methionine, Phenylalanine, Tryptophan, lysine, Histidine, Isoleucine, Leucine, Valine and Threonine. Alanine, Asparagine, Cysteine, Glutamine, Glutamic acid, Glycine, Proline, Serine, and Tyrosine.	*T. cuneifolia*	Root	Mangalorkar, 2013
	Serine, Asparagine, Glutamine, Glycin, Alanine, Valine, Methionine, Cystine, Isoleucine, Leucine, Tyrosine, Phenylalanin, Ornithine, Lysine, Histidine, Tryptophan, Arginine.	*T. lappacea*	Aerial Part	El-Moaty, 2016
Fatty acids	Caproic aci, myristic acid, lauric acid, palmitic acid, linolenic acid, stearic acid, oleic acid, behenic acids.	*T. cuneifolia*	Root	Mangalorkar, 2013
	Capric acid, Undecylic acid, Lauric acid, Myristic acid, Pentadecylic acid, Palmitic acid, Margaric acid, Stearic acid, Oleic acid, Linoleic acid.	*T. lappacea*	Aerial Part	El-Moaty, 2016

Sugars	Glucose, fructose, arabinose, maltose, furfuryl alcohol, β-d-glucopyranose.	*T. cuneifolia*	Root	Mangalorkar, 2013
	Xylose, maltose, fructose, inulin, sorbitol, ribose, glucose, glucuronic acid, glacturonic acid and stachyose.	*T. lappacea*	Aerial Part	El-Moaty, 2016
Vitamins	Vitamin B_1, Vitamin B_2, VitaminB_3 and VitaminB_6.	*T. cuneifolia*	Root	Mangalorkar, 2013

2.5.2 Secondary metabolites

In this section a comprehensive list of chemical constituents, so far reported from the genus *Taverniera* can be easily grouped into the following category:

2.5.3 Phenolic compounds

Phenols are potential antioxidants that protect biomolecules (proteins, nucleic acids, polyunsaturated lipids, and sugars) from oxidative damage caused by free radicals (Heleno *et al*., 2015). A wide range of therapeutic properties of phenolic compounds such as anti-inflammatory, cardioprotective, antitumor, anti-aging etc. have been mentioned in the literature (Zhang *et al*., 2017). Phenolic compounds are further divided into different sub-classes such as Phenolic acid, Coumarins and Chalcone (Harborne, 1998). The compounds from these sub-classes have also been reported from *Taverniera* genus. Phenolic compounds reported from the genus *Taverniera* includes eight Phenolic acids, two Lignins. forty-three Flavonoids, and one Retrochalcones.

Major phenolic acids found from root portion of *T. cuneifolia* are Caffeic acid, Cis and trans *O*-coumaric acid, Ferulic acid, p-hydroxy benzoic, Protocatechuic acid, Rosmarinic acid, Syringic acid, vanillic acid (Mangalorkar *et al*., 2013), (Table 2.4).

Lignans present in *T. cuneifolia* are Conocarpan and 9-O-Feruloyllariciresinol (Mangalorkar, 2013) (Table 2.4).

Of the 43 flavonoids reported, various sub-classes under flavonoids are as follows:

Delphinidin, an anthocyanin, has been reported from the flower of *T. cuneifolia*. (Mangalorkar, 2013) (Table 2.5).

Flavan: 3-ol – Catechin 7-glycoside and (-)-Epiafzeechin are the two flavans reported from the roots of *T. cuneifolia* (Mangalorkar, 2013; 2016) (Table 2.4).

Flavonols reported from roots and aerial parts of *T. cuneifolia* and *T. lappacaea* are Isorhamnetin, Kaempferol tetraacetate, Quercetin and Rhamnetin of which Isorhamnetin is only reported in *T. aegyptiaca* (Mangalorkar, 2013; 2016; Heba Ibrahim Abd EI-Moaty 2016; Hassan *et al*., 2019) (Table 2.4).

Flavones: Total 10 flavones were found in *Taverniera* genus, out of which 5,7- diacetoxy, 8-methoxy flavone, 3',4,'5,'3,5,7,8- heptamethoxyflavone, were reported from *T. cuneifolia* and kaempferol-3-7-di rhamnoside, apigenin-7-O-neohespiroside, Luteolin-7-glucose were

reported from *T.lappacea* and rest 4 flavones were common in both *T. cuneifolia* and *T. lappacea* (Mangalorkar, 2013; Mangalorkar *et al.*, 2016; Heba Ibrahim Abd EI-Moaty, 2016) (Table 2.4).

Isoflavone: 2',4', 5'- trimethoxy- 2"2"- dimethyl pyrano [5",6", 6,7] isoflavone were documented in the roots of *T. cuneifolia* and Afrormosin; Calycosin and Formononetin were isolated from the aerial part of *T. aegyptica* (Mangalorkar, 2013; Hassan *et al*., 2019; Etagegnehu and amha, 2019; Duddeck *et al*., 1987) (Table 2.4).

Flavanone: Naringenin was recorded in *T. cuneifolia* (roort) and *T. lappacea* (aerial part). Whereas Hespirtin and Naringin were reported from the aerial parts of *T. lappacea* (Mangalorkar, 2013; Heba Ibrahim Abd EI-Moaty, 2016) (Table 2.4).

Flavonoid glycoside: There are total eight Pyranoside and pyranosyl based glycosides present in *T. aegyptica.* In Quercetin, Apignin, Luteolin and isorhamnetin based glycosides, main aglycone part of the sugar are glucose, arabinose and rhamnose. Rutin and Hesperidin are present only in *T. lappacea* (Heba Ibrahim Abd EI-Moaty, 2016; Hassan *et al*., 2018) (Table 2.4).

Retrochalcones: Only one Retrochalcone i.e., 4,4′-dihydroxy-2′- methoxychalcone is reported by Hassan *et al*., (2018) from *T. aegyptica* (Table 2.4).

2.5.4 Terpenoids

Phytochemical studies have shown that *Taverniera* genus is a rich source of terpenoids. Total eighteen terpenoids have been reported from *Taverniera* genus, in which two are diterpenoids, two are triterpenoids, one is triterpene glycoside and thirteen are saponins.

Diterpenoid: Diterpenoid compounds isolated from the roots of *T. cuneifolia* are Coronarin A and Przewalskin (Mangalorkar, 2013; Heba Ibrahim Abd EI-Moaty, 2015) (Table 2.5).

Triterpenoids: Alpha and beta amyrins, were isolated from the roots of *T. cuneifolia* (Mangalorkar, 2013; Mangalorkar *et al*., 2014; 2016) while odoraten was located in the aerial parts of *T. aegyptica* (Hassan *et al*., 2018). Additionally, one triterpene glycoside Glycyrrhizic acid was reported by Vitthal, (2011) and Ghasemi, (2019) from the roots of *T. cuneifolia* (Table 2.5).

Saponins: There are total thirteen saponins reported in *Taverniera* genus (only recorded in *T. cuneifolia* and *T. aegyptic*). The majority of the saponins described in the Taverniera genus were of glucopyranosyl type, including one rhamnopyranosyl, one xylopyranosyl, one dihydroxylolean, one trihydroxyolean whereas oleanolic acid 3-β-O-β-glucoside was reported as a minor saponin. *Glycyrrhizin* was reported by Jamdhade and surwase 2013 which was recognized as a significant breakthrough component in *T. cuneifolia* (Mangalorkar, 2013; Jamdhade and surwase, 2013; Zedan *et al*., 2002). One hydroxyolean and two dihydroxyolcan based sikosaponins were reported from the stem of the *T. aegyptica* (Hassanean, 1998) (Table 2.5).

2.5.5 Sterols

Sterols are group of fat-like substances which occur naturally in plant and animal kingdom. The roots of *T. cuneifolia* have shown to contain three sterols i.e., lupeol, stigmasterol, and β-sitosterol (Mangalorkar, 2013; Mangalorkar *et al*., 2014; 2016) (Table 2.6).

Table 2.4: Phenolic acid and Lignans reported from genus *Taverniera*

Group of natural compounds	**Compound**	**Plant source**	**Plant part**	**References**
Phenolic acid	Caffeic acid, Cis and trans *O*-coumaric acid, Ferulic acid, p -hydroxy benzoic acid, protocatechuic acid, Rosmarinic acid, Syringic acid, Vanillic acid	*T. cuneifolia*	Root	(Mangalorkar, 2013)
Lignans	Conocarpan, 9-O-Feruloyllariciresino	*T. cuneifolia*	Root	(Mangalorkar, 2013)

Table 2.5: Naturally occurring secondary metabolites, reported from genus *Taverniera*

Flavonoids				
Group of natural compounds	**Compound**	**Plant source**	**Plant part**	**References**
Anthocyanin	Delphinidin	*T. cuneifolia*	Flower	Manglorkar, 2013
Flavan	3-ol – Cate chin 7-glycoside, (-)-Epiafzeechin.	*T.cuneifolia*	Root	Mangalorkar, 2013
Flavonols	Isorhamnetin,	*T. aegyptiaca*	Root	Mangalorkar, 2013; El-Moaty, 2016 Hassan *et al*., 2019

	Kaempferol tetraacetate, Quercetin, Rhamnetin	*T. cuneifolia* *T. lappacea*	Aerial Part and Root	
Flavones	5,7- diacetoxy,	*T. cuniefolia*	Root	Mangalorkar, 2013
	8-methoxy flavone, acaceti, 3',4,'5,'3,5,6,7-oheptamethoxyflavone,	*T. cuniefolia* *T. lappacea*	Root Root, Aerial Parts	Mangalorkar *et al*., 2016
	luteolin, Apigenin,	*T. cuneifolia* *T. cuneifolia*	Root Root, Aerial Parts	El-Moaty, 2016
	3',4,'5,'3,5,7,8-heptamethoxyflavone, kaempferol-3-7-di rhamnoside, apigenin-7-O-neohespiroside, Luteolin-7-glucose.	*T. cuneifolia, T. lappacea* *T.cuneifolia* *T. lappacea* *T.lappacea*	Root Aerial Part Aerial Part Aerial Part	

		T.lappacea		
Isoflavone	2',4', 5'- trimethoxy- 2"2"- dimethyl pyrano[5",6", 6,7] isoflavone, Afrormosin Calycosin Formononetin	*T. cuniefolia* *T. aegyptica*	Root Aerial part	Mangalorkar, 2013 Hassan *et al*., 2019; Etagegnehu and amha, 2019; Duddeck *et al*., 1987
Flavanone	Hespirtin, Naringenin, Naringin	*T. lappacea* *T. cuneifolia* *T. lappacea* *T. lappacea*	Aerial Part Root, Aerial Parts Aerial Part	Mangalorkar, 2013; El-Moaty, 2016
Flavonoid glycoside	Hesperidin quercetin-3-o-glucoside, Apigenin 7-o-glucoside, Rutin, Luteolin-6- glucose -8- arabinose, Apigenin-6- arabinose -8-glactose, Apignin-6- rhamnose -8- glucose, Apignin-6- glucose -8- rhamnose	*T. lappacea*	Aerial part	El-Moaty, 2016

	isorhamnetin-3-O-robinobioside quercetin-3-O-robinobioside kaempferol 3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-rhamnopyranosyl-(1→6)-β-D-galactopyranoside] isorhamnetin 3-O-α-L-rhamnopyranosyl-(1→2)- [α-L-rhamnopyranosyl-(1→6)-β-d-glucopyranoside] isorhamnetin 3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-rhamnopyranosyl-(1→6)-β-D-galactopyranoside] isorhamnetin-3- O-α-L-rhamnopyranosyl-(1→6)-β-d-glucopyranoside quercetin-3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside isorhamnetin-3-O-α-L-arabinopyranoside quercetin-3-O-α-L-rhamnopyranosyl-(1→2)-[α-L-rhamnopyranosyl-(1→6)-β-d-galactopyranoside]	*T. aegyptica*	Aerial Part	Hassan *et al*., 2019

	isorhamnetin-3-O-α-L-rhamnopyranosyl-(1→2)-α-L-arabinopyranoside			
Retrochalcones	4,4′-dihydroxy-2′- methoxychalcone	*T. aegyptica*	Aerial Parts	Hassan *et al*., 2019

Table 2.6: Terpenoids reported from genus *Taverniera*

Terpenoids				
Group of natural compounds	**Compound**	**Plant source**	**Plant part**	**References**
Diterpenoid	Coronarin A,	*T. cuneifolia*	Root	El-Moaty, 2016
		T. lappacea	Aerial Part	Mangalorkar, 2013
	Przewalskin	*T. cuneifolia*	Root	
Triterpenes	α and β amyrin, Glycyrrhizic acid	*T.cuneifolia*	Root	Mangalorkar, 2013; Mangalorkar *et al*., 2016;
	Odoratin	*T. aegyptica*	Aerial Parts	Hassan *et al*., 2019; Vitthal *et al*., 2011; Ghasemi, 2019
Saponins	28-methyl serratagenate-3-β-O-β-xylopyranosyl (1 → 2)-β-glucopyranoside,	*T. aegyptica*	Root and stem bark	Zedan *et al*., 2002;
		T. cuneifolia		Mangalorkar, 2013

	28-methyl serratagenate 3-β-O-α-rhamnopyranosyl (1→2)-β-glucopyranoside, 3β-O-α-rhamnopyranosyl (1→2) β-glucopyranosyl-olean-11,13(18)-dien-1β, 3β, 22β-triol, 3β-O-β-glucopyranosyl (1 → 2)-β-glucuronopyranosylolean-11,13(18)-dien-1β,3β,22β-triol, 3β-O-β-xylopyranosyl(1→2)-β-glucuronopyranosylolean-11,13(18)-dien-1 β,3 β,22 β triol, 3β-O-α-rhamnopyranosyl (1→2)-β-glucuronopyranosylolean-11,13(18)-dien-1β, 3β, 22β-triol and oleanolic acid 3-β-O-β-glucoside 1β,3β,22β-trihydroxyolean-11,13(18)-diene 1β,22β dihydroxylolean-11,13(18)-diene *Glycyrrhizin* 22β-hydroxyolean-11,13(18)-dien-3β-yl-β-D-glucopyranoside. 1β. 22β-dihydroxyolean- 11, 13(18)-dien-3β-yl β-D-glucopyranoside and 1β, 22β -dihydroxy-olean- 11, 13(18)-dien-			

	3β-yl-β-D-xylopyranosyl (1 → 2) β-D-glucopyranoside	*T. cuneifolia* *T. aegyptica*	Root Stem bark	Jamdhade and surwase, 2013 Hassanean, 1998

Table 2.7: Sterols reported from genus *Taverniera*

Sterols				
Group of natural compounds	**Compound**	**Plant source**	**Plant part**	**References**
Sterols	lupeol, stigmasterol, β-sitosterol	*T. cuneifolia*	Root	Mangalorkar, 2013, Mangalorkar *et al*., 2014, 2016

2.6 Pharmacological activities

2.6.1 Cytotoxic activity

Toxicity of four species of *Taverniera* genus has been documented. With the oral dosage of 2.5g/kg, *T. abyssinica* has shown no noticeable toxic effect on Swiss mice (Dagne *et al*., 1990). Similarly, no noticeable alterations were recorded with the methanolic extract of *T. glabra* administered at a dosage of 1250 mg/kg and 625 mg/kg in Swiss albino mice (Marvi *et al*., 2016). However, *T. glabra* has shown mild toxicity against the *Artemia saline* (brine shrimp) (Keymanesh *et al*., 2009). *T. cuneifolia* extract showed protection of 75% cells against EMS toxicity at 6mg/plate (Zore *et al.*, in 2008). Later**,** Mangalorkar, (2013) has reported that 5gm/kg aqueous extract of *T. cuneifolia* did not show any toxic effect on adult female Charles foster rats and even the higher dose of short exposure was not able to cause marked alteration in important physiological processes. Similarly, *T. aegyptica* hydro-ethanolic extract with maximal dose of 5g/kg, showed no harm or notable changes in mice behaviour (Salah *et al*., 2016).

2.6.2 Anticancer activity

Anticancer activity in three species of *Taverniera* has been recorded, of which *T. abyssinica* showed 50% inhibition on Leuckemia cell line (L 1210) with a dosage of 100µg/ml (Stadler *et al*., 1994). Similar study on *T. spartea* showed 50% inhibition on breast cancer cell line (MCF-7 and BT474) and human prostate cell line (PC-3 and DU-145) (Khalighi-Sigaroodi *et al*., 2014). *T. cuneifolia* is used in treatment of spleen tumors (Alexiades & Laird, 2002).

2.6.3 Anti-HIV activity

Anti-HIV activity has been reported only in T. cuneifolia by Zore *et al*., (2008), wherein 50% cytotoxicity was noted at ≥ 62.5 µg/ml of concentration with no substantial anti-HIV activity on MT-2 cells.

2.6.4 Anti-inflammatory activity

The anti-inflammatory study has been reported from two species of *Taverniera* genus, of which the ethanolic and chloroform fractions of *T. cuneifolia* extract showed 22% inhibition of inflammation after 6 hours and 74% inhibition on the fifth day in wister rats at 500 mg/kg body weight, (Zore *et al*., 2008). Similar study in hydroethanolic extract of *T. aegyptiaca* showed

maximum inhibition/ anti-inflammatory effect at the dosage of 500mg/kg (42.65 %) which is close to the standard drug Diclofenac sodium (47.06 %) in wister albino rats and Swiss male mice (Salah *et al.* 2016).

2.6.5 Antimicrobial activity

Antimicrobial activity was reported from four species of *Taverniera* genus. In *T.abyssinica,* two phytoalexins i.e. medicarpin and 4-hydroxymedicarpin showed the antimicrobial inhibition against fungi, bacteria and yeasts at the dosage of 100µg/ml (Stadler *et al*., 1994). Similarly, the extract of *T. cuneifolia* inhibited germ tube formation in *C. albicans* (Zore *et al*., 2008). Keymanesh *et al*., (2009) stated that *T. glabra* have strong antimicrobial effect against *B. subtilis*. *T. glabra* is also known to have acceptable antimicrobial and antifungal activity with mild toxicity. Arabi and Sardari, (2010) also reported the antifungal activity of *T. cuneifolia*. Another antimicrobial research on *T. lappacea* was reported by EI-Moaty, (2016) wherein it was found that 70 percent of methanolic extract (100µg/ml) is effective against bacterial (*Staphylococcu aureus, Streptococcus spp., Escherichia coli, Klebsiella pneumonia and Acinetobacter spp*.) and fungal (*Candida albicans*) species.

2.6.6 Analgesic and antipyretic

Analgesic and antipyretic activity have been reported from the two species of *Taverniera* genus. Dagne *et al*., (1990) demonstrated that ethanolic extract of *T. abyssinica* root has antipyretic (at 200mg/kg) and analgesic properties (at 1200mg/kg) in Male Wister rats and Swiss mice.

The central analgesic effect of *T. aegyptiaca* hydro ethanolic extract was studied which exhibited morphine-like effects on the CNS, which may induce the antinociceptive effects. (Salah *et al*., 2016). Similar effect was observed in methanolic extract of *T. glabra* at a dose of 250 and 500mg/kg (Marvi *et al*., 2016).

2.6.7 Antioxidant activity

The antioxidant activity has been documented in *T. cuneifolia* and *T. spartea*. The methanolic extract of *T. cuneifolia* showed the highest free radical scavenging activity at the dose of 20µg/ml by DPPH assay whereas nitric oxide showed no significant radical scavenging activity. The maximum prevention of DNA damage was shown at 4 µg/ml concentration (Jamdhade *et al.,* 2015). Khalighi *et al.,* (2012) showed a similar investigation on *T. spartea*

methanolic extract (2-1000 g/ mL). According to the DPPH method, the extract has considerable antioxidant activity, with an LC50 value of 20.32 g/ mL.

2.6.8 Antitussive activity

Antitussive activity was reported from *T. cuneifolia.* The test formulation of *T. cuneifolia* at a dosage of 400mg/kg given to mice showed the best antitussive effect compared to *G. glabra.* The result indicated that the frequency of cough for the control group was 52.50± 2.24, for *G. glabra* it *was* 35.67± 1.38$^{\#}$, whereas for *T. cuneifolia,* it was 30.168.87$^{\#}$ (Note: $^{\#}$P<0.05, one way ANOVA) (Mangalorkar, 2013).

2.6.9 Gastroprotective activity

Gastroprotective activity of *T. cuneifolia* methanolic extract in pylorus ligation model has demonstrated the reduction in the number of ulcers and ulcer index, thus conferring to its beneficial property in treatment of gastric ulcers (Jamdhada *et al*., 2015).

T. cuneifolia root powder (Churna-2gm) was found useful in treatment of 18 patients suffering from digestive impairment (*amlapitta*). The treatment showed 44.44% patient with marked improvement followed by 38.89% mild improvement and 16.67% showed moderate improvement (Prajapati and Patel, 2015).

2.6.10 Antiulcerative activity

Anti-ulcerative activity has been recorded in two species of *Taverniera*. Jamdhade et al., (2015) has stated that *T. cuneifolia* methanolic extract (150 and 300mg/kg) has effective gastroprotective properties in pylorus ligation model, based on reducing ulcer number and ulcer index. Similarly, Salah *et al*., (2016) has shown the effectiveness of hydro-ethanolic extract of *T. aegyptiaca* in significant reduction of ulcer index.

2.6.11 Memory enhancing activity

The methanolic and aqueous extracts of *T. cuneifolia* was found to be effective against anti-amnesic in scopolamine-induced male Swiss albino mice at a dose of 150 and 300 mg/kg respectively. The research suggests that extract has a neuroprotective function in memory enhancement (Jamdhada and Surwase, 2013).

2.6.12 Nematicidal activity

Methanolic extract of *T. abyssinica* is the only species of *Taverniera* where nematicidal activity has been reported. Medicarpin and 4-hydroxymedicarpin were the components that showed weak nematicidal activity when compared to the control drugs rotenone and ivermectin, in which 50% of nematodes were found dead at a dosage of 25g/ml. (Stadler *et al*., 1994).

2.6.13 Spasmolytic action

T. abyssinica aqueous extract was shown to inhibit the smooth muscle spasmogenic activities of both acetylcholine and histamine, two of the important spasmogens responsible for gastrointestinal hyperactivity (Noamesi *et al*., 1990).

2.6.14 Sedative activity

T. glabra methanolic extract was found to have sedative and CNS depressing effects in swiss albino mice. The study revealed that *T. glabra* reduces locomotor activity at a dosage of 500mg/kg when compared to the control Diazepam, which indicates that it is a CNS depressant (Marvi *et al*., 2016).

2.6.15 Wound healing activity

Wound healing activity is only reported in *T. cuneifolia*. Ointment 2% (w/w) of *T. cuneifolia* showed significant wound healing activity in Wistar strain albino rats and Swiss albino mice) (Mangalorkar, 2013).

2.7 General uses

T. cuneifolia root decoction when orally given twice a day for 3 days is useful in treatment of throat problems (Shashikant *et al*. 2014). It has also shown 50% inhibition of Agrobacterium induced tumours in plants. (Zore *et al*., 2008).

Heba Ibrahim Abd El-Moaty (2009) investigated *T. lappacea* as a herbicide, using aqueous extracts of vegetative parts at doses of 8 and 10 g (dry wt) 100 ml-1, which inhibited germination and seedling growth of *Convolvulus arvensis, Abutilon thiophrastes, Echinochloa crus-galli,* and *Portulaca oleracea.*

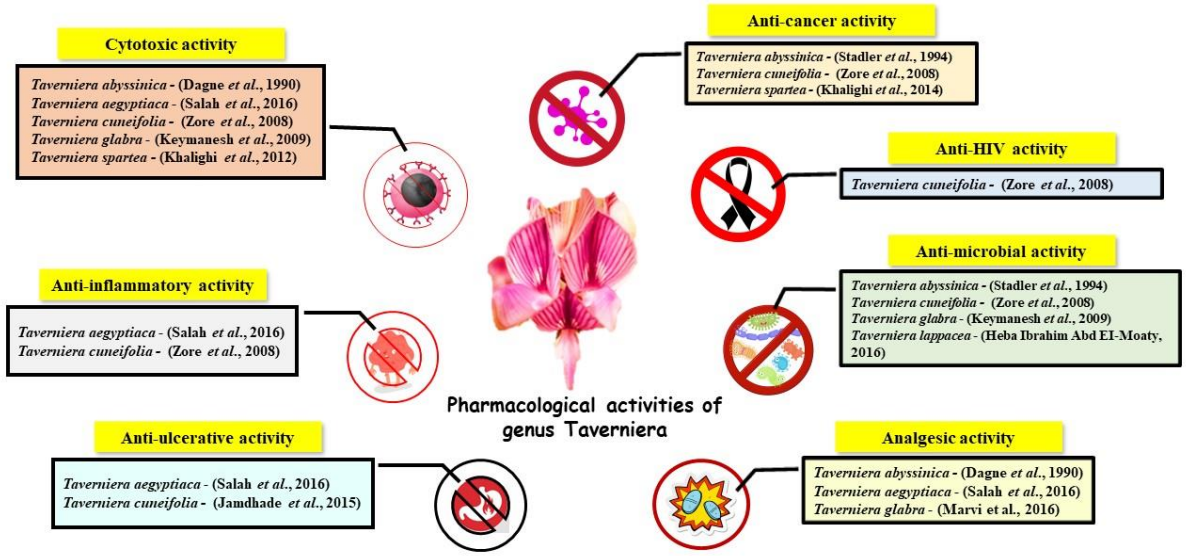


Figure 2.4: Sumarized chart of pharmacological activities reported on Taverniera species.

Table 2.8: Summary of some reported pharmacological studies on *Taverniera* genus

Property	**Concentration**	**Method/model organisms/cell line**	**Major findings**	**Reference**
Taverniera abyssinica				
Cytotoxic activity	2.5g/kg of extract	Male Wistar rate and Swiss mice	No mortality or side effects were reported in animal	(Dagne *et al.*, 1990)
Anticancer activity	100µg/ml	Leukaemia cell line (L 1210)	50% inhibition was reported at the dosage of 100µg/ml.	(Stadler *et al.*, 1994)
Antimicrobial activity	100µg/ml of medicarpin and 4-hydroxymedicarpin	Plate diffusion assay of bacteria, Yeasts and filamentous fungi	confirmed the antimicrobial inhibition against fungi, bacteria and yeasts	(Stadler *et al.*, 1994)
Antipyretic activity	25-200mg/kg plant extract.	Male Wistar rate and Swiss mice	No toxicity is reported in mice upto the dosage of 2.5g/kg	(Dagne *et al.*, 1990)

Analgesic property	1200 mg/kg plant extract.	Male Wistar rate and Swiss mice	Extract was found to be capable of reducing body temperature.	(Dagne *et al*., 1990)
Spasmolytic action	12.5, 25 and 50 mg/ml plant material	Adult guinea-pigs Rabbit duodenum	Relaxed the smooth muscles of duodenum in rabbit and antagonized the effect of acetylcholine and histamine in adult guinea-pigs.	(Noamesi *et al*., 1990)
Taverniera aegyptiaca				
Cytotoxic activity	100, 500 and 1000mg/kg hydro-ethanolic extract	Wister albino rats and Swiss male mice	No toxicity observed.	(Salah *et al*., 2016)
Anti-inflammatory effect	250 and 500 mg/kg hydro-ethanolic extract	Wister albino rats and Swiss male mice	Shows significant anti-inflammatory activity.	
Analgesic activity	250 and 500 mg/kg hydro-ethanolic extract	Wister albino rats and Swiss male mice	Extract shows anti-analgesic activity at the dosage of 250mg/kg	
Anti-ulcerative activity	250 and 500 mg/kg of Hydro-ethanolic extract	Wister albino rats and Swiss male mice	Reduction in ulcer index were reported.	
Taverniera cuneifolia				
Cytotoxic activity	6mg of extract	In -vitro- *Salmonella typhimurium*	showed protection of 75% cells against EMS toxicity *Salmonella typhimurium* at 6mg/plate	(Zore *et al*., 2008)

	5 mg/mL	In vivo- larvae of *Artemia salina* (brine shrimp)	No toxicity reported.	(Khalighi *et al*., 2012)
	5gm/kg	adult female Charles foster rats	Dose does not cause any noticeable changes.	(Mangalorkar, 2013)
Anti-HIV activity	a. Viral binding inhibition assay: 62.5,31.25 and 15.6µg/ml b. Viral replication inhibition assay: 62.5,31.25 and 15.6 µg/ml	In-vitro a. Viral binding Inhibition assay: HIV-1 III B strain b. Viral replication inhibition assay: MT-2 cell line	Plant extract shows 50% toxic effect at 62.5µg/ml of concentration.	(Zore *et al*., 2008)
Anti-inflammatory activity	250-500 mg/kg extract	In-vivo- Wistar rats	Chloroform extract shows maximum inhibition	(Zore *et al*., 2008)
Antimicrobial activity	2, 4 and 6 mg/plate	In-vitro - ATCC 10231	Extract inhibits the formation of germ tube in *C. albicans*.	(Zore *et al*., 2008)
Antioxidant activity	2-1000 µg/ mL	DPPH method	Extract shows significant antioxidant activity with LC_{50} value of 56.29 ± 0.02 µg/ mL	(Khalighi *et al*., 2012)
	1-20 µg/ ml	DPPH	Extract shows maximum scavenging activity i.e. 84.48% at the	(Jamdhade *et al*., 2015)

	5-50 µg/ ml 0-6 µg/ ml extract	NO_2 DNA damage scavenging activity	dosage of 20 µg/ ml. 36.05% scavenging activity reported at 5 µg/ml minimum DNA damage were reported at the dosage of 4 µg/ ml.	
Antitussive activity	400mg/kg	mice	42.55% inhibition of so_2 induce cough in mice.	(Mangalorkar, 2013)
Gastroprotective	2g root powder* 2 week with water	Clinical trials	Found useful in managing of symptoms related to Amlapitta.	(Prajapati and Patel, 2015)
Antiulcerative activity	methanolic extract (150 and 300mg/kg)	In vivo-Female albino Wister rats	Effective in gastroprotective properties in pylorus ligation model based on reducing ulcer number and ulcer index.	(Jamdhade *et al*., 2015)
Memory enhancing activity	methanolic and aqueous extract (150, 300mg/kg)	In vivo- male Swiss Albino mice	Improved the learning capability and memory of mice	(Jamdhade & Surwase 2013)
Wound healing activity	treated with ointments with concentrations of *T. cuneifolia* viz. 2% (w/w) incorporated in simple ointment base.	In vivo - Wistar strain albino rats (200 ± 20g) and Swiss albino mice (30 ± 4g)	Significant wound healing activity observed.	(Mangalorkar, 2013)

Anti-tumor activity	2mg/ml extract	In- vitro- *Agrobacterium tumefaciens* (approx.-5x10^9 cell/ml)	Inhibition of 50% tumor induced by Agrobacterium.	(Zore *et al*., 2008)
Taverniera glabra				
Cytotoxic activity	10,100,1000 µg/ml extract	In vivo- larvae of *Artemia salina* (brine shrimp)	Shows toxicity (LC_{50}- 471.39)	(Keymanesh *et al*., 2009)
	1250 mg/kg and 625 mg/kg	In vivo - Swiss albino mice	no noticeable alterations were recorded	(Marvi et al. 2016)
Antimicrobial activity	10µg/ml extract	Microdilution method	Extract is effective against B. subtilis	(Keymanesh *et al*., 2009)
Analgesic	250 and 500 mg/kg	Swiss albino mice	Shows peripheral and central activity of antinociception	(Marvi et al., 2016)
Sedative	500mg/kg	Swiss albino mice	Extract has sedative and CNS depressing effects in mice and also reduces locomotor activity	(Marvi et al., 2016)
Taverniera lappacea				
Antimicrobial activity	100 µg/ml extract	**Gram (+ve) bacteria:** Staphylococcus aureus, Streptococcus spp., **Gram (-ve) bacteria:** Escherichia coli, Klebsiella	70 % ethanolic extract is most effective against bacteria and fungus.	El-Moaty, 2016

		pneumonia, Acinetobacter ssp., **Fungi:** Candida albicans		
Taverniera spartea				
Cytotoxic activity	5 mg/mL	In vivo- larvae of *Artemia salina* (brine shrimp)	(LC_{50} value 0.34 ± 0.01 µg/ mL)	(Khalighi *et al*., 2012)
Anticancer activity	2.5 µl	In vitro- human cancer cell line MCF-7 and BT-474 BT-474 and PC-3	Chloroform fraction shows highest toxicity in MTT assay.	(Khalighi *et al*., 2014)
Antioxidant activity	2-1000 µg/ mL	DPPH method	Extract shows significant antioxidant activity with LC_{50} value of 20.32 µg/ mL	(Khalighi *et al*., 2012)

Due to their intense pharmacological effects, low toxicity, and economic feasibility, the therapeutic qualities of plants have been explored all over the globe in light of current scientific advancements (Auddy *et al*., 2003). Several medicinal plants have been utilised extensively in the Indian traditional medical system to treat a variety of ailments (Chopra *et al*, 1992). The vast majority of plants have not been examined for their pharmacological properties. In order to advance the understanding of Indian traditional herbs, the current research focuses on alternate species of Glycyrrhiza glabra, namely *T. cuneifolia*. The pharmacognostic, phytochemical, and bioactive qualities of *T. cuneifolia* are relatively limited, as shown by the lack of information on *T. cuneifolia* species found in the literature.