J Herbmed Pharmacol. 2025; 14(3): 302-314.

http://www.herbmedpharmacol.com doi: 10.34172/jhp.2025.53116

Journal of Herbmed Pharmacology

Exploring the cytotoxic potential of genus *Tecoma*: An in-depth review

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ARTICLE INFO

Article Type:
Review

Article History:
Received: 26 Apr. 2025
Revised: 8 Jun. 2025
Accepted: 9 Jun. 2025
epublished: 1 Jul. 2025

Keywords:
Bignoniaceae
Tecoma
Cytotoxicity
Anticancer
Breast cancer
Lung cancer
Liver cancer

ABSTRACT

Introduction: Species in the genus *Tecoma* are traditionally valued for a wide range of medicinal properties, including antidiabetic, antispasmodic, diuretic, and vermifuge effects, and are also used to treat stomach ulcers. Over the past two decades, there has been growing interest in exploring the cytotoxic and anticancer properties of different *Tecoma* species and their potential applications in cancer treatment. The aim of this review is to assess the reported cytotoxic activity of different *Tecoma* species, identify their bioactive metabolites, and elucidate the underlying mechanisms contributing to their cytotoxic potential.

Methods: The current review utilized online databases and studies published until May 2025. It documented and summarized the recently reported cytotoxic activity of *Tecoma* species and the key bioactive compounds isolated from them against 12 cancer types through *in vitro*, *in vivo,* and *in silico* studies

Results: The review revealed that the majority of the studies predominantly focused on evaluating the cytotoxic potential of *Tecoma* species against breast, lung, and liver cancers. Among these, *T. stans* has emerged as the most promising candidate, likely due to the presence of bioactive compounds such as rutin, acteoside, paulownin, and paulownin acetate.

Conclusion: This review highlights *T. stans* as the most extensively investigated and cytotoxically examined species within the genus. The review also identifies key gaps in the current research on *Tecoma* species and their cytotoxic properties. It also provides valuable recommendations for future mechanistic and *in vivo* studies to enhance the understanding and therapeutic potential of *Tecoma* species in cancer treatment.

Implication for health policy/practice/research/medical education:
The findings of this review underscore the growing importance of *Tecoma* species in oncology research. The compiled cytotoxic and mechanistic data offer a rationale for prioritizing *Tecoma*-derived compounds in anticancer drug development. This review also highlights key research gaps particularly *in vivo* and mechanistic validation that are essential for translational progress. Additionally, it supports the integration of evidence-based phytotherapy into medical education to raise awareness of plant-based anticancer agents.

Please cite this paper as: Sekkien AM, Swilam NF, Al-Mahdy DA, Elmazar MM, Meselhy MR. Exploring the cytotoxic potential of genus *Tecoma*: An in-depth review. J Herbmed Pharmacol. 2025;14(3):302-314. doi: 10.34172/jhp.2025.53116.

Introduction

Cancer remains one of the most significant global health challenges, characterized by the uncontrolled proliferation of abnormal cells that can invade and destroy normal body tissues (1). According to the World Health Organization, cancer accounted for nearly 10 million deaths in 2022, with lung, colorectal, prostate, stomach, and breast malignancies being the leading causes of mortality (2).

Although conventional chemotherapy and radiotherapy are effective in treating cancer (3,4), limitations such as drug resistance, toxicity, and relapse highlight the urgent need for safer, more effective therapies (5,6). Recently, there has been a growing interest among researchers in exploring potential anticancer lead compounds from

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natural products (7,8). These compounds often exhibit diverse mechanisms of action and reduced toxicity compared to synthetic drugs (9).

Natural products have been instrumental in the advancement of cancer treatments (10). Over 60% of the currently used anticancer agents are derived from natural sources, including plants, marine organisms, and microorganisms (11-13). For example, paclitaxel, derived from the Pacific yew tree, and vinblastine from the Madagascar periwinkle, are prominent examples of plant-based anticancer drugs that have been effectively integrated into contemporary oncology (14).

The genus *Tecoma*, a member of the Bignoniaceae family, comprises 15 species, 13 from the Americas, and 2 species from Africa (15,16). Aside from their ornamental value. *Tecoma* species have been traditionally used as antidiabetic, antipyretic, vermifuge, and diuretic agents, as well as for treating stomach ulcers (17-20). Several reports have documented the promising cytotoxic activity of *Tecoma* species against various cancer cell lines (21-23). This activity is likely due to the presence of a diverse array of phytochemicals identified or isolated from various *Tecoma* species, including *T. stans* (24), *T. castanifolia* (25), *T. capensis* (22) and *T. mollis* (26). These species contain a range of phytochemical compounds belonging to flavonoids, terpenoids, alkaloids, phenolics, anthraquinones, coumarins, anthocyanins, and lignans, among others. Many of these classes are well documented for their effective cytotoxic and anticancer properties (27-30).

While several individual studies have investigated the cytotoxic effects of *Tecoma* extracts or isolated metabolites, there is currently no comprehensive review summarizing and comparing these findings across species, assay models, and mechanisms of action.

This article tries to fill the gap by providing the first in-depth evaluation of the cytotoxic potential of different *Tecoma* species based on *in vitro*, *in vivo*, and *in silico* evidence. It also identifies promising bioactive metabolites and highlights their interactions with cancer-related molecular targets. By consolidating this evidence, the review supports future pharmacological research aimed at developing *Tecoma*-based anticancer agents and offers mechanistic insights that may inform preclinical and clinical exploration of plant-derived cytotoxins.

Methods

Data search

A thorough search for data related to *Tecoma* species (Table 1) for this review was conducted using various online databases, including SCOPUS, Google scholar, PubMed, Web of Science, Science direct, ACS, Wiley, and SciFinder. The following keywords were utilized: *Tecoma*, anticancer, antiproliferative, cytotoxicity, phytochemicals and phytochemical profile.

Data inclusion and exclusion criteria

Data from all reports published before May 2025 that pertained to the anticancer or cytotoxic activities of species belonging to genus *Tecoma* were included in the review. These encompassed studies employing *in vitro*, *in vivo*, and *in silico* methods. However, studies lacking a clear connection to these activities were excluded. Only studies published in English were included.

Results

In vitro cytotoxic activity

The *in vitro* cytotoxicity of *Tecoma* species has been primarily investigated in five species, namely: *T. stans, T. castanifolia, T. garrocha, T. sambucifolia*, and *T. capensis*. Additionally, two varieties of *T. stans* (var. *angustata* and var. *stans*) (Figure 1) were included in the studies. The reports utilized the 3-(4,5-dimethylthiazol-2-yl) 2,5 diphenyltetrazolium bromide (MTT) assay to assess the cytotoxic effects.

These studies examined cytotoxicity across 14 human cancer cell lines, including MCF-7 (Breast cancer), HepG2 (liver cancer), A549 (lung cancer), HeLa (cervix cancer), and others (Table 2). Notably, MCF-7, HepG2, and A549 cell lines were the most frequently investigated. In addition, some of these studies evaluated the cytotoxic effects on normal cell lines to determine their selective toxicity toward cancerous cells.

The results indicated that various extracts of *T. stans* exhibited comparatively higher cytotoxic activity than other *Tecoma* species against most of the tested cell lines based on reported IC_{50} values (Table 2). Furthermore, the findings revealed that the extracts derived from the stems of different *Tecoma* species were generally more cytotoxic than those obtained from other plant organs (Table 2) (21).

Cytotoxic activity of the isolated metabolites

Among the studies reporting the cytotoxic activity of

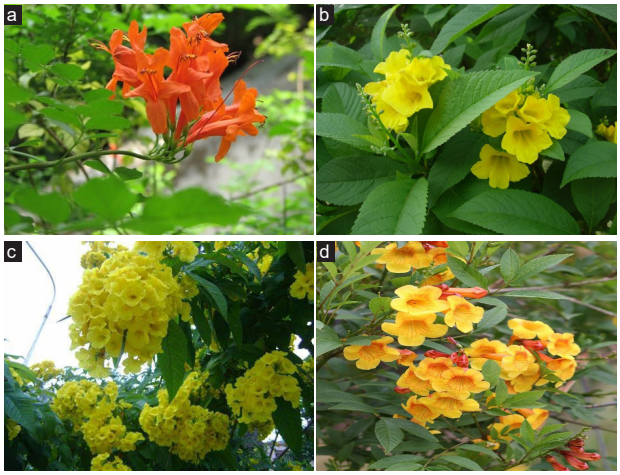

Figure 1. Photos of different species from genus *Tecoma*. a: *T. capensis*; b: *T. stans;* c: *T. castanifolia*; d: *T. garrocha.*

Table 1. Names and distribution of *Tecoma* species with reported cytotoxic activities (15,16)

Name of the species	Geographical distribution
Tecoma arequipensis (Sprague) Sandwith	Southern Peru, Northern Bolivia and through the dry slopes of Andean valleys
Tecoma beckii J.R.I.Wood	Bolivia
Tecoma capensis (Thunb.) Lindl.	South Africa and adjacent to Southern Mozambique
Tecoma castanifolia (D.Don) Melch.	Ecuador coast and north west of Peru
Tecoma cochabambenesis (Herzog) Sandwith	Dry Andean slopes of Cochabamba area of central Bolivia
Tecoma fulva (Cavanilles) D. Don	Atacama Desert in Chile
Tecoma garrocha (Hieron.) Bol. Acad.	Dry Andean slopes, northwest Argentina and south Bolivia
Tecoma guarume A.P. de Candolle	Ica department of Peru
Tecoma nyassae (Oliv.)	Tropical East Africa from easternmost Angola, Tanzan and northern Mozambique
Tecoma rosifolia Humboldt, Bonpland and Kunth	Northern Andean Peru in the dry valleys of the Rio Maranon
Tecoma sambucifolia Humboldt, Bonpland and Kunth	Dry Andean valleys of Peru and south Ecuador
Tecoma stans L. Juss. Ex. Kunth	Southern parts of north and central American continent.
Tecoma tanaeciiflora (Kranzlin) Sandwith	Chuquibamba area of Arequipa department in Peru
Tecoma tenuiflora (DC.) Fabris	Southern Bolivia and North Argentina
Tecoma weberbaueriana (Kranzlin) Melchior	Northwestern Peru

Tecoma species crude extracts, some also focused on assessing this activity for metabolites isolated from different *Tecoma* species and identified through various spectroscopic techniques (21,23,31).

In the first study, Marzouk et al (23) reported the isolation of metabolites belonging to the classes of phenylethanoids, flavonoids, and monoterpene alkaloids from the fruits and flowers of *T. stans* (Table S1). This study primarily emphasized the cytotoxic activity of the fruit extract.

The key identified metabolites included 5-hydroxy-skytanthine, *E/Z*-acteoside, parvifloroside A, and isoacetoside. These metabolites showed IC_{50} values ranging from 23.9 µM to 113.11 µM against MCF-7 and HepG2 cell lines (Table S1). Later, Elsayed et al (31) evaluated the cytotoxicity of the endophytic metabolites from the rice culture of *Aspergillus sp.* isolated from the leaf tissues of *T. stans* (Table 2) and seven endophytic metabolites were isolated (Table S1). Among these, iso-emericellin, sterigmatocystin and dihydrosterigmatocystin showed the most promising cytotoxic activity with IC_{50} values ranging from 161.81 µM to 453.57 µM against MCF-7 and HepG2 cell lines. On the other hand, the cytotoxic potential of ergosterol was not evaluated (Table S1). In the same context, Reis et al (21) assessed the cytotoxic activity of *T. castanifolia*, T. *garrocha*, *T. stans var. angustata and T. stans var. stans* against five cell lines, including T24 (Urinary bladder cancer), TOV-21G (Ovarian cancer) and MDA-MB-231(breast cancer), which were only reported in that study. The study utilized normal human lung fibroblast cell (MRC-5) to evaluate selectivity and used podophyllotoxin as a positive control. The results showed that the stem extracts were generally more cytotoxic than leaf extracts (Table 2).

The ethanolic stem extract of *T. stans* var. *stans* exhibited markedly greater cytotoxic potency than its isolated lignans, with IC_{50} values as low as 0.42 µg/mL against HeLa cells. In contrast, lignans such as paulownin and sesamin showed reduced activity, with IC_{50} values ranging from 13.01 µg/mL to >100 µg/mL, indicating a substantial decline in potency upon isolation. Similarly, the standard reference compound podophyllotoxin demonstrated superior cytotoxicity, with IC_{50} values ranging from 0.0025 to 0.1339 µg/mL, significantly outperforming *T. stans*-isolated lignans. However, all of the isolated lignans exhibited comparatively lower cytotoxicity against the normal MRC-5 cell line than against the cancer cell lines, unlike podophyllotoxin, thereby indicating a more favorable selectivity profile.

In 2022, Krobthong et al (32) conducted the only study focused on isolating peptides, extracting 126 distinct peptides from the flowers of *T. stans*, which were identified using LC-MS/MS. These peptides were evaluated for their cytotoxic activity against five human cancer cell lines: non-small cell lung cancer (A549), hepatocellular carcinoma (HepG2), cervical carcinoma (HeLa), skin melanoma (SK-MEL-28), and breast carcinoma (MCF-7), in addition to the non-cancerous immortalized keratinocyte cell line (HaCaT). The IC_{50} values for the cancer cell lines ranged from 0.1786 to 0.5679 ng/mL, indicating a high potency at the nanogram scale. Notably, the IC_{50} value in HaCaT cells was 3.531 ng/mL, suggesting that these peptides exhibit selective, dose-dependent cytotoxicity toward malignant cells (Table 2). In addition to inhibiting proliferation, treatment of A549 cells with the peptide fraction significantly reduced cell motility and altered protein expression profiles. Cancer-promoting proteins such as AMD, NCBP2, ENC1, COA4 and MER34 were notably downregulated.

Mechanism of the cytotoxic activity

The mechanistic pathways of the cytotoxic activity of *Tecoma* species were reported in four studies that focused mainly on three different biomarkers including Bcl-2,

Table 2. Reported *in vitro* cytotoxic activity of *Tecoma* species

Cell line	Species name	Part used	Type of extract	Cytotoxic activity and/or IC_{50} values	Reference
Breast cancer (MCF-7)	*T. stans*	Fruits and flowers	Hydro- ethanol	IC_{50} value of 73.8 µg/mL	(23)
		Leaves		1000 µg/mL exhibited maximum inhibition of cell viability at 95.9%, 7.8 µg/mL showed minimal inhibition of 14.6%.	(43)
				IC_{50} value of 64.5 µg/mL.	
				500 µg/mL reduced viability of MCF-7 cells to approx. 45%, compared to the control.	(33)
		Barks		400 µg/mL of the extract achieved 80.94% cytotoxicity, reduced cell viability by 19.05%.	(44)
				IC_{50} value of 196.61 µg/mL.	
		Barks and flowers	Ethyl acetate	400 µg/mL of bark and flowers extracts showed cytotoxic effect of 81.38% and 80.94%, respectively.	(34)
				IC_{50} values of the extracts were 208.5 µg/mL and 207.4 µg/mL, respectively	
		Aspergillus sp. endophyte from leaves	Ethyl acetate	IC_{50} value of 186.66 µg/mL	(31)
		Flowers	Pressurized hot water extraction	Isolated peptides showed the most potent cytotoxic effect (IC_{50} value of 0.2756 ng/mL).	(32)
			Methanol	Minimal photodynamic activity at a concentration of 100 µg/mL.	(36)
		Leaves		IC_{50} value of 205.35 µg/mL	(35)
		Roots		IC_{50} value of 196.61 µg/mL	
	T. castanifolia	Leaves	Acetone, ethanol and ethyl acetate	IC_{50} value > 1000 µg/mL (for acetone extract) IC_{50} value of 926.67 µg/mL (for ethanol extract) IC_{50} value of 335 µg/mL (for ethyl acetate extract)	(45)
		Flowers	Chloroform, ethyl acetate and methanol	IC_{50} value of 378.3 µg/mL (for chloroform extract) IC_{50} value > 1000 µg/mL (for methanol extract) IC_{50} value of 180 µg/mL (for ethyl acetate extract)	(46)
Breast cancer (MDA-MB-231)	*T. castanifolia*	Leaves	Ethanol	No cytotoxicity was detected	(21)
		Stem		IC_{50} value of 23.24 µg/mL	
	T. garrocha	Leaves		No cytotoxicity was detected	
		Stem		IC_{50} value of 53.07 µg/mL	
	T. stans var. *angustata*	Leaves		No cytotoxicity was detected	
		Stem		IC_{50} value of 19.59 µg/mL	
	T. stans var. *stans*	Leaves		No cytotoxicity was detected	
		Stem		IC_{50} value of 0.268 µg/mL	

Table 2. Reported *in vitro* cytotoxic activity of *Tecoma* species

Cell line	Species name	Part used	Type of extract	Cytotoxic activity and/or IC_{50} values	Reference
Hepatocellular carcinoma (HepG2)	*T. stans*	Fruits and flowers	Ethanol	IC_{50} value of 36.4 µg/mL (for the fruits extract)	(23)
		Aspergillus sp. endophyte from *leaves*	Ethyl acetate	IC_{50} of 158.54 µg/mL	(31)
		Flowers	Pressurized hot water extraction	IC_{50} value of 0.5679 ng /mL (for isolated peptides).	(32)
	T. castanifolia	Leaves	Ethanol	IC_{50} of 48.03 µg/mL	(21)
		Stem		IC_{50} value of 25.56 µg/mL	
	T. garrocha	Leaves		IC_{50} value of 119.10 µg/mL	
		Stem		IC_{50} value of 92.53 µg/mL	
	T. stans var. *angustata*	Leaves		IC_{50} value of 64.41 µg/mL.	
		Stem		IC_{50} value of 0.196 µg/mL	
	T. stans var. *stans*	Leaves		IC_{50} value of 62.48 µg/mL.	
		Stem		IC_{50} value of 0.1198 µg/mL	
	T. sambucifolia	Flowers	Aqueous	IC_{50} value of 31.6 mg/mL (for the aqueous extract) IC_{50} value of 22.49 mg/mL (for the alcoholic extract)	(47)
			Alcohol		
		Pods	Aqueous		
			Alcohol		
Human lung carcinoma cell line (A-549)	*T. stans*	Leaves and flowers	Methanol	99% cell inhibition observed at 100 µg/mL with morphological changes characteristic of apoptosis, such as cellular shrinkage and blebbing.	(48)
		Flowers	Pressurized hot water extraction	IC_{50} value of 0.3321 ng/mL (for isolated peptides) At the lowest concentration of 0.0625 ng/mL, significant inhibition of migration and invasion of A549 cells.	(32)
			Methanol	TSFE exhibited significant cytotoxicity against A549 cells. In the dark, the cell viability was reduced to 78% at 100 µg/mL, which further decreased to 64% upon irradiation with blue light (450 nm).	(36)
			Aqueous	The nanoparticles CuONPs showed % cell viability of 72.31%, 61.63%, 37.77%, 26.30% and 17.33% for the concentrations of 20, 40, 60, 80 and 100 µg/mL respectively.	(39)
	T. castanifolia	Leaves	Aqueous*	IC_{50} value of 65 µg/mL (for ZnONPs of the extract)	(25)
	T. capensis	Flowers		IC_{50} value of 71.79 µg/mL (for AgNPs of the extract)	(22)

Table 2. Reported *in vitro* cytotoxic activity of *Tecoma* species

Cell line	Species name	Part used	Type of extract	Cytotoxic activity and/or IC_{50} values	Reference
Cervix cell carcinoma (HeLa)	*T. castanifolia*	Leaves	Ethanol	IC_{50} of 58.86 µg/mL	(21)
		Stem		IC_{50} of 110.80 µg/mL	
	T. garrocha	Leaves		No cytotoxicity was detected for both extracts	
		Stem			
	T. stans var. *angustata*	Leaves		IC_{50} values of 185.80 µg/mL.	
		Stem		IC_{50} value of 56.03 µg/mL	
	T. stans var. *stans*	Leaves		No cytotoxic activity	
		Stem		IC_{50} value of 0.5533 µg/mL	
	T. stans	Flowers	Pressurized hot water extraction	IC_{50} value of 0.1786 ng/mL (for isolated peptides)	(32)
Human laryngeal carcinoma (HEP-2)	*T. sambucifolia*	Flowers	Aqueous	IC_{50} value of 30.8 mg/mL (for the aqueous extract) IC_{50} value of 21.7 mg/mL (for the alcoholic extract). No cytotoxicity for both extracts	(47)
			Alcohol		
		Pods	Aqueous		
			Alcohol		
	T. stans	Flowers	Methanol	Concentration of 250, 500 and 1000 µg/mL reduced cell viability by 53.56%, 32.24% and 23.51%, respectively.	(41)
Melanoma skin cancer cell line (SK-MEL-28)	*T. stans*	Flowers	Pressurized hot water extraction	The peptides showed a potent cytotoxic activity with IC_{50} value was found to be 0.5291 ng/mL, indicating effective inhibition of cell viability.	(32)
Rhabdomyosarcoma (RD-CCL 136)	*T. stans*	Branches and leaves	Deionized water*	IC_{50} values of 79.4 µg/mL and 75.9 µg/mL (for extracts from branches and leaves, respectively).	(40)
				IC_{50} values of 2.26 and 12.5 µg/mL (for AgNPs of extracts from branches and leaves, respectively).	
				Combination of each of the extracts or its AgNPs with a photosensitizer and light exposure in PDT enhanced the cytotoxic activity and reduced cell viability to 22.4% and 24.9% for branch and leaf extracts, respectively.	

Table 2. Reported *in vitro* cytotoxic activity of *Tecoma* species

Cell line	Species name	Part used	Type of extract	Cytotoxic activity and/or IC_{50} values	Reference
Bladder cancer (T24)	*T. castanifolia*	Leaves	Ethanol	IC_{50} value of 18.31 µg/mL	(21)
		Stem		IC_{50} value of 15.90 µg/mL	
	T. garrocha	Leaves		IC_{50} value of 27.93 µg/mL	
		Stem		IC_{50} value of 12.96 µg/mL	
	T. stans var. *angustata*	Leaves		IC_{50} values of 24.22 µg/mL.	
		Stem		IC_{50} value of 0.0841 µg/mL	
	T. stans var. *stans*	Leaves		IC_{50} value of 39.89 µg/mL.	
		Stem		IC_{50} value of 0.0156 µg/mL	
Ovarian cancer (TOV-21G)	*T. castanifolia*	Leaves		IC_{50} value of 83.40 µg/mL	
		Stem		IC_{50} value of 17.51 µg/mL	
	T. garrocha	Leaves		IC_{50} value of 88.94 µg/mL	
		Stem		IC_{50} value of 16.76 µg/mL	
	T. stans var. *angustata*	Leaves		IC_{50} value of 140.30 µg/mL.	
		Stem		IC_{50} value of 0.1697 µg/mL	
	T. stans var. *stans*	Leaves		IC_{50} value of 69.28 µg/mL.	
		Stem		IC_{50} value of 0.1043 µg/mL	
Ovarian cancer (SKOV3)	*T. stans*	Flowers		IC_{50} value of 158.34 ± 1.76 µg/mL	(49)
Prostate cancer (PC3)	*T. stans*			IC_{50} value of 113.27 ± 1.59 µg/mL	
Human colorectal carcinoma (HCT 116) and (SW 480)	*T. stans*	Leaves and flowers	80% Methanol	At concentrations from 50µg/mL to 300µg/mL, the AgNPs loaded extract exhibited antiproliferative effects on both colorectal cancer cell lines HCT 116 and SW 480.	(37)
Bone cancer (MG-63)	*T. stans*	Leaves	Aqueous*	IC_{50} of 106.3 µg/mL (for the CuONPs of the extract)	(38)

The symbol "*" denotes for cytotoxicity data from nanoparticles synthesized using *Tecoma* extracts.

Bcl-xl and VEGFR-2, in addition to the assessment of cell death mode (Figure 2). In the first study, Elsayed et al. (2021) (31) assessed the modes of cell death for the active metabolites isolated from *T. stans* endophytes. Among these, iso-emericellin exhibited 15% necrosis and 15% apoptosis in MCF-7 cells, while dihydrosterigmatocystin demonstrated a 60% apoptotic mode of cell death with minimal necrosis in MCF-7 cells, while induced 70% apoptosis and 10% necrosis in HepG2, which was linked to its high binding affinity for the Hsp90 ATP binding cleft through *in silico* molecular docking analysis (Table 3).

Later, Reddy et al (33) used quantitative real-time PCR to examine the *T. stans* leaves extract and revealed that the extract significantly downregulated Bcl-2 mRNA expression in a dose-dependent manner as compared to the control group. However, the effect on Bcl-xL mRNA expression was less pronounced.

Similarly, Narayanan et al (34) and Durgadevi et al (35) examined the extracts of *T. stans* bark, flowers, leaves and roots against MCF-7 cells, and tentatively identified metabolites from both extracts using LC-MS. Both studies also investigated the *in silico* interactions of the identified metabolites with Bcl-2 and VEGFR-2.

In a study, 3,5-O-dicaffeoylquinic acid exhibited the strongest binding affinity toward Bcl-2 (−8.8 kcal/mol), while isorhamnetin-3-O-rutinoside demonstrated the highest binding to VEGFR-2 (−8.3 kcal/mol) (Table 3) (34). While Durgadevi et al (35) reported that gallic acid and rutin, two abundant polyphenols, exhibited notably high binding energies (−23.18 kcal/mol and −23.68 kcal/mol, respectively) with Bcl-2 and VEGFR-2, further supporting their potential role in modulating apoptotic signaling pathways (Table 3).

Applications in different areas of anticancer treatment

Tecoma species have also been incorporated into alternative cancer treatment therapies, particularly as photosensitizers in photodynamic therapy (PDT). Khattab et al (36) reported that the methanol extract of *T. stans* flowers has a photosensitizing effect on A549 and MCF-7 cells. The cytotoxicity was assessed through sulforhodamine B (SRB) assay, where the extract showed a significant photodynamic activity against A549 cells, while no significant inhibition was observed in MCF-7 cells (Table 2). UPLC/MS/MS analysis of the extract led to the tentative identification of 87 and 44 compounds in positive and negative modes. The identified metabolites included flavonoids (49%), coumarins (8%), anthocyanins (4%), phenolics (21%), alkaloids (4%), oligopeptides (4%), terpenes (4%), benzoquinone (4%), and sugars (2%).

Other measures of cancer treatments included the synthesis of cytotoxic nanoparticles of zinc oxide (ZnONps), silver (AgNPs) and copper oxide (CuONPs) using extract from different *Tecoma* species including *T. castanifolia* (25) and *T. stans* (37-39) (Table 2). AgNPs was also incorporated in PDT where the AgNPs were synthesized via *T. stans* leaves and branches and were used to enhance the efficacy of the used photosensitizer in affecting the viability of RD-CCL 136 cells (40) (Table 2).

In vivo cytotoxic activity

Two independent studies have investigated the *in vivo* anticancer potential of *T. stans* using the Ehrlich Ascites Carcinoma (EAC) mouse model. In the first study, Kameshwaran et al (41) evaluated the effect of a methanolic extract of *T. stans* flowers (METS) in Swiss albino mice. The experimental design included five groups: a normal control group, an EAC control group, a standard treatment group receiving 5-fluorouracil (20 mg/kg) and two treatment groups administered METS at doses of 200 mg/kg and 400 mg/kg. EAC cells were inoculated intraperitoneally, and treatments were given daily for 14 consecutive days. In the second study, Sridharan et al (42) assessed the anticancer efficacy of a

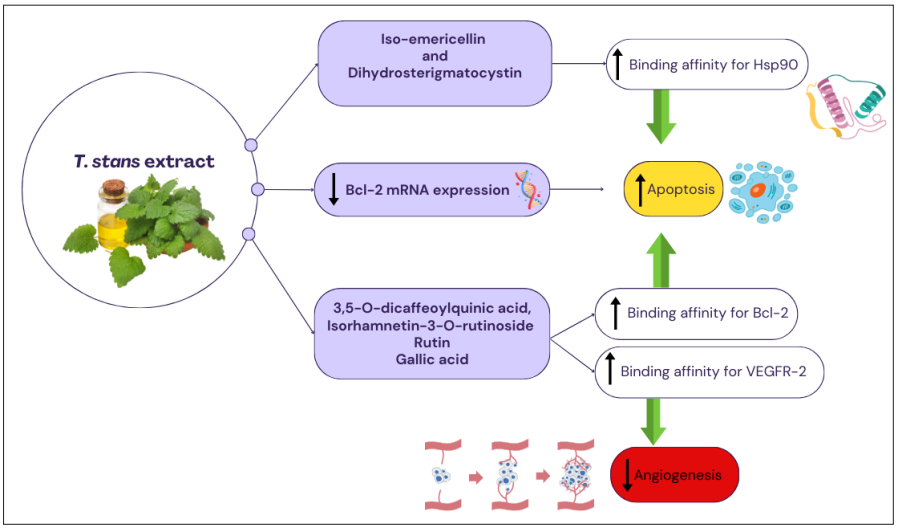

Figure 2. Proposed mechanisms of cytotoxic activity of *Tecoma stans* extract and isolated compounds.

water extract prepared from the aerial parts of *T. stans* (WETS) using a similar EAC model. Treatment doses were administered at 100, 200, and 300 mg/kg body weight for 14 days following EAC cell inoculation. As summarized in Table 4, both extracts demonstrated promising *in vivo* anticancer activity; however, the standard agent 5-fluorouracil exhibited superior efficacy, as reflected by key parameters such as mean survival time (MST) and tumor volume reduction.

Discussion

Among various cancer cell lines included in this review, the highest number of cytotoxicity studies was specifically reported for breast cancer, with 12 studies, followed by lung cancer with 6 studies, and liver cancer with 5 studies. Given that most investigations were conducted *in vitro*, further *in vivo* studies employing relevant animal models are strongly recommended. These studies have utilized either standardized extracts from different *Tecoma* species or individual cytotoxic compounds (21,23). Such an investigation could lead to the identification of promising lead cytotoxic compounds that might be further evaluated in preclinical and clinical studies.

The cytotoxic activity of *Tecoma* species has only been reported once against cell lines representing colorectal cancer, rhabdomyosarcoma, prostate cancer, bladder cancer, and resistant forms of breast cancer (21,37,40,49). This indicates a need for further research to assure the cytotoxic activity of *Tecoma* species against these cell lines.

It is worth mentioning that studies by Lavudi et al and Vasantharaj et al (37,39) reported the cytotoxic activity of *T. stans* extracts-loaded AgNPs and CuONPs against colorectal cancer and lung cancer, respectively. However, the lack of reported IC_{50} values limited the interpretability and reproducibility of these findings.

Noteworthy findings reported by Krobthong et al (32) on peptides isolated from flowers of *T. stans* demonstrated the most potent cytotoxic activity against all the tested cell lines at effective concentrations in the nanogram range and with relative selectivity, as evidenced by the higher IC_{50} against the normal keratinocytes, HaCaT cell lines. This potent cytotoxicity of the peptides may be attributed

Table 3. Molecular docking scores of *Tecoma compounds* against key cancer-associated targets

Compound	Target	Binding Score (kcal/mol)	Reference
Dihydrosterigmatocystin	Hsp90	-8.3	(31)
Sterigmatocystin	Hsp90	-8.4	
Isoemericellin	Hsp90	-7.7	
3,5-O-Dicaffeoylquinic acid	Bcl-2	-8.8	(34)
	VEGFR-2	-8	
Isorhamnetin-3-O-rutinoside	Bcl-2	-8.1	
	VEGFR-2	-8.3	
Gallic acid	Bcl-2	-23.18	(35)
	VEGFR-2	-29.63	
Rutin	Bcl-2	-23.68	
	VEGFR-2	-33.33	

Table 4. Reported *in vivo* cytotoxic activity of *Tecoma* species

In vivo model	Species	Part used	Type of extract	Anticancer activity	Reference
Ehlich ascites carcinoma (EAC)	*T. stans*	Flowers	Methanol	Treatment with methanol flower extract of *T. stans* (METS) resulted in significant reductions in tumor volume, tumor weight, and viable tumor cell count, accompanied by a notable increase in non-viable cell count. The mean survival time (MST) was extended to 31.66 ± 6.02 days and 26 ± 1.0 days for the 400 mg/kg and 200 mg/kg doses, respectively, corresponding to increased life spans of 75.39% and 61.9%. For comparison, 5-fluorouracil, administered intraperitoneally at 20 mg/kg, exhibited superior efficacy by extending MST to 35.33 ± 5.85 days and achieving an 84.12% increase in life span, along with more pronounced suppression of tumor progression parameters.	(41)
		Aerial parts	Aqueous	The water extract of *T. stans* (WETS) significantly increased the MST of EAC-bearing mice to 24.15 ± 2.67, 29.36 ± 2.26, and 31.05 ± 1.75 days for the 100, 200, and 300 mg/kg doses, respectively, corresponding to a lifespan extension of 27.84%, 51.96%, and 60.71% compared to the disease control. These effects were accompanied by a dose-dependent reduction in tumor volume (from 4.21 ± 0.26 mL in control to 2.23 ± 0.41 mL at 300 mg/kg)	(42)

to their ability to form α-helical structures that penetrate cell membranes, leading to pore formation and membrane disruption (50).

Future research on peptide cytotoxicity should include a standard anticancer agent as a positive control to enable the comparison of selectivity and efficacy with anticancer agents. Alguacil et al (47) reported the cytotoxic activity of *T. sambucifolia* extracts against HepG2 and Hep2 cell lines; however, the extract showed relatively weak cytotoxicity, with IC_{50} values in the milligram range making it the least active *Tecoma* species investigated to date. This contrasts sharply with the markedly lower IC_{50} values reported for *T. stans* extracts and isolated compounds, which often fall in the low micromolar or micrograms range. These findings suggest that *T. sambucifolia* may possess limited cytotoxic potential, although further investigations are needed to fully assess its therapeutic relevance.

Regarding other fields of cancer treatment, the use of *Tecoma* species in PDT as a photosensitizer (36) or in the green synthesis of nanoparticles that enhance the photosensitizing activity (40) appears promising. However, discrepancies in the results across different cell lines suggest that further studies are needed involving a range of cell lines to confirm the potential applications of *Tecoma* species in such area of cancer treatment.

The proposed mechanisms underlying the cytotoxic activity of *Tecoma* species were explored in four studies, with varying levels of experimental validation. Notably, an *in vitro* study investigated the modulation of anti-apoptotic proteins, specifically Bcl-2 and Bcl-xL, indicating a potential role in apoptosis regulation (33).

Other *in silico* studies assessed the molecular interactions of *Tecoma* identified compounds with cancer-associated targets, namely VEGFR-2 and the ATP-binding site of Hsp90 (31,34). Among these, the study by Elsayed et al (31) provided key insights into cell death modality by comparing the apoptotic and necrotic effects of isolated metabolites. Dihydrosterigmatocystin exhibited a pronounced pro-apoptotic profile, inducing apoptosis in 70% of HepG2 and 60% of MCF-7 cells. This selective induction of programmed cell death supports its potential as a targeted cytotoxic agent. In contrast, isoemericellin induced only minimal apoptotic or necrotic effects, suggesting a weaker or non-specific cytotoxic mechanism (31).

The phytochemical profile of the cytotoxic extracts has been reported only for *T. stans*, revealing the presence of four major classes: flavonoids, phenyl ethanoids, anthraquinones, and lignans. Among the identified metabolites, rutin, acteoside, paulownin, and paulownin acetate (21,23) exhibited the most promising cytotoxic activity against various cell lines, with paulownin and paulownin acetate showing relative selectivity for cancerous cell lines over normal ones.

In contrast to acteoside, both paulownin and paulownin acetate expressed less cytotoxic activity than the parent fractions (21). This observation suggests that both compounds may serve more effectively as scaffolds for the synthesis of more potent derivatives or as complementary agents in combination therapies, rather than as stand-alone cytotoxic compounds.

Notably, only Reis et al (21) reported cytotoxicity data for both crude extracts and isolated lignans in consistent units (μg/mL), permitting valid quantitative comparison. In contrast, Marzouk et al (23) and Elsayed et al (31) used μg/mL for extracts versus μM for compounds, rendering direct comparison unreliable due to unit inconsistency. Thus, any comparative interpretation should be viewed as qualitative and illustrative rather than definitive.

Previous studies on the aforementioned metabolites have demonstrated that they have exhibited their cytotoxic activity through various mechanisms. For example, rutin exhibits its cytotoxic activity through multiple molecular mechanisms, including modulation of PI3K/Akt, JAK/STAT, Wnt/β-catenin, NF-κB, and EGFR signaling pathways. It induces G2/M cell cycle arrest and apoptosis via upregulation of p53 and Bax, and downregulation of Bcl-2. Rutin also suppresses MMP-2 activity, reduces tumor cell migration, and enhances ROS generation selectively in cancer cells, leading to oxidative stress-induced apoptosis. These effects have been confirmed in various models, supporting rutin's role as a multi-targeted anticancer agent (52).

A recent *in vivo* study by Park et al (51) demonstrated that paulownin significantly suppressed the growth of B16F10 melanoma tumors in mice by enhancing NK cell cytotoxicity. Mechanistically, paulownin promoted NK cell degranulation by upregulating CD107a, perforin, and granzyme B expression, and this effect was shown to be dependent on JNK pathway activation.

The cytotoxic enhancement was confirmed in both NK-92 and primary human NK cells, and NK cell depletion *in vivo* abolished the antitumor effect, confirming the central role of NK-mediated immunity in paulownin's mechanism of action. In the same context, acteoside exhibited its anticancer activity by selectively inducing cytotoxicity in tumor cells through inhibition of the ubiquitin-proteasome system. It also inhibited protein kinase C (PKC), suppressed matrix metalloproteinases (MMP-2 and MMP-9), and triggered an anti-tumor immune response in a mouse melanoma model (53).

These findings are consistent with other studies regarding the cytotoxic and anticancer activity of acteoside at *in vitro*, *in vivo* and preclinical models (54,55). These findings also support advancing *in vivo* and possibly clinical studies to evaluate acteoside's selectivity and potential as a novel natural anticancer agent. These reports suggest that *T. stans* may exert its cytotoxic activity through one or more of the aforementioned pathways. Nevertheless, further studies are required to confirm these mechanisms

Conclusion

This review highlights the significant potential of *Tecoma* species in various cancer treatment modalities, with *T. stans* emerging as the most promising cytotoxic species. The high efficacy of *T. stans* could be attributed to the presence of bioactive compounds such as rutin, acteoside, paulownin, and paulownin acetate. However, it is important to note that the majority of *Tecoma* species remain largely unexplored in this context. This strongly suggests that future research should focus on assessing the cytotoxic and anticancer activity of other *Tecoma* species through both *in vitro* and *in vivo* approaches. Additionally, isolating potentially active phytochemicals from the cytotoxic extracts of already reported *Tecoma* species could yield significant candidates with anticancer activity.

The promising *in vitro* cytotoxic findings reported herein support the need for preclinical investigations including pharmacokinetic, bioavailability, toxicity, and *in vivo* efficacy studies to determine the translational viability of *Tecoma*-derived compounds. Moreover, exploring their potential synergy with established chemotherapeutic agents may enhance therapeutic efficacy while minimizing associated toxicity.

While the cytotoxic potential of *Tecoma* extracts and their isolated compounds are well documented, it is important to note that the majority of *Tecoma* species remain largely unexplored in this context. Moreover, current literature is constrained by non-standardized extract dosing, limited *in vivo* evaluations, and insufficient mechanistic insight.

These gaps highlight the need for future studies that adopt standardized animal models and employ advanced mechanistic assays such as cell cycle analysis, caspase activation profiling and mitochondrial pathway assessments to clarify the modes of action and enhance our understanding of the cytotoxic properties of these compounds.

Authors' contribution

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Conflict of interests

The authors declare that there is no conflict of interests

Declaration of generative artificial intelligence (AI) and AI-assisted technologies in the writing process

In the preparation of this work, the authors utilized a large language model (ChatGPT-4) to improve the readability of certain sections of the article. After using this tool, the authors carefully reviewed and edited the content as needed, taking full responsibility for the content of the final published article.

Ethical considerations

Not applicable.

Funding/Support

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Supplementary files

Supplementary file 1 contains Table S1.

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